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Exploring the Complexity of Teaching: The Interaction between Teacher Self-regulation and Pedagogical Content Knowledge

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This study combined two important frameworks—teacher self-regulation and pedagogical content knowledge (PCK)—to reveal whether they were related to each other. To fulfill this aim, researchers utilized a case-study design. Data were collected from five preservice chemistry teachers through semi-structured interviews, lesson plans in the form of content representations, and video recordings of teaching practice. Both deductive and inductive analyses were used to analyze the data. Results indicated that preservice teachers utilized different PCK components in each self-regulation phase. They were good at regulating their teaching when they had developed PCK components. Especially, a lack of subject matter knowledge accounted for ineffective self-regulation in teaching. The findings of this study imply that teacher education programs should provide meaningful opportunities to preservice teachers for improving both their self-regulation for teaching and PCK.

Introduction

Teaching is a complex activity, influenced by various factors such as a teacher's knowledge base (e.g., pedagogical content knowledge -PCK-) (Bond-Robinson, 2005), their beliefs (e.g., self-efficacy) (Tschannen-Moran, Woolfolk-Hoy, & Hoy, 1998), capabilities (e.g., self-regulation) (Gordon, Dembo, & Hocevar, 2007), and students (e.g., understanding level) (Park & Oliver, 2008). Therefore, focusing solely on one factor may not be helpful in fully understanding the complexity of teaching. There is a need for more studies investigating the teaching act from a multi-angle point of view. With this in mind, as a first step, we aimed in this study to understand the nature of the teaching process by considering whether there is any interaction between pre-service chemistry teachers' self-regulation for teaching and their PCK within the context of teaching gas laws in practicum at high school.

Self-regulation is a cyclic construct that adapts one's planned thoughts, feelings, and actions to achieve the goals set (Zimmerman, 2000). In the literature, self-regulation is accepted as one of the defining charaterictics of humans, who are uniquely able to adapt to different conditions and plan varying strategies for problems (Zimmerman, 2000). According to Bembenutty (2006), how teachers use self-regulatory processes is the key point that enables us to differentiate between effective and non-effective teachers.

Previous conventional notions of teaching effectiveness placed the focus on their skills to learn how to teach. However, recent notions from a social cognitive perspective view teachers as self-regulated agents who could activate their beliefs and take appropriate actions in order to successfully complete their professional tasks. (Bembenutty, 2006, pp.3-4)

Effective teachers regulate their own learning and teaching through goal-setting, strategic planning, monitoring and controlling their teaching, reflecting, and motivating themselves for the teaching process (Capa-Aydin, Sungur, & Uzuntiryaki, 2009; Chatzistamatiou & Dermitzaki, 2013; Zimmerman, 2000). However, taking the complexity of teaching into account, being self-regulated may not be easy for teachers. Several factors might interfere with self-regulatory processes. For example, having learners with different abilities and interests, contextual factors, the nature of the content, and many other factors require teachers to make modifications in their plan or use a completely different strategy for effective instruction (Butler, 2003). Regarding effective instruction, there has been a long debate on defining effective instruction among the researchers and stakeholders. One of the criteria defining it is PCK proposed by Shulman's (1986) significant work and described in the next paragraph.

PCK is a beneficial theoretical framework for defining teachers' knowledge and practice (Abell, 2007). According to Shulman (1986, 1987), PCK is the knowledge that makes the difference between a chemist and a chemistry teacher. In science education, research revealed that teachers with developed PCK use appropriate instructional strategies to make the content more understandable, take learners' difficulties into account, implement different assessment strategies, and be knowledgeable about the specific curricular programs and objectives in the curriculum (Loughran, Berry, & Mulhall, 2006; van Driel, De Jong, & Verloop, 2002).

Consequently, both teacher self-regulation (TSR) and PCK have

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been proposed as vital components in helping teachers to design and perform effective instruction, and to reflect on their performance to improve quality of instruction, which in turn enhances students' understanding. However, to the best of our knowledge, how teachers' self-regulatory processes are related to PCK has not been examined deeply through observing teachers' practice. To address this gap in the related literature, in this study we aimed to shed light on what relationship, if any, exists between preservice chemistry teachers' self-regulation for teaching and their PCK in the practicum.

Literature Review

This study is guided by two main frameworks: TSR and PCK. These constructs are explained in the next sections.

Teacher Self-Regulation

Self-regulation is defined as "self-generated thoughts, feelings, and actions that are planned and cyclically adapted to the attainment of personal goals" (Zimmerman, 2000, p. 14). The roots of self-regulation date back to the social cognitive theory proposed by Bandura (1986). This theory postulates that human beings possess some capabilities that enable them to shape and control their motivation, cognition, and action. People do not simply react to changes; instead, they are active in determining their actions. Self-regulatory processes, in this sense, appear to be one of the major mechanisms of human functioning.

Although the importance of self-regulation has been recognized and confirmed by the researchers over decades, it has been studied mostly in terms of learning (Zimmerman & Kitsantas, 2014). On the other hand, teachers are also expected to self-regulate to enact their instruction effectively. Self-regulated teachers construct their knowledge about teaching and perform their instruction through planning, self-monitoring, and self-evaluating. TSR, therefore, can be viewed from two aspects: self-regulation for learning how to teach and self-regulation for teaching (Butler, 2003). In the present study, we focused on the latter perspective, using the definition of TSR proposed by Capa-Aydin et al. (2009) —self-regulated strategies used by teachers in their teaching. TSR requires teachers to actively direct their metacognition, motivation, and actions in order to teach effectively. Self-regulated teachers plan their instruction considering factors such as time and student background knowledge. They search for appropriate teaching and assessment strategies, get help from their colleagues when needed, monitor their teaching, and evaluate and reflect on their instruction. At the same time, self-regulated teachers utilize those processes to learn more about teaching; they may discuss advanced teaching methods with colleagues or examine literature to get new ideas (Butler, 2003).

The Use of Zimmerman's Self- Regulation Model in Teacher Self-regulation

Zimmerman's (2000) model can be utilized to explain TSR. It is a cyclic model that includes three phases: forethought, performance control, and self-reflection.

Forethought phase. It covers activities teachers undertake before the instruction. In this phase, teachers prepare for the instruction through goal setting and strategic planning. For example, science teachers set their objectives (e.g., to develop students' science process skills), decide the teaching strategies to achieve their goals, arrange the physical conditions of the classroom, and select appropriate assessment methods. According to Zimmerman, teachers' motivational characteristics (i.e., self-efficacy, goal orientation, and interest/value) play a crucial role in teachers' use of self-regulatory strategies, particularly in this phase. Self-regulated teachers have high self-efficacy, possess mastery goal orientation, and have an intrinsic interest in teaching, which shapes their goal-setting and strategic planning. Teacher self-efficacy reflects teachers' beliefs about their capability to perform effectively (Tschannen-Moran et al.,1998). Self-efficacious teachers tend to plan their instruction (Allinder, 1994), use new approaches in their teaching (Guskey, 1988; Mulholland & Wallace, 2001) and persevere when encountering difficulties (Ross, 1998; Tschannen-Moran et al., 1998). Butler (2007) employs achievement goal theory (Elliot, 1999) to explain why and how teachers are motivated for teaching. She proposes four dimensions of teacher goal orientation: Teachers may aim at (a) learning and improving their competence (mastery goal orientation); (b) performing better than other teachers (ability-approach goal orientation); (c) avoiding poorer performance than others (ability-avoidance goal orientation); and (d) working with little effort on the teaching task (work-avoidance goal orientation). Teachers' goal orientation relates to their self-regulation in several aspects. For instance, teachers with mastery goal orientation are likely to view help as beneficial for their professional knowledge, whereas teachers with avoidance goal orientation perceive help-seeking (a kind of self-regulatory strategy) as an indicator of their low ability and therefore do not ask for help frequently. Furthermore, students reported that mastery oriented teachers tend to encourage them to ask questions and get help; thus, these teachers tend to support self-regulated learning (Butler & Shibaz, 2008). Lastly, the findings of multiple research studies revealed that teachers' interest and value is positively related to their self-regulation (Bembenutty, 2007; Chatzistamatiou, Dermitzaki, & Bagiatis, 2014). Consequently, although Zimmerman includes motivational variables only in his conceptualization of forethought phase, those variables are effective in all phases in the self-regulation model.

Performance phase. The second phase of TSR, which is the performance phase, covers teachers' self-regulatory processes during instruction. The main processes in the performance phase are self-control and self-observation/monitoring. In self-control processes, teachers work to achieve their objectives and to effectively apply the intended teaching method. They may also change their instructional strategy when needed. Self-control is closely related to self-monitoring and self-observation as ways in which teachers track their teaching. For instance, when science teachers realize that they do not have enough time for an experiment during instruction (monitoring), they may regulate their teaching by giving homework to students about the concepts of the experiment (controlling). Teachers also use a variety of processes to monitor and observe their instruction. For instance, during

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instruction they take notes that may be helpful for future instructions (self-recording); they focus on a specific aspect of their teaching (attention focusing); they change their instructional strategy upon seeing that it does not work (self-experimentation); they divide teaching tasks into parts (task strategies); they form mental pictures (imagery); or they monitor themselves to control what they will do in class (self-instruction, Zimmerman, 2000). In addition, during instruction teachers regulate their emotions. They try not to get angry with misbehaving students and seek ways to control their anxiety (Corno & Kanfer, 1993; Pintrich & Schunk, 2002).

Self-reflection. After their instruction, teachers judge their performance using certain standards for comparison. Teachers may evaluate their performance based on their previous performances, student achievement, or their closeness to the lesson plan. Using these evaluations, teachers make casual attributions and react to their performance accordingly. Self-regulated teachers hold positive self-reactions, adapt their instructions easily, and attribute the effectiveness of their performance to the controllable factors like teaching strategies. As a result of evaluations, teachers make some decisions about their future instructions; thus, this phase shapes the forethought phase of the next instruction. These processes highlight the cyclical nature of the self-regulation model (Zimmerman, 2000). All teachers use the processes explained in each phase to some extent. Therefore, it is not appropriate to talk about "no self-regulation." Instead, teachers' effective use of self-regulatory strategies differs.

Research on Teacher Self-regulation

Most of the studies related to TSR focus either on teachers' own self-regulated learning (e.g., Kreber, Castleden, Erfani, & Wright, 2005; Michalsky, 2012) or teachers' strategies to develop students' self-regulation (e.g., Perry, VandeKamp, Mercer, & Nordby, 2002). Regarding TSR about teaching, a recent study conducted by Chatzistamatiou et al. (2014) utilized the Zimmerman self-regulation model to examine the relationship between the use of self-regulatory strategies in mathematics and elementary school teachers' motivation and affect. Results of path analysis indicated that teachers' self-efficacy beliefs, the value they give to mathematics, and their emotional commitment to the teaching profession predicted their use of self-regulatory strategies. This result was consistent with the findings of Capa-Aydin et al. (2009), which showed that efficacious teachers had a personal interest in the profession and were likely to set instructional objectives, use regulatory strategies to control and monitor both their teaching and emotions, evaluate their teaching, and had adaptive responses toward their performances. These results provided evidence for the role of motivational and affective variables in TSR. Still, more research is needed in this area to gain a deeper understanding about how science teachers regulate their instruction, what kind of self-regulatory strategies they utilize, and what factors influence their use of self-regulatory strategies so that we can improve the quality of science teaching.

In the TSR model based on Zimmerman's model, all phases are dependent on each other. For example, teachers' effective performance in class is related to their effective strategic planning. Furthermore, how teachers monitor their instruction has potential to shape their use of controlling strategies. Therefore, some deficiencies in teachers' knowledge may prevent their use of self-regulatory strategies and in turn hinder effective teaching. Accordingly, PCK may be influential in TSR (Yetkin-Ozdemir, Gurel, Akdal, & Bozkurt, 2014). When teachers identify problems in their teaching but have poor PCK, it becomes difficult for them to correct those difficulties. For example, in science education, self-regulated teachers are supposed to plan, perform, and evaluate their instruction to develop student skills for scientific inquiry (Michalsky, 2012; National Research Council [NRC], 2011). When teachers do not possess satisfactory knowledge about common student misconceptions, the specific instructional strategies that promote students' science process skills, or assessment techniques, they may experience complications in regulating their instruction. Therefore, PCK plays an important role on teachers' use of self-regulatory strategies.

Pedagogical Content Knowledge and its components

PCK was first proposed by Shulman (1986) and conceptualized as "an understanding of how particular topics, problems, or issues are organized, presented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (1987, p.8). Subject matter knowledge (SMK) and pedagogical knowledge are the knowledge bases necessary for PCK development. Since the inception of PCK, researchers have proposed various PCK models (e.g., Grossman, 1990; Magnusson, Krajcik, & Borko, 1999; Park & Oliver, 2008). The current study employed Magnusson et al.'s (1999) PCK model, one of the widely used PCK models, because it represents a broader view of PCK than the original conceptualization.

In Magnusson et al.'s (1999) PCK model, PCK has five main components, namely, science teaching orientation, knowledge of curriculum, knowledge of learner, knowledge of instructional strategies, and knowledge of assessment. Magnusson and her colleagues stated that science teaching orientation component is an over-arching one influencing teachers' view of teaching, how to teach, and assess students' understanding. Regarding the definition of science teaching orientation component, Friedrichsen, van Driel and Abell (2011) criticized Magnusson et al.'s (1999) definition and categorization of the component. The definition of science teaching orientation should be multi-dimensional with teachers' beliefs and curriculum emphasis. In this regard, Roberts' (1988) orientation perspective is stated as more useful to grasp teachers' knowledge and beliefs about goal of teaching science. Hence, in light of Friedrichsen et al.'s (2011) suggestion, we used Roberts' (1988, 2007) orientation categorization in this study, which is a modification on the Magnusson et al.'s PCK model (see Table 1).

Although the model states that PCK has a fragmental nature, Abell (2007) stated that PCK is more the sum of those components. Furthermore, all components interact and inform each other when a teacher realizes that students have a difficulty in understanding the dynamic nature of chemical equilibrium (i.e., related to knowledge of learner component), s/he would prefer to include animations or simulations showing how dynamic it is (i.e., related to knowledge of instructional strategy).

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Table 1 PCK components, explanations and examples from chemistry

PCK components	Explanation	Example
Science teaching orientation	Represents a general way of viewing or conceptualizing science teaching	**Everyday coping:** use of events happening in daily-life and/or phenomena using in our life to teach science topics **Scientific skill development:** Focusing on helping students develop science process skills such as forming hypothesis or analyzing data
Knowledge of curriculum	Involves; • mandated goals and objectives, and • knowledge about specific curricular programs	• There is an objective as ''Students should be able to relate acid strength with strength of electrolyte concept'' in Turkish high school chemistry curriculum for 11th grade • Recent Turkish high school chemistry curricula are structured based on Constructivist paradigm that highlights students' active participation to learning process, conceptual teaching, and students' prior knowledge
Knowledge of learner	Includes; • requirements for learning particular science concepts, • alternative conceptions, and • areas of science that students find difficult	• Teachers need to know that students should know what redox reaction is before learning electrochemical cells • An example of alternative conception: 'Strong acids have a higher pH than weak acids' • Difficulty in discriminating pH and acid strength concepts, or in understanding dynamic nature of chemical equilibrium
Knowledge of instructional strategies	Comprises; • science-specific strategies (such as the learning cycle) and • strategies for specific science topics (e.g., illustrations and analogies)	• Teaching instant and average rate of reaction concepts through 5E • Teaching the rate determining step concept by the use of car convoy analogy which shows that no matter how fast you drive, a slow car in the convoy determines the others rate as well
Knowledge of assessment	Consists of, • knowledge of the dimensions of science learning that are important to assess, and • knowledge of the methods by which that learning can be assessed.	• Knowing the necessity of assessing nature of science (NOS), science process skills and/ or science knowledge • Assessing NOS understanding by the use of VNOS-C instrument or semi-structured interview

Research on Pre-service Teachers' PCK and Its Development

Research on teachers' PCK has revealed that SMK, teaching experience and support from experienced ones are important factors supporting PCK development (Abell, 2007; Friedrichsen et al., 2009; Grossman, 1990). In the literature, many researchers have focused on how pre-service teachers' PCK develops (Appleton & Kindt, 2002; van Driel et al., 2002), which types of experiences augmented pre-service teachers' PCK development (Aydin et al., 2013; Friedrichsen et al., 2009), and how to assess pre-service teachers' PCK (Loughran, Mulhall, & Berry, 2004). Some of the research was conducted with elementary science teachers (e.g., Nilsson & Loughran, 2012) and some others were done with secondary science teachers (e.g., Aydin et al., 2013) whose SMK is deeper than the elementary science teachers.

Loughran, Mulhall, and Berry (2008) utilized PCK construct to help pre-service teachers see the relation between teaching and learning. By the use of Content Representation (CoRe) and Pedagogical and Professional-experience Repertoires (PaP-eRs) as tools for capturing PCK, the researchers concluded that the prompts in the CoRe instrument (e.g., Why is it important for students to know this?) provided a shared language for designing and performing of teaching for pre-service teachers (Loughran et al., 2004). Likewise, Hume and Berry (2011) also used CoRe in their study; however, the participants prepared the CoRes in a group rather than doing it alone. Scaffolding for how to design a lesson and to fulfil the CoRe was provided as well. Another useful part of their study was providing a chance to pre-service teachers to examine CoRes prepared by experienced teachers. The research revealed that lack of teaching experience restrained pre-service teachers' planning. Discussion on experienced teachers' CoRes, scaffolding, and preparing a CoRe in groups supported participants' PCK development. To conclude, introduction of PCK and its components at the beginning to form a shared language for how to plan teaching, offering mentoring and/or scaffolding from experienced teachers and/or teaching assistants, and the use of

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CoRe and PaP-eRs are vital parts of research digging into developing pre-service teachers' PCK. Still, there is a need to examine PCK with a broad perspective. Especially, the nature of the relationship between this construct and other constructs related to teaching profession should be deeply investigated. In this sense, examining the interaction between PCK and TSR might be fruitful to fill the gap in literature. This study is also likely to be valuable for professional development because the findings may suggest ways to increase effectiveness of an instruction.

The Present Study

Although there have been several studies on TSR (e.g., Butler & Shibaz, 2008; Chatzistamatiou et al., 2014), there have been limited qualitative studies which investigate TSR in action. In addition, limited studies exist in the literature investigating the relationship between self-regulation and teachers' pedagogical professional knowledge base. The present study investigates TSR and PCK in the context of teaching gas laws and hence compensates for the limitations of studies relying on self-reported data (e.g., Chatzistamatiou & Dermitzaki, 2013) and not utilizing a theoretically grounded framework for teachers' knowledge base, such as PCK (e.g., Kreber et al., 2005). Moreover, studies regarding TSR have mostly been conducted in the areas of mathematics (e.g., Chatzistamatiou & Dermitzaki, 2013) and science (e.g., Kramarski & Michalsky, 2010; Michalsky, 2012). This study comes into prominence by investigating how teachers from specific disciplines (e.g., chemistry and physics) regulate themselves during their teaching in K-12 classrooms.

Although the TSR and PCK constructs are related to each other and both are of paramount importance for effective teaching, they are distinct from each other both in theory and practice. In terms of theory, TSR includes "processes" which teachers use to systematically organize their instruction (Capa-Aydin et al., 2009) whereas PCK involves "knowledge and skills" that teachers utilize to design an instruction (Aydın & Boz, 2013; Gess-Newsome, 2015; Park & Oliver, 2008). In practice, then, teachers could employ their PCK and skills while they are experiencing TSR processes. For instance, if a teacher's goal is to design a learner-centered instruction, he or she is expected to put his or her PCK knowledge and skills (e.g., knowledge of learner and knowledge of instructional strategy) into play during forethought, performance, and self-reflection phases of TSR. Teacher education researchers have investigated these two constructs separately when they try to understand teachers' practice. However, our extensive search of TSR and PCK literature, our research studies on both of these constructs, and our experiences with pre and inservice teacher education direct us to embrace the idea of integrated PCK and TSR. As a result, we propose a hypothetical wheel-shaped PCK-TSR model (see Figure 1), which is integrated in nature. In Figure 1, we intended to represent this integrated nature by using a dashed line between outermost circle representing TSR and middle circle representing PCK. The inner two circles represent PCK with its components (Magnusson et al., 1999). Since science teaching orientation is an overarching component of PCK and therefore, we preferred to indicate all components of PCK except orientation at the innermost circle (i.e., the circle where knowledge of learner [KoL], knowledge of instructional strategy [KoIS], knowledge of assessment [KoA], and knowledge of curriculum [KoC] take place). Although PCK components are pedagogically transformed version of SMK (Magnusson et al., 1999) and SMK is implicitly embedded in PCK components, we placed SMK at the centre of the PCK-TSR model explicitly. Hence, we aimed to indicate the role of SMK in both PCK and TSR. The outermost circle refers to TSR with its all phases. The arrows between the phases of TSR indicate its cyclic nature. Double arrows between PCK and TSR circles indicate mutual interaction between teachers' PCK and self-regulation. That is either teachers' robust PCK may result in more effective regulation during teaching or self-regulated teachers develop their PCK. Some specific examples for this interaction would be helpful to understand the nature of relation between TSR and PCK. Teachers plan, perform, and reflect on their instruction under the influence of their science teaching orientation, their knowledge of the curriculum, student understanding, instructional strategies, and assessment (i.e., PCK is influential during all phases of TSR). This entails both knowledge-in-action and knowledge-on-action aspects of PCK (Park & Oliver, 2008), which can be linked to TSR. The knowledge-in-action aspect emerges when a teacher encounters an unexpected moment during teaching. A teacher is expected to bring all the PCK components into play at this moment, and also to regulate his/her teaching using strategies such as self-experimentation. On the other hand, knowledge-on-action occurs when teachers evaluate, and reflect on, and modify their planning, teaching for effective instruction, which also refers to the self-reflection phase of self-regulation (i.e., TSR relates to PCK). These ideas drove us to empirically support this potential interaction. We believe that not PCK or self-regulation alone, but the intentional and integrated enactment of these two constructs together may empower teachers to ensure meaningful learning in science and to strengthen their pedagogical professional knowledge.

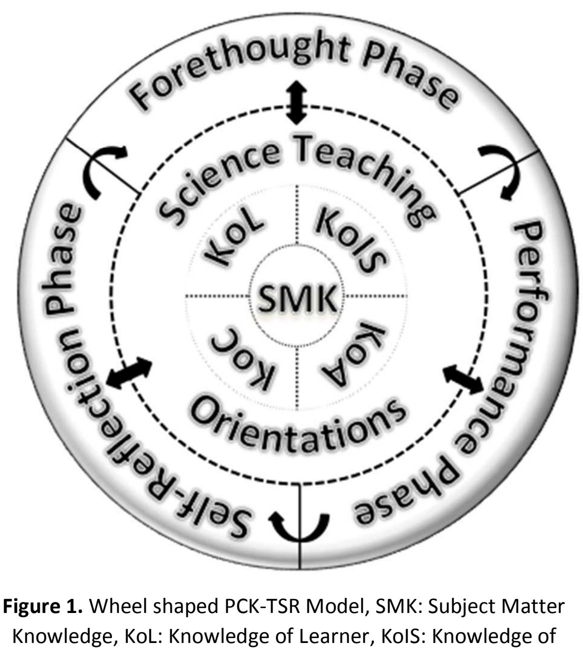

Figure 1. Wheel shaped PCK-TSR Model, SMK: Subject Matter Knowledge, KoL: Knowledge of Learner, KoIS: Knowledge of Instructional Strategies, KoC: Knowledge of Curriculum, KoA: Knowledge of Assessment

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Finally, teachers are not technicians who carry out prescribed instructional changes (Butler, Lauscher, Jarvis-Selinger, & Beckingham, 2004). Instead, they should be regarded as skilled professionals, inventors, decision makers, and problem solvers (Perry, Phillips, & Dowler, 2004). Therefore, their pedagogical professional knowledge and capabilities, which guide them throughout their decision-making and problem-solving processes, need to be investigated in detail. This investigation has the potential to contribute to research on teacher knowledge, which is clearly missed by teacher educators (RAND Reading Study Group, 2002; U.S. Department of Education, 2008). The findings of the study might allow teacher educators to design courses aimed to enhance both their pedagogical professional knowledge base and their self-regulatory processes. Encompassing the aforementioned points about research and knowledge on teaching, we investigated whether preservice teachers' self-regulation and PCK are related to each other. The following research question guided the study:

What relationship, if any, exists between preservice chemistry teachers' self-regulation for teaching and their PCK in the context of teaching gas laws at 9th grade during practicum?

Methodology

Research Design

Case study, one of the qualitative strategies, guided the design, collection, and analysis of this data. According to Yin (2009), this research method is the best vehicle for providing answers when "a how or why question is being asked about a contemporary set of events, over which the investigator has little or no control" (p. 13). Since we have no control of preservice teachers' use of PCK during the self-regulation process, their instruction as a case provided intensive information about the interaction between the two constructs. The scope of a case study is to understand a phenomenon in depth and within its real-life context, but such understanding includes important contextual conditions—since they are rather relevant to the phenomenon of study (Yin, 2009). Because of the blurred boundaries between the phenomena (the interaction between PCK and TSR) and the context (teaching gas laws in student practice), we chose a case study design for this research study.

Participants

The participants of this study were five preservice chemistry teachers out of 13 (nine female, four male) enrolled in a practicum course. They were information rich cases and agreed voluntarily to involve in the study. Four of the participants were female (Daphne, Emily, Lily, and Maggie); one was male (Adam). Their ages varied from 22 to 24. Each participant was in his or her last semester of a five-year chemistry teacher education program that provides a qualification for teaching chemistry at secondary level (grades 9–12). They completed several prerequisite courses, such as subject matter courses (e.g., Physical Chemistry), general pedagogical courses (e.g., Classroom Management), and subject-specific pedagogical courses (e.g., Methods of Science Teaching). In addition, before the practicum course, all participants had to complete a School Experience course in which they observed their co-operating teachers in high schools. In another prerequisite course of practicum, Methods of Science Teaching, their performance varied in course grades, which was determined through microteachings and pen and paper content test. Accordingly, Maggie and Adam showed poor performance, Daphne was moderate while Lily and Emily outperformed their classmates.

Context

This study took place within the context of 14-week practicum course. Table 2 indicates what is taught, how it is taught, and assessment methods used throughout the course.

In the first week of the course, the PCK construct and Magnusson et al.'s PCK model (1999) were introduced to preservice teachers as a professional knowledge base for science teaching through lecturing with topic-specific examples from chemistry. For instance, a teacher's knowledge about students' difficulties in understanding of chemical equilibrium at microscopic level reflects knowledge of learner component and his/her choice of a specific instructional strategy (e.g., conceptual change) indicates knowledge of instructional strategy component of PCK. A handout covering PCK examples were distributed to preservice teachers. In addition, Content Representation (CoRe), which was developed by Loughran et al. (2004), was presented as a tool for lesson planning. Preservice teachers were instructed about how to use CoRe as a lesson-planning tool. During CoRe instruction, a CoRe designed on factors affecting chemical equilibrium was distributed. The instructor focused on each dimension of the CoRe and discussed with the preservice teachers on how each dimension of CoRe relates to specific PCK component. For instance, items numbered five and six focusing on students' difficulties and misconceptions about each concept aim to develop knowledge of learner component of PCK. In the practicum course, the preservice teachers were expected to spend two hours per week in microteaching sessions held in the College of Education, which is different from the most of the countries. Over the microteaching sessions each preservice chemistry teacher enacted two 30-minute instructions on different chemistry topics assigned by the instructor. Additionally, similar to their counterparts in other countries, they spend a period of time throughout the semester at the cooperating high school (grades 9-12). They attended six-hour a week in a cooperating high school in which they observed a veteran teacher's classes, taught chemistry topics, and participated in some administrative tasks. In the cooperating high school, they taught two chemistry topics (each during a 50-minute class period) over the semester and their instructions were observed by the veteran teacher and one of the teaching assistants of the practicum course. At the end of the each instruction, the strong and weak parts of the instruction were discussed and feedback was provided to the preservice teachers. Moreover, preservice teachers were required to submit a lesson plan in the format of CoRe for their instructions.

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Table 2. Teaching and assessment methods used in practicum course

What is taught?	How is it taught?	How is it assessed?
PCK construct as pedagogical professional knowledge base	• Arguing on knowledge base that differentiates science teachers from content specialists • Presentation on knowledge base for teachers (i.e., PCK) and Magnusson et al.'s (1999) PCK model • Distribution of a hand-out including topic-specific examples for each PCK component and discussing each example with pre-service teachers	• Throughout the semester with ○ CoRe ○ Microteaching at college of education ○ Practice teaching at high school ○ Reflection papers
CoRe as a lesson planning tool stimulating PCK development	• Instruction about how to use CoRe as a lesson-planning tool • Distribution of a sample CoRe designed on factors affecting chemical equilibrium • Focusing on each dimension of the CoRe by explicitly discussing how each dimension relates to PCK component	• CoRe preparation for ○ Microteaching at college of education ○ Practice teaching at high school
Teaching chemistry effectively	• Microteaching at college of education using CoRe as a lesson planning tool and putting PCK into play • Practice teaching at high school using CoRe as a lesson planning tool and putting PCK into play	• Microteaching at college of education • Practice teaching at high school • CoRe

Data Collection Sources

CoRes, video recordings, and semi-structured interviews were used to determine the interaction between preservice teachers' self-regulation and PCK. CoRe is a tool used to portray a teacher's PCK in relation to teaching a particular science topic (Loughran et al., 2006; Loughran et al., 2004). In this study, the revised form of the CoRe (Aydin et al., 2013, see Appendix A) was used as lesson planning format and organizing framework for interviews. The preservice teachers' one instruction covering gas laws at the cooperating high school and their CoRes on this topic were examined. Before this instruction, all participants had already prepared their CoRes and completed one teaching experience in both microteaching sessions and at the cooperating high school. To ensure triangulation, their instructions were observed and recorded by a video camera. Immediately after each participant enacted his/her instruction on the topic of gas laws at the cooperating high school, semi-structured interview was conducted. Before the interviews, video recordings and CoRes were analysed and compared to determine whether the lesson plans were parallel to the instruction. When we found an inconsistency between the CoRe and instruction, we asked for clarification during the interview in order to understand the reason the plan and instruction did not match. The interviews mainly focused on the preservice teachers' self-regulation for teaching and their PCK. We asked about their design of lesson plan, choices regarding instructional strategies and materials, motivation before and during the instruction, reactions to the events during the instruction, and opinions about their performance. In addition, the elements in the preservice teachers' CoRes were explored during the interview in order to get deep information about their reasoning for their planning and teaching (i.e., PCK). For the validity of interview protocol, two scholars with Ph.D. degree who studied self-regulation examined the interview questions in terms of clarity, content, and comprehensiveness. Each interview lasted approximately 120 minutes. All of the interviews were audio-recorded and transcribed verbatim for the analysis. Interview protocol for teacher self-regulation is displayed in Appendix B.

Data Analysis

Data obtained from all data sources were analysed using both deductive and inductive analysis (Patton, 2002). Deductive analysis based on already existing frameworks—Zimmerman's (2000) model of self-regulation, Magnusson et al.'s PCK model (1999) and Roberts (1988, 2007) — were used in analysis of the preservice teachers' self-regulation and PCK, respectively (see Appendices C and D). On the other hand, the interaction between preservice teachers' self-regulation and PCK was analysed using inductive analysis to discover categories.

Deductive coding process. For data analysis, first we came together to examine preservice teachers' CoRes and video recordings. In their CoRes, we particularly focused on whether preservice teachers set goals, took student learning difficulties into account, chose appropriate instructional and assessment technique etc. Because CoRes reflected Magnusson et al.'s components, they provided us information about preservice teachers' PCK. For example, one of the items in CoRe read, "What difficulties do students typically have about each concept/idea?" constituted one

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of our deductive code "knowledge of students' understanding of science." In order to identify science teaching orientation component of PCK, the CoRe and associated interviews were analysed based on existing codes from Roberts (1988, 2007). Then, we checked video recordings to explore not only how and to what extent preservice teachers implemented their plans but also what kind of regulatory processes they utilized in performance phase. Zimmerman's model guided us to determine their self-regulation. Afterwards, we analysed interviews deductively considering the codes based on Zimmerman's frameworks (see Appendix C) and Magnuson et al. (1999) (see Appendix D). First, we separately coded the one participant's interview data, came together, and discussed the codes. The inter-rater reliability for each phase of teacher self-regulation ranged between .82 and .93 while it was between .89 and .96 for PCK components.

Inductive coding process. The inductive coding was accomplished in three steps. First, one interview was coded by all the researchers independently for possible interactions between PCK and TSR. To do this, we initially determined which parts reflected some interaction within our data. For example, preservice teachers' planning their instruction considering students' prerequisite knowledge, difficulties, and misconceptions provides evidence for an interaction between the *strategic planning* and the *knowledge of learner components of PCK*. In some cases, analysis of interview oriented us to create new subcategories for TSR. For instance, we added previous teaching performance, student performance, classroom environment, lesson plan, time management, and emotion as self- monitoring and controlling criteria. We presented new codes as italics in Appendix C.

Second, another preservice teacher interview's data were coded by all the researchers independently again. In some situations, discrepancies among the codes were encountered and resolved through discussion. At this point, we calculated inter-rater reliability to determine consistency among the number of same interactions between TSR and PCK. Following these steps, the other three interviews were coded by different pairings of the researchers independently. After that, they shared their coding and associated data with the other researchers. Again, we calculated inter-rater reliability between researchers who worked in pairs. Finally, the inter-rater reliability ranged between .88 and .97, indicating a good level of agreement (Miles & Huberman, 1994). Thereby, we established the trustworthiness of the study. In addition, use of multiple data sources and engagement of more than one researcher in the analysis process ensure data and investigator triangulation, respectively. Table 3 displays all categories emerged out of the interactions within the data and their explanations.

Ethical Issues of the Study

All activities in the study were conducted in alignment with the Institutional Review Board (IRB). Participation to the study was on voluntary basis and all participants submitted written consent form. Preservice chemistry teachers were also aware of the role of participant observers. An external gatekeeper (Department Chair) served as a point of contact for participants to voice any concerns. The names of the subjects were removed from all data collection forms by giving pseudonyms to participants. Therefore, issues regarding ethics in research (i.e., protection of the participants from harm and confidentiality) were assured (Fraenkel & Wallen, 2006).

Results

To provide a clear picture, we created Table 4 that organized the interactions between TSR and PCK. This table summarizes how each PCK component interacted with a particular TSR process during each phase of self-regulation for preservice teachers. When an interaction was observed in a participants' teaching, we put his/her name to the related cell in Table 4. We also presented the supporting evidence in detail for each section in the following parts.

The Interaction between Forethought Phase and PCK

The relation between TSR and PCK in forethought phase is presented under Goal setting and Strategic planning processes.

Goal setting. Analysis of the data showed that science teaching orientation and knowledge of curriculum components interacted with goal setting. These components were a north star for participants in setting their goals of instruction. The data did not provide any evidence of an interaction between other PCK components and goal setting.

Three preservice teachers (Maggie, Lily, and Daphne) set goals that were consistent with their science teaching orientation. In the interview, Lily expressed her purposes for teaching chemistry as increasing students' ability to explain daily life phenomena (i.e., her science teaching orientation is "everyday coping"). Thus, her goal would be that students use their knowledge when faced with a new daily-life application of gases (e.g., explaining breathing by the use of the Boyle-Mariotte law). When we examined her CoRe, we saw that she had written as one of her goals: "Student will be able to explain the daily life examples of gas laws."

Second, curriculum knowledge interacted with goal setting. All participants used the chemistry curriculum formed by the Ministry of National Education for secondary level during their goal-setting process, indicating the role of knowledge of curriculum in setting the goals. Data from the CoRes also supported this point. All of them wrote the objectives from the curriculum (e.g., "Student will be able to analyze the different graphs of P-V relations"). Additionally, they all added extra objectives to address in their teaching. For example, Adam augmented one objective at sub-microscopic level. In his CoRe, he wrote: "Students will be able to describe Boyle's law and Charles' law in a macroscopic and microscopic manner."

Strategic planning. All PCK components interacted with strategic planning. First, all participants utilized curriculum knowledge in planning their instruction. They stated in the interview that they examined the national curriculum, and thus they were aware of the objectives stated there. Moreover, they had curriculum materials (high school chemistry textbooks, web-sites representing particles or events which exist or happen at a sub-micro level, etc.) useful for planning to teach gas laws. However, both analyses of CoRes and interviews yielded that the participants except Emily were unable to focus on the horizontal and vertical relationships within the gas laws topic. Emily explained that she

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checked what was taught in the previous grade -8th grade- (i.e., vertical relation of the topic to the earlier grades).

Table 3 Codes and Explanations for Interaction between TSR and Components of PCK

Self-regulation Phase	Code	Explanation
Motivation	Self-efficacy – KoL	Preservice teachers' beliefs in their ability to elicit students' pre-requisite knowledge, difficulties and misconceptions, and then overcome them.
	Self-efficacy – KoIS	Preservice teachers' beliefs in their ability to use their knowledge of subject and topic-specific instructional strategy.
	Self-efficacy –SMK	Preservice teachers' confidence in their SMK.
	Goal orientation – STO	Interactions between Preservice teachers' purposes for teaching and their beliefs about science, goals for teaching science, and science teaching and learning.
	Goal orientation – KoIS	Interactions between Preservice teachers' purposes for teaching and their use of knowledge of subject and topic-specific instructional strategy.
Forethought	Goal setting – STO	Preservice teachers set learning goals considering their beliefs about science, purposes and goals for teaching science, and science teaching and learning.
	Goal setting – KoC	Preservice teachers set learning goals considering curriculum objectives in the topic they are teaching, and horizontal and vertical relationships in the curriculum.
	Strategic planning – STO	Preservice teachers plan their instruction considering their beliefs about science, purposes and goals for teaching science, and science teaching and learning.
	Strategic planning – KoL	Preservice teachers plan their instruction to elicit students' pre-requisite knowledge, difficulties and misconceptions, and then to overcome those.
	Strategic planning – KoIS	Preservice teachers use their knowledge of subject and topic-specific instructional strategy while planning their instruction.
	Strategic planning – KoC	Preservice teachers plan their instruction considering curriculum objectives in the topic they are teaching, and horizontal and vertical relationships in the curriculum.
	Strategic planning – KoA	Preservice teachers use their knowledge of various and appropriate assessment techniques during planning their instruction.
	Strategic planning – SMK	Preservice teachers effectively/ineffectively plan their instruction because of their adequate or inadequate SMK
	Performance – STO	Preservice teachers monitor and control their instruction considering their beliefs about science, purposes and goals for teaching science, and science teaching and learning.
Performance	Performance – KoL	Preservice teachers monitor and control their instruction to elicit students' pre-requisite knowledge, difficulties and misconceptions, and then to overcome those.
	Performance – KoIS	Preservice teachers use their knowledge of subject and topic-specific instructional strategy to monitor and control their teaching for the purpose of implementing what plan or solving a problem.
	Performance – KoC	Preservice teachers monitor and control their instruction considering curriculum objectives in the topic they are teaching, and horizontal and vertical relationships in the curriculum.
	Performance – KoA	Preservice teachers monitor and control their instruction using various assessment techniques and assessing what they intend to teach.
	Performance – SMK	Preservice teachers are/are not able to monitor and control their instruction because of their adequate/inadequate SMK.
	Self-reflection – KoL	Preservice teachers evaluate their instruction considering their knowledge related to students' prerequisite knowledge, difficulties and misconceptions
Self-reflection	Self-reflection – KoIS	Preservice teachers assess their instruction based on their knowledge related to teaching methods and strategies specific to science.
	Self-reflection – STO	Preservice teachers evaluate their teaching considering why, what and how to teach science.
	Self-reflection – KoC	Preservice teachers' evaluations reflect their knowledge on curriculum goals and curricular materials.
	Self-reflection – KoA	Preservice teachers uses their knowledge of various and appropriate assessment techniques to evaluate their instruction.
	Self-reflection – SMK	Preservice teachers evaluate their instruction considering their SMK.

Notes. STO: Science teaching orientation, KoL: Knowledge of learner, KoC: Knowledge of curriculum, KoIS: Knowledge of instructional strategies, KoA: Knowledge of assessment, SMK: Subject matter knowledge.

Second, regarding knowledge of learner, all participants except Adam paid attention to learners' pre-requisite knowledge, difficulties, and/or misconceptions in planning. In terms of the pre-requisite knowledge necessary for learning gas laws, Maggie and Daphne stated that learners need to know kinetic-molecular theory during interview. They thought that it would help explain behaviours of gas particles and the effect of changes in temperature or pressure on gases' behaviour. Therefore, they planned to begin by teaching kinetic-molecular theory. Regarding difficulties, Daphne thought that learners would have difficulty in understanding gas behaviour at atomic level so she made accommodations in selecting the topic-specific instructional strategy (e.g., a submicroscopic level simulation for explaining the relationships among pressure, volume, temperature, and mass). Finally, Maggie and Lily considered possible misconceptions during their planning. For example, Lily included the misconception that "when the air is compressed, the air particles are all pushed to the

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end of the syringe" and she made plans (e.g., syringe activity) to address that misconception in her CoRe.

Table 4 Pre-service teachers' interactions between teacher self-regulation and PCK

		STO	KoC	KoL	KoIS	KoA	SMK
Forethought Phase	Goal Setting	Maggie Lily Daphne	Adam Emily Maggie Lily Daphne				
	Strategic Planning	Maggie Lily Daphne	Adam Emily Maggie Lily Daphne	Emily Maggie Lily Daphne	Adam Emily Maggie Lily Daphne	Maggie Lilly Daphne	Daphne Lily
Performance Phase	Self-experimentation			Lily	Adam Lilly		Lily
	Attention Focusing	Adam Emily	Daphne	Adam Emily Maggie Lily	Daphne	Maggie Emily Adam Lily Daphne	Emily Daphne
Self-reflection Phase	Emotional reactions	Lily Daphne	Daphne		Adam Lily Daphne		
	Decision-making			Emily Lily	Emily Daphne	Maggie Emily Lily	Lily Emily Daphne
Motivation	Self-Efficacy			Emily	Daphne Maggie		Adam Emily Maggie Lily Daphne
	Goal Orientation	Adam Lily Maggie			Lily		

Notes. STO: Science teaching orientation, KoL: Knowledge of learner, KoC: Knowledge of curriculum, KoIS: Knowledge of instructional strategies, KoA: Knowledge of assessment, SMK: Subject matter knowledge.

Third, all participants utilized their knowledge of instructional strategies to design their instruction during strategic planning. None of the participants planned to implement subject-specific instructional strategy (e.g., 5E learning cycle) in their CoRes. When asked for the reason in the interview, Lily stated:

> First of all, I thought about whether I could use 5E strategy in teaching the particular topic. But the classroom environment, lack of the Internet access, etc… I could neither use animations and simulations nor do experiments. All those problems made me think that I would not be able to implement 5E in teaching.

As the quote above shows, she thought that the 5E learning cycle could only be used with particular activities. Therefore, she decided not to implement the strategy. Regarding the topic-specific instructional strategies, all participants planned to use both topic-specific representations (e.g., analogies, and illustrations) and activities (e.g., syringe activity and marshmallow activity video) to teach gas laws. In addition, Daphne and Adam preferred to use simulations (e.g., a simulation that shows the particles at submicroscopic level and how changes in pressure, temperature, and volume affect particles) in order to meet particular learning goals. However, they stated that they did not check whether the simulation worked or practiced the activity before the instruction. Therefore, they had to change their plan during the instruction as they emphasized in the interview. When their CoRes were examined, we saw that they generally planned to teach through the didactic method, enriched with activities, reference to daily-life events, and representations.

Fourth, regarding the science teaching orientation component, Maggie, Lily, and Daphne also planned their teaching in light of their orientation. For example, Daphne thought that learners should be able to explain daily-life phenomena with what they learned about gas laws (science teaching orientation). She planned to ask daily-life questions in her teaching in the CoRe: "How can you explain why a package of chips puffs up on-board a high-flying airplane by the use

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of Boyle law?" and "What is the idea behind hot air balloons?" During the interview, she said that these types of questions encourage meaningful learning.

Fifth, the data revealed that only Daphne, Lily, and Maggie tried to include the assessment component of PCK during strategic planning. Daphne prepared a worksheet with multiple-choice items about gas laws. Maggie and Lily aimed to teach the interpretation of graphs for pressure-temperature or pressure-volume relations. During planning, they informally intended to assess learners' understanding in interpreting graphs. However, they did not prepare any specific questions to assess it. Rather, Maggie just planned to select a question from the textbook during the instruction. In other words, their planning was not specific and well-defined; rather, they superficially and broadly proposed assessing learners' understanding without following through.

Finally, data analysis revealed that the participants' (Daphne and Lily) SMK also had some influence on their strategic planning. For instance, Daphne used a video to show how pressure and temperature are related. In the interview, we asked why she decided to use that video. Daphne stated:

> I could find two experiments regarding Gay-Lussac law. In one of them [candle-in-jar demonstration], a burning candle was placed in a cup filled with some water. Then, a beaker was placed upside-down in the cup. The water level in the cup increased after the flames went out. I could not understand this demonstration and explain why it happened. The other one was it [Collapsing can experiment that she showed in the class]. I chose it because it was simple and easy to explain.

As the quote shows, during planning phase, Daphne decided to use the 'collapsing can' experiment video because she believed that she had adequate SMK for gas laws to explain. To conclude, the preservice teachers' low SMK influenced their strategic planning negatively.

The Interaction between Performance Phase and PCK

Analysis of the data revealed that participants used self-experimentation and attention focusing as their only monitoring and controlling processes in the performance phase. Hence, we provided the results for this part under two sub-titles, namely; self-experimentation and attention focusing processes. SMK, knowledge of learner, and knowledge of instructional strategies were influential during self-experimentation, whereas all PCK components were utilized during attention focusing. A commonality between the two controlling processes was SMK: Poor SMK led to ineffective self-experimentation and poor attention focusing. How each PCK component was utilized in each process is explained in detail below by presenting the corresponding self-regulation and PCK categories (Appendices C and D) in parentheses.

Self-experimentation process. Knowledge of learner and instructional strategy components supported participants' self-experimentation process while inadequate SMK inhibited their self-experimentation. For instance, Lily stated that she did not fully grasp why the inverse relationship between pressure and volume is shown as curvilinear in graph form. During the lesson, she asked students to draw the graph by giving the data. Students showed the inverse relationship between pressure and volume as linear. As a result of analysis of videos, we observed that Lily realized the students' difficulty but did not effectively regulate her instruction to resolve it (self-experimentation). In the interview, she attributed her ineffective regulation to her lack of SMK for gas laws. Knowledge of instructional strategy was helpful in regulating instructional strategies for the purpose of solving students' learning problems during self-experimentation. For instance, during instruction we observed that Adam asked students to design an experiment on Boyle's law by giving students a marshmallow and syringe to observe how pressure changes with volume. He walked around the class and realized that one student put the marshmallow outside the syringe. Moreover, many students were not completely closing the edge of the syringe (criteria: student performance). Then, he adjusted his teaching strategy by asking guiding questions (regulations: instructional strategy) that led students to consider what they learned about gases (purpose: solving problems). The questions were as follows: "What did we discuss about gas pressure? What about the properties of systems where we can change volume? Is that an open or closed system?" With these reflective questions, students re-thought their experiments and put the marshmallow into the syringe with a closed edge to observe how volume and pressure are related (strategy: self-experimentation).

Only Lily brought her knowledge of learner into play when regulating her instructional strategies, either to implement her lesson plan or to deal with students' learning issues. Lily stated in the interview that she realized that there were some disinterested students when she asked the class to draw a pressure-volume graph by giving the data. This was because the students were not used to drawing graphs (criteria: student performance). Since Lily observed students' difficulty in graph drawing, she guided them to tackle this challenge (purpose: solving the problem) by explaining that the data should be placed on the *x* and *y* axis (regulations: instructional strategy). With this guidance, students started to draw the graph (strategy: self-experimentation).

Science teaching orientation, curriculum, and assessment components were never utilized by the participants while controlling their instruction through self-experimentation.

Attention focusing process. Interactions between PCK components and self-regulatory processes were much more complicated during attention-focusing than in the process of self-experimentation. First, all PCK components, including SMK, played a role. Second, inadequate SMK was an inhibiting factor, which led to ineffective attention focusing (strategy). Third, quality of the PCK components influenced the effectiveness of attention focusing.

Participants could not focus their attention on students' performance (criteria) satisfactorily to help students to tackle their learning difficulties (purpose) due to their limited SMK. For instance, Emily asked students to draw a pressure-volume graph. Students drew an inversely proportional linear graph instead of curvilinear one. Emily mentioned that she confused pressure-volume graph with volume-temperature (SMK) and explained her insufficiency during the interview as follows;

> R: Did you realize that you taught the pressure-volume graph wrong?
> E: No, I did not.

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> R: Did you expect students to draw an inversely proportional linear graph beforehand?
>
> E: Actually, they drew two graphs. One student drew a curvilinear graph. There were two students who drew the graph right. He explained the graph well. When I asked for another student with different drawing, students drew an inversely proportional and linear graph.
>
> R: There were two students on the board. One of them drew curvilinear while the other drew a linear line on the same graph.
>
> E: At that point, I realized that I got confused. I have never thought about the explanation [about why the graph is curvilinear]. I have never thought about what students said [about linear graph]. I did not focus my attention deeply enough.

Similarly to the problems stemmed from a lack of SMK, only Daphne's relatively undeveloped curriculum knowledge precluded her from regulating their teaching during the process of attention focusing (strategy). Daphne realized that students did not know the mole concept (criteria: student performance) while teaching Avogadro's hypothesis about gases' mole and volume. During the interview, she expressed that she did not look into what students had learned beforehand about the mole (knowledge of curriculum) since she thought that students should have known that topic before learning about Avogadro's hypothesis.

On the other hand, a strong science teaching orientation was influential when the participants regulated their teaching. As a sub-dimension of their orientation, the participants (Adam and Emily) defined the students' role as active and their role as a facilitator in the interview. Being directed by their orientation, the participants continuously kept students active (strategy: attention focusing) throughout the instruction through regulating their teaching strategies (purpose: implementing plan) as we observed in their instruction.

With regard to relationships between knowledge of learner, instructional strategy, and assessment and attention focusing, it was revealed that preservice teachers who have developed those PCK components attentively focused on their CoRes. However, poor knowledge of learner, instructional strategy, and assessment resulted in ineffective attention focusing. Maggie's teaching provided evidence for how her assessment knowledge supported her attention focusing. Maggie was knowledgeable about a student misconception: particles are as colourful as the matter itself. Therefore, she intentionally asked questions (strategy: attention focusing) to reveal students' misconceptions (criteria: student performance). By relying on her knowledge of assessment, she asked what students thought about gases and their particles, and whether the particles were colourless or colourful (purpose: solving problems). Contrary to Maggie, Daphne, because of her limited assessment knowledge, did not focus her attention (strategy) to assess whether students could draw graphs for all the gas laws (criteria: student performance), which was an explicit goal in her objectives (purpose: lesson plan). During the interview she explained that "…I did not focus my attention to assess whether students learned drawing graphs or not. I wrote objectives about drawing graphs but I did not assess it."

In general, participants with more robust knowledge of learner focused their attention (strategy) to students' learning for the purpose of implementing their plan. For instance, in her CoRe, Lily noted a misconception that students have—that gases move towards the edge of a syringe when squeezed (knowledge of learner). Therefore, she intentionally selected two topic-specific representations and activities—three cylinders with different volumes and a syringe to change the volume—to address students' difficulties on the movement of gas particles. Using these topic-specific strategies, Lily focused on what students think about the movement of particles when the volume of cylinder and syringe is decreased (criteria: student performance). When asked during the interview she said

> …I talked about it [the movement of particles] without emphasizing it on three cylinders with different volume. Then, I asked students what they think about [the movement of particles] on the syringe [when the syringe is squeezed]. I realized that they knew the correct explanation. I made a comparison…..Students think that gases move towards the end of syringe when we squeeze it. Therefore, I focused on this misconception.

The data revealed only one case where learner knowledge did not enact in a way to result in deliberate attention focusing (strategy). Although Daphne was knowledgeable about students' difficulty in drawing graph (knowledge of learner) and included objectives related to drawing graph for gas laws in her CoRe, she could not focus her attention (strategy) on whether students were able to draw graphs related to gas laws (criteria: student performance) because of her limited topic-specific activities (knowledge of instructional strategy). Daphne solely showed graphs to students, instead of asking them to draw.

Lily and Daphne's cases where their knowledge of learner interacted with attention focusing also provided evidence for how their knowledge of instructional strategy played a role while they were focusing their attention. As explained above, Lily purposefully used a syringe activity (knowledge of instructional strategy) to overcome students' difficulties on movement of gas particles when squeezed (i.e., gases move towards the edge of a syringe when squeezed). She asked one student to decrease the volume of the syringe by closing the edge of it and then asked students to explain the movement of particles. By relying on her knowledge about this topic-specific activity, Lily was able to focus on students' learning. On the contrary, Daphne's limited knowledge on topic-specific instructional strategy did not result in satisfactory attention focusing. Although Daphne's CoRe included objectives requiring students to draw graphs for gas laws, she could not focus her attention whether students were able to draw graph related to gas laws because of her limited topic-specific activities. Daphne preferred to present graphs to the students instead of encouraging them to draw graphs.

Finally, in some cases, knowledge of learner triggered knowledge of assessment, and hence preservice teachers focused their attention (strategy) on students' learning (criteria). In others, participants' assessment knowledge informed their knowledge of learner to focus their attention. As an example of the former, Emily stated that she knew that the definition of gas and its properties are required to understand the gas laws, therefore she checked her

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students' understanding about these concepts (criteria: student performance). Because she knew that knowledge about gas properties is a prerequisite (knowledge of learner), Emily purposefully asked questions (knowledge of assessment) to focus her attention (strategy) on students' difficulties (purpose: solving problem).

The Interaction between Self-reflection Phase and PCK

The relation between TSR and PCK in self-reflection phase is presented under emotional reactions and decision-making.

Emotional reactions. The participants had emotional reactions to their science teaching orientations and knowledge of instructional strategies. Lily and Daphne gave emotional reactions to their orientations. For instance, Lily believed that chemistry is strongly related to daily life (science teaching orientations) and she satisfied that she was able to emphasize daily-life examples in class (internal factors). In addition, she was pleased to see that she encouraged students to draw conclusions and find the law by drawing a graph. Here, she evaluated herself in terms of developing higher order skills (science teaching orientations).

Adam, Lily and Daphne assessed themselves about their instructional strategies and gave emotional reactions. To illustrate, Adam evaluated his instruction based on student performance as a criterion. He started instruction with an animation to remind students of their previous knowledge related to phases of matter. Regarding animation, the class discussed the motion of particles and the space between them in solid, liquid, and gas phases. Then, Adam used an analogy to explain the phases of matter. He let students imagine a stadium where people watch a sporting event. He asked students how this stadium and phases of matter were similar to each other and what players and viewers stand for. During the interview, he expressed that when he used this analogy in class (knowledge of instructional strategies), students were able to construct relationships between the source and target. This delighted him (emotional reactions). Similarly, Lily was satisfied with her instruction and attributed the effective instruction to internal factors, i.e., to her use of a teaching method that promoted conceptual understanding. This view is reflected in the interview excerpt below:

> R: In your opinion, what was the strength of your instruction?
>
> L: It was conceptual. In general, inservice teachers state Boyle-Mariotte law, solve questions, and pass to the next topic without detailed explanation or daily life examples… [However], I talked about daily life examples in class. [Students] could see chemistry is closely related to daily life. I tried to make students think about the relationship between pressure and volume by drawing a graph and explore the relationship…Therefore, these were strong points of my instruction.

Decision-making process. The participants made decisions about their learner, assessment, instructional strategy, and SMK.

Lily, Emily, and Daphne decided to review their SMK for gas laws before their future teaching practices. Emily stated that she had difficulty in explaining graphs related to Boyle's and Charles's laws (SMK) because of her lack of knowledge (internal factors). As a result of self-evaluation, Emily made a decision to improve her SMK and study the topic in more detail before instruction. Daphne also made a conscious reflection about her SMK. During instruction, she employed simulations to present the relationship between pressure and volume. One of the students asked how much they could compress the piston. Daphne could not answer this question. During the interview, this situation was explained as follows:

> R: Why did not you answer this question?
>
> D: I showed it in the simulation, I think. I compressed till end.
>
> R: He said let's try. In your opinion, did you answer that question?
>
> D: I could not provide explanation but I showed it.
>
> R: Why?
>
> D: I had not thought about it before. I think I had no clear answer to that question; therefore, I did not respond…I think I have to study all the details. We forgot general chemistry concepts so we have to review those concepts [internal factors].

Three preservice teachers' (Maggie, Emily, and Lily) evaluations of their instruction based on student performance also indicated an interaction between knowledge of assessment and self-reflection. Lily used student performance as feedback for the effectiveness of her instruction. For instance, she asked students to give daily-life examples related to the topic during class. During her interview, she stated "…if students could find examples, this indicated that they understood what I explained and thus it is a feedback to me." However, after the instruction she felt that her questions about the pressure-volume relationship were not clear enough to understand whether the students could provide conceptual explanations. Therefore, she decided to focus on finding appropriate questions to assess student understanding in more detail in the future (decision making). Maggie, on the one hand, reflected on her knowledge of assessment during the interview. Before the instruction, she did not plan how to assess students. She reflected on this issue after her instruction: "It would be effective if I planned the questions beforehand" (decision making).

The preservice teachers reflected on their instruction considering knowledge of learner (Emily and Lily) and knowledge of instructional strategies (Emily and Daphne), though it did occur occasionally. For instance, Emily made decisions about knowledge of learner referring to internal and controllable factors. During the interview she said "…I need to consider students' possible answers to my questions and investigate their difficulties and misconceptions Then, I need to make research and read a lot. This can be possible by reading and making search much more." Similarly, Lily decided to examine students' possible difficulties and misconceptions (knowledge of learner) in more detail before class. Furthermore, Emily made a decision about designing her next instruction to eliminate students' misconceptions and about improving her teaching in terms of using micro-level representations (knowledge of instructional strategies), as evident in her statements.

> …I clearly observed that students had confusion about theory and law. While I was explaining the difference between theory and law, I thought what could be the

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> reason why students had such an idea. This was an experience for me and I evaluated my instruction…For example, instead of presenting the concepts directly, I would plan my instruction taking misconceptions into consideration…I need to develop my instruction at micro level because I could not explain concepts at that level during my instruction [internal factors].

The Interaction between Motivation and PCK

Among the factors shaping motivation, only self-efficacy beliefs and goal orientation interacted with preservice teachers' PCK components.

Self Efficacy. While SMK for gas laws affected their self-efficacy the most, their knowledge of instructional strategies and learner components were also influential. All participants stated that they felt inadequate with regard to their SMK for gas laws. Lily expressed her inadequacy as follows:

> I realized that I have some deficiencies [in my SMK]. I noticed that I did not know the topic in detail while teaching the subject… I have difficulties in explaining daily life events in the subject I am teaching. There is a relationship [between the topic and daily life event] but how does the daily life event relate to the topic? I have problems with [explaining] that.

The preservice teachers' relatively undeveloped knowledge of 5E-learning cycle (Maggie and Daphne), subject-specific instructional strategy, also resulted in low self-efficacy. They did not feel adequate in using the 5E learning cycle method. Therefore they did not select 5E and instead used questioning enriched with topic-specific instructional strategies when teaching gas laws. As Daphne stated,

> …5E is applicable to my topic but I don't like it. I have difficulties related to 5E. The E's makes me nervous since I am trying to fit activities to 5E steps…I knew theoretically but it did not work well when I designed.

There was one case in which a preservice teacher's low knowledge of learner made her feel non-efficacious. Emily explained how she had difficulties in preparing to teach the subject in the interview:

> R: Was there anything that you had difficulty in?
> E: Yes. I could not find the difficulties that students might have about this topic. I could not have the students' point of view. I think as a teacher. I had difficulty in that. Gases are abstract topic to me. Therefore, I think it's hard to teach….What can I find? Which example is the best in helping [students] visualize? or which is the best way to learn the topic? I have difficulties about these issues.

Goal Orientation. Science teaching orientation is the PCK component that contributes to goal orientation most. Especially, teachers' beliefs about science and the purpose of teaching science were influential on preservice teachers' goal orientations (Adam, Lily, and Maggie). For instance, in the interview Maggie explained her science teaching orientation as enabling students to explain daily life events (everyday coping) and parallel to this view she stated that she taught gas laws to the students to make them meaningfully understand the concepts (goal orientation).

There was evidence for an interaction between goal orientation and knowledge of instructional strategies as well. Directed by her goal orientation, Lily selected particular topic-specific strategies to teach the pressure-volume relationship. Lily's goal orientation was teaching gases for understanding daily-life events. During the interview, she explained that she used the popcorn example to teach pressure and volume and to enable students to better understand Boyle's law.

Discussion

Data in the present study provided evidence for the interaction between TSR and PCK components. Especially, the participants' ineffective instruction can be linked to the quality of their self-regulation for teaching-PCK interaction. In the following parts, we discuss results for interactions considering each TSR dimension and focus on possible reasons why participants' instructions were not effective.

Discussion on the Interaction between Forethought Phase and PCK

In this phase, we observed a relationship between goal setting and science teaching orientation and knowledge of curriculum, as well as between strategic planning and all PCK components. However, we can argue that the quality of interactions was determined by the quality of PCK, which might play role in the effectiveness of instruction. First, although preservice teachers considered national curriculum in their strategic planning, their inadequate knowledge about vertical and horizontal relations among topics prevented them from planning their instruction effectively. Therefore, they isolated the topics taught. However, as a self-regulated teacher, they were supposed to check those topics, plan their instruction with a broader angle, and try to base their teaching on previous topics. Lack of teaching experience (Sickel, 2012) may impede preservice teachers' ability to pay specific attention to horizontal and vertical relations of the topic during strategic planning.

Second, while planning, the participants avoided using subject-specific strategies (e.g., 5E-learning cycle); rather, they all used topic-specific representations (e.g., lung model) and activities (e.g., syringe activity) in teaching gas laws. This situation might bring about ineffective teaching. In terms of PCK, use of topic-specific strategies effectively has the potential to result in meaningful learning. However, their reluctance to use of 5E-learning cycle can be attributed to deficient knowledge about those strategies (Settlage, 2000). Although preservice teachers took science teaching methods courses, it seems that their limited experience in using such strategies (Sickel, 2012) played a role in regulating their teaching. In addition, the fragmented nature of preservice teachers' PCK, called "activities that work" by Appleton (2003), might also be influential in their planning of subject specific strategy, namely 5E-learning cycle. When planning their teaching, participants paid more attention to selecting activities and representations rather than focusing on how to implement them to ensure meaningful learning. Kagan (1992), and Appleton and Kindt (2002) stated that inexperienced teachers prefer to consider themselves rather than the learners and their needs. Accordingly, in this study, we

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observed that participants took almost entirely personal factors into account, even though self-regulated teachers are expected to plan their teaching by considering many different factors (e.g., contextual factors and learners' needs and levels) (Boekaerts, Pintrich, & Zeidner, 2000; Yetkin-Ozdemir et al., 2014). Furthermore, preservice teachers' experience in elementary and high schools as students may not serve as a good example of how to utilize these strategies—a failed "apprenticeship of observation" (Grossman, 1990). In Turkey, teaching is generally teacher-centered and high-stake exams dominate the education system. Hence, their lack of apprenticeship of observation may force them to ignore the use of subject-specific instructional activities. Lastly, another possible explanation of their evasion may be their poor SMK (Magnusson et al., 1999). SMK is one of the basic domains contributing to PCK development (Abell, 2007; Shulman, 1986). Unfortunately, preservice teachers in this study did not possess strong SMK for gas laws. Designing a lesson with 5E-learning cycle requires adequate knowledge for gas laws since it requires use of this knowledge in each phase (e.g., engage and explain). Thus, they might tend not to focus on using 5E-learning cycle subject-specific strategy in their instruction, in particular in the planning phase.

Third, preservice teachers generally did not specify how they would assess learners' understanding before the instruction, even though that is a critical component of self-regulation (Yetkin-Ozdemir, et al., 2014). PCK literature clearly has stated that PCK components' development may not occur evenly. The assessment and curriculum components especially need more time to improve (Hanuscin, Lee, & Akerson, 2011; Henze, van Driel, & Verloop, 2008) than other components such as instructional strategy. This may account for the difficulties in those areas and be barrier to teaching effectively.

Discussion on the Interaction between Performance Phase and PCK

In the present study, the preservice teachers monitored and controlled their instruction for the purpose of implementing their lesson plan and/or finding ways to solve problems during their practice. Several interactions between self-regulation and PCK stood out during the performance phase and the effectiveness of instructions can be explained by these interactions. First, inadequate SMK for gas laws was revealed as an inhibiting factor that leads to ineffective self-experimentation and attention focusing. This finding is compatible with the research stating that a rich SMK is a prerequisite for robust PCK (Henze et al., 2008; Shulman, 1986; Van Driel et al., 2002), which enables teachers to answer to the demands of teaching and learning. In a similar vein, weak SMK makes regulation of the instruction challenging (Sanders, Borko, & Lockard, 1993). Second, the more preservice teachers developed components of PCK, the more efficiently they regulated their teaching. This could be explained by the assertion that "PCK was manifested as a feature of knowledge in action" (Park & Oliver, 2008, p. 268). This aspect requires integrating PCK components accessible for teacher when encountering a problem related to teaching and learning. Therefore, in this study, there was interaction between more developed PCK components and TSR, since these components were accessible to the participants when regulating their teaching. This is compatible with the view that PCK is a construct consisting of "understanding" and "enactment" dimensions (Aydın & Boz, 2013; Park & Oliver, 2008). The PCK components about which preservice teachers only had knowledge did not appear during the instruction, which might lead to difficulties in regulating instruction. Third, preservice teachers' orientation was an important aspect of the performance. This finding is expectable, knowing that teachers' orientations act as filters that guide teachers throughout their decisions about the content, instructional strategies, and assessment (Abell, 2008; Magnusson et al., 1999).

Discussion on the Interaction between Reflection Phase and PCK

Results related to the interaction between self-reflection and PCK indicated that the preservice teachers utilized mostly SMK, knowledge of instructional strategies, and knowledge of assessment to reflect on their instruction. We observed that they experienced difficulty in conceptually explaining basic relationships and providing answers to students' questions in gases; and they tended to regulate their teaching by avoiding having to provide deep information. During the self-reflection phase, therefore, they focused on their poor SMK for gas laws to evaluate their instruction. Considering the related literature, this finding is hardly surprising. There is a body of research in science education showing the deficiency of preservice teachers in SMK (Abell, 2007; Appleton, 2003; de Jong, Veal, & van Driel, 2002). In the same vein, they had difficulty in assessing students during instruction. They took this weakness into account and decided to ask more appropriate questions to understand student reasoning in their further instructions. This finding is compatible with the research stating that teachers and interns have a limited repertoire of assessment strategies (Windschitl, Thompson, Braaten, & Stroupe, 2012; Friedrichsen et al., 2009). On the other hand, they had a still inadequate but more developed knowledge of instructional strategies in terms of topic-specific ones as compared to SMK and knowledge of assessment, which is compatible with related literature (Friedrichsen et al., 2009; Hanuscin, 2013). Although preservice teachers satisfied with their instruction embedded topic-specific instructional strategies, they felt they had difficulty with 5E-learning cycle subject-specific strategy. However, they did not resolve to co-construct knowledge about instructional strategies. Self-satisfaction in teaching is important, especially for preservice teachers, who should enter the profession motivated. Teachers' evaluations of their teaching shape their motivation (Zimmerman, 2000).

In general, since preservice teachers have less experience in teaching, their orientations are broad and non-specific (Friedrichsen et al., 2009; Friedrichsen & Dana, 2003). This situation may have role in the interaction between science teaching orientation and self-reflection in the present study. Likewise, preservice teachers have a less-developed knowledge of curriculum, especially in terms of horizontal and vertical relationships. Therefore, they might not pay attention to their knowledge of curriculum during self-reflection. Lastly, the preservice teachers became aware of their insufficient knowledge about learners and made some decisions.

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This finding confirms that they lacked topic-specific knowledge about science learners and curriculum, as Friedrichsen et al. (2009) reported.

Considering the cyclical nature of TSR (or self-regulated teaching), the self-reflection phase is important because the decisions preservice teachers make in this phase and their emotional reaction to their instruction play a role in planning and enacting later instructions (forethought and performance phases). According to Park and Oliver (2008), PCK development occurs as a result of knowledge-on-action, that is, knowledge elaborated and enacted through reflection after the instruction. Therefore, if preservice teachers make comprehensive evaluations using their PCK in the self-reflection phase, this may help them develop both their further instruction and PCK. Unfortunately, the reflections of preservice teachers in this study were superficial and did not cover all PCK components. This is expectable knowing that preservice teachers have low PCK (Magnusson et al., 1999) and limited teaching experience, which may prevent their use of self-regulatory processes (Delfino, Dettori, & Persico, 2010; Zimmerman, 1989).

Discussion on the Interaction Motivation and PCK

Regarding motivation, the findings indicated that preservice teachers' self-efficacy beliefs interacted with their SMK, knowledge of instructional strategies, and knowledge of learner. This is compatible with the research advocating teacher efficacy as an effective affiliate of PCK (Park & Oliver, 2008). For most of the preservice teachers, low self-efficacy about their SMK and use of subject-specific strategies shaped their planning and instruction; accordingly, they preferred to give lectures enriched with topic-specific strategies (e.g., analogy, model, etc.). This situation is consistent with the Allinder's (1994) study that proposed that self-efficacious teachers plan and organize instruction in a more effective way. Such teachers are eager to use innovative instructional strategies to promote student learning (Guskey, 1988). Another interaction we observed was between goal orientation and PCK. The preservice teachers who had the view of teaching chemistry for everyday coping (science teaching orientation) had mastery goal orientation. This result supported Butler's (2003) study, which emphasized that teachers' goal orientations help them regulate their teaching through planning, using instructional strategies, monitoring the instruction, and making revision. Thereby, the interaction between their goal orientation and PCK may determine the effectiveness of instruction.

Conclusion

In this qualitative study, the purpose was to investigate how preservice chemistry teachers' PCK and self-regulation integrated in the context of teaching gas laws to high school students. Based on the literature on both PCK and TSR, and our research and teacher education experiences, we proposed a hypothetical wheel-shaped PCK-TSR model (Figure 1). We advocate that science teachers would design more effective learning environments, and develop their professional knowledge and skills more effectively for teaching when they purposefully enact their TSR and PCK in an integrative manner. With this hypothetical model, we also contented that teachers with effective TSR might stimulate their PCK development (i.e., TSR influences PCK, one direction of reciprocal relation between PCK and TSR in Figure 1) and vice versa (i.e., PCK influences TSR, one direction of reciprocal relation between PCK and TSR in Figure 1). By putting SMK at the centre of model, we aimed to indicate its effect on both PCK and TSR. As a result of a thorough analysis of data obtained from multiple sources, first, findings revealed that PCK including SMK was one of the dominant factors in shaping preservice teachers' self-regulation. The frequency of utilization for each PCK components as well as SMK differed in each phase of self-regulation during forethought, performance, self-reflection, and motivation phases (see Table 4). Second, it appeared that they were good at regulating their teaching when they had developed PCK components. For instance, Maggie had more developed knowledge of learner and assessment. During performance phase, Maggie put those developed PCK components into play and intentionally asked questions (strategy: attention focusing) to reveal students' misconceptions (criteria: student performance): particles are as colorful as the matter itself (knowledge of learner). She asked what students thought about whether the particles were colorless or colorful (purpose: solving problems) by relying on her knowledge of assessment. This also supports the relation between PCK and TSR. Based on these findings, we can conclude that one direction of interaction where PCK influences TSR was supported more by the evidence in this study. However, analysis of data did not provide any evidence for other direction of interaction where TSR influences PCK. There may be possible reasons for this. First, although participants were self-regulated to a degree they did not used different self-regulation processes during phases of self-regulation effectively. Since these were the preservice teachers and did not have adequate experience in teaching (Abell, 2007) this is expectable.

Limitations, Implications, and Suggestions for Science Teacher Education and Future Research

The present study points out a relationship between TSR and PCK in designing, performing, and reflecting on instruction. In spite of the strong points of the study, which we emphasized in the previous parts, there may be several limitations. One of the possible limitations of the study may be related to the participants, who were preservice teachers. Since they had limited teaching experience, they might have had difficulty in utilizing their PCK and regulating their instruction. In the future, by studying inservice teachers, we could obtain additional information to deepen our knowledge. In addition, this study is limited to a single chemistry topic—gases—and we observed preservice teachers' practice in only one class hour. Future studies may deal with different topics at different grade levels, ranging from elementary to college, by working with more participants over a longer period of time so that we can have more evidence for the relationship. Finally, these findings are limited to the group of participants. However, the purpose of this case study was not to generalize the findings about the relation between PCK and TSR to all teachers. Instead, this was one of the initial attempts to expand the theory of self-regulation

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model proposed by Zimmerman (2000) for teaching and to understand the interactions between TSR and PCK.

The findings of this study suggest a need to develop preservice teachers' self-regulation during their training programs. As Peeters, et al. (2014) stated, "Rather than waiting until ineffective strategies have been adopted, it is recommended to start [self-regulation] promotion early on in teachers' professional development" (p.1966), similarly, we believe that self-regulation in teaching should be an explicit focus of teacher education programs. According to Michalsky (2012), explicit support should be provided to teachers to develop self-regulation for teaching as early as possible. Specifically, science teaching method courses, the practicum, and other courses as well should offer opportunities for preservice teachers to understand what self-regulation is and how it is useful for designing effective instruction and solving instruction problems. Moreover, the outcomes of this study revealed that preservice teachers' insufficient PCK prevented the use of self-regulatory strategies during each phase: forethought, performance, and self-reflection. Therefore, teacher education programs should focus on both the development of preservice teachers' PCK and self-regulation for teaching by offering sufficient and meaningful opportunities for teaching and reflection. Furthermore, considering the participants poor SMK, the findings of this study call for changes to undergraduate science content courses to improve preservice teachers' learning of the content. Science content courses should be revised to increase preservice teachers' meaningful understanding of the content that they teach when preservice teachers start teaching profession.

Understanding the nature of teaching with regard to various factors contributes to the design of more meaningful inservice and preservice science teacher education programs. Therefore, this study has several implications for research on teachers' professional knowledge and capabilities. Drawing on the literature on both self-regulation for teaching and PCK, this study was a first attempt to understand what interactions existed between teachers' self-regulation and PCK. Further research may investigate the direction of these interactions—whether interactions between self-regulation and PCK are directional or bi-directional as depicted in wheel-shaped PCK-TSR model. Studying with inservice teachers with different levels of PCK and self-regulation (i.e., teachers with high, medium, and low self-regulation or teachers with robust and weak PCK) may help researchers in resolving this issue. Also, studying interactions in the context of teaching other topics in chemistry (e.g., the atom) and with teachers from different disciplines (e.g., physics) would provide in-depth information about whether those interactions are specific to the topic or discipline. Moreover, this kind of research may shed light on factors determining the specificity of PCK, since it is well evidenced that PCK is specific to both topic and teacher (Park & Oliver, 2008). For helping both pre– and inservice teachers tackle the challenges of teaching through the enactment of more intentional and powerful PCK and self-regulation, more research exploring what kind of opportunities are available to stimulate the development of both (e.g., educative mentoring and the explicit use of PCK and self-regulation) is needed. As a result, the present research is a promising study in the field of science education and has the potential to improve science teaching by underlining a relatively uncovered construct (TSR) and attempting to find out its interplay with the much more prevalent PCK components.

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APPENDIX A

CONTENT REPRESENTATION

Chemistry Topic/Content Area:		Grade Level:	Curriculum Objectives to be Addressed:
	Concept and/or important idea #1:	*Concept and/or important idea #2:*	*Concept and/or important idea #3:*
1. What concepts/big ideas do you intend students to learn?			
2. What do you expect students to understand about this concept and be able to do as a result?			
3. Why is it important for students to learn this concept? (Rationale)			
4. As a teacher, what should you know about this topic?			
5. What difficulties do students typically have about each concept/idea?			
6. What misconceptions do students typically have about each concept/idea?			
7. Which teaching strategy and what specific activities might be useful for helping students develop an understanding of the concept?			
8. In what ways would you assess students' understanding or confusion about this concept?	Formative Assessment:		
	Summative Evaluation:		
9. What materials/ equipment are needed to teach the lesson?			

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APPENDIX B

TSR INTERVIEW QUESTIONS

FORETHOUGHT PHASE

1. How did you prepare for this instruction?
2. What was the purpose of this lesson? What did you intend to teach? How did you determine your goals?
3. How did you decide which teaching method to use? What did you take into consideration during this decision process?
4. How did you decide which assessment method to use? What did you take into consideration during this decision process?
5. How did you feel before the lesson? Do you think you can teach this subject and evaluate students' learning effectively? Why?
6. Is it important to teach "Gas Laws"? Why?

PERFORMANCE PHASE

7. What did you pay attention to during the instruction?
8. Did you follow the curriculum strictly during the instruction? If not, how and when did you change it?
9. Did you follow the lesson plan strictly during the instruction? If not, how and when did you change it?
10. How did you evaluate your students? How did you use the evaluation results?
11. During your instruction, did you control whether your instruction was effective or not?
12. How did you feel during the instruction?

SELF-REFLECTION PHASE

13. What did you do immediately after the instruction?
14. How did you decide whether your instruction was effective or not? (This question was asked when the answer to question 13 included self-evaluation)
15. How did you use the results of self- evaluation? (This question was asked when the answer to question 13 included self-evaluation)
16. How did you feel after the instruction?
17. What can you say about the pleasure/satisfaction regarding your instruction? Why?
18. If you had another chance to teach that topic again, what and how would you change any part of this instruction?

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APPENDIX C

CATEGORIES AND SUB-CATEGORIES FOR TEACHER SELF-REGULATION

Category	Sub-category
Motivation	Self-efficacy Outcome expectation Intrinsic value Goal orientation
Forethought phase	Goal setting Strategic Planning
Self-monitoring and controlling (Performance phase)	*Which criteria does teacher use to monitor? (Criteria)* *i. previous teaching performance* *ii. student performance* *iii. classroom environment* *iv. lesson plan* *v. time management* *vi. emotion* Which monitoring strategies does teacher use? (Strategies) i. self-recording ii. attention focusing iii. self-experimentation iv. task strategies v. imagery vi. self-instruction *Why does teacher control? (Purpose)* *i. implementing the plan* *ii. solving problems* *How does teacher use controlling strategies? (Regulations)* *i. Regulating content* *ii. Regulating instructional strategy* *iii. Regulating instructional materials* *iv. Regulating physical environment* *v. Regulating classroom environment*
Self-judgement and self-reaction (self-reflection phase)	Which criteria does teacher use to evaluate his/her instruction? i. Prior performance ii. Student achievement iii. Lesson plan iv. SMK Which factors does teacher attribute results of his/her performance to? i. internal factors ii. external factors iii. controllable factors iv. uncontrollable factors v. unstable factors vi. stable factors How does teacher react and respond at the end of the instruction? i. Emotional reactions (satisfaction/dissatisfaction) ii. Decision making

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APPENDIX D

COMPONENTS AND SUB-COMPONENTS OF PCK USED IN THIS STUDY (ROBERTS, 1988, 2007; MAGNUSSON ET AL., 1999)

Components	Sub-components	Definition
Orientations toward teaching science	Everyday coping	Using science to understand everyday objects and events
	Structure of science	Understanding how science functions as an intellectual enterprise
	Science, technology, and decisions	Understanding the interrelationship between science, technology, and society and hence make informed decision-making about socio-scientific issues
	Scientific skill development	Acquiring conceptual and manipulative scientific process skills
	Correct explanation	Learning about the end of scientific inquiry, which are concepts, theories, laws, models etc. in a scientific discipline
	Self as explainer	Understanding their effort to explain phenomena by appreciating the conceptual underpinnings that influence scientists when they are in the process of developing an explanation
	Solid foundation	Using science to prepare them for the topics that they are going to learn next year
Knowledge of science curriculum	Knowledge of aims, goals and objectives of science courses	Teachers' knowledge of learning goals (objectives) in the subject(s) they are teaching
	Knowledge of horizontal curriculum	Teachers' knowledge of curriculum connections across topics in the same grade
	Knowledge of vertical curriculum	Teachers' knowledge of curriculum connections across topics in different grades.
	Knowledge of specific curricular programs	Teachers' knowledge of curriculum and materials related to the subject they teach and other related subjects.
Knowledge of students' understanding of science	Knowledge of requirements for learning	Teachers' knowledge of prerequisite abilities and skills for students' learning a concept.
	Knowledge of areas of students' difficulty	Teachers' knowledge about science concepts or topics that students find difficult to learn.
	Knowledge of areas of students' misconceptions	Teachers' knowledge about students' ideas different from scientifically accepted explanation.
Knowledge of assessment for science teaching	Knowledge of dimensions of students' learning (What to assess)	Teachers' understanding of which dimensions of students' learning are important or not to be assessed.
	Knowledge of methods for assessing students' science learning (How to assess)	Teachers' understanding of assessment strategies to assess students' learning.
Knowledge of instructional strategies	Knowledge of subject-specific strategies for science teaching	Teachers' knowledge of strategies used for teaching science which are more general and could be used to teach almost any subject (e.g., inquiry)
Knowledge of instructional strategies	Knowledge of topic-specific strategies for science teaching	Teachers' knowledge of topic-specific representations (e.g., illustrations, examples, models) and topic-specific activities (e.g., problems, demonstrations, simulations) for teaching particular topics in science.