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THE PEDAGOGICAL CONTENT KNOWLEDGE OF POLLUTION HELD BY SECONDARY CHEMISTRY TEACHERS IN LEBANON

by
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AN ABSTRACT OF THE THESIS OF

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In teacher education, it is vital to evaluate the conceptions held by pre-service teachers. If they have misconceptions, it is likely they will pass the inaccurate content on to their future students. The result of persistent wrong conceptions about scientific phenomena is an ill-informed citizenry and a reduced probability of suitable preventive actions by these citizens against future environmental issues such as pollution, the greenhouse effect in specific. Consequently, it is important to investigate teachers' preparedness to help students develop correct conceptions about environmental issues. One of the best measures to gauge this preparedness is to investigate teachers' pedagogical content knowledge (Shulman, 1986). Consequently, the purpose of this study is to examine the pedagogical content knowledge (PCK) of in-service experienced and not-experienced Grade 9 Chemistry teachers on the topic of pollution. The study also aims to relate the teachers' PCK to their level of education and years of teaching experience. The qualitative research approach used in this study allowed for the generation of rich descriptions of six chemistry teachers' PCK. Half of these teachers have six or more years of experience and the second half have less than six years of experience in teaching pollution. Three instruments were used for data generation: (1) a unit plan followed by a semi-structured interview, (2) a videotaped teaching lesson followed by a guided case analysis and a semi-structured interview and (3) a CoRe matrix followed by a semi-structured interview. A framework for defining PCK that consists of six dimensions and research findings were used to build a rubric, specific to teaching the PCK of greenhouse effect and global warming, and a coding scheme derived from it that contains descriptors for each dimension was used in data analysis. Data were coded based on a rubric described above. A frequency count was calculated for every form of knowledge (PCK in planning, PCK in action and PCK in reflection) for every teacher. This frequency count described their proficiency levels along each PCK dimension. In addition, for each level of performance, a score was calculated so that the overall PCK score of performance, for all dimensions, can be generated for each teacher. Findings revealed that teachers' PCK profiles varied along a continuum ranging from poor to moderate PCK of the greenhouse effect and its consequences. Experience and completing a teaching diploma influenced the PCK score positively but none of the teachers achieved a proficient PCK score. The study also revealed that all teachers were found to have moderate PCK score in the knowledge of the content and in the knowledge of orientations. However, all teachers showed a similar poor PCK score across the domains of 'knowledge about the curriculum', 'knowledge of assessment', 'knowledge of the student's learning' and 'knowledge of instructional strategies'. Moreover, all teachers showed a moderate PCK score in planning, action and

reflection but scored the highest in their PCK in planning and lowest in their PCK in reflecting. It seems that the school learning environment might not offer enough opportunities for teachers to reflect about their various PCK dimensions following instruction such as providing them the opportunity to participate in teacher development programs that helps them to deliver environmental issues efficiently in class. In addition, teacher education programs do not seem to prepare teachers to integrate all PCK dimensions when teaching any topic. Moreover, the high stake exams at the grade 9 level deprives teachers from the opportunity to work on their various PCK dimensions because teachers are required to prepare students for the exams. Implications for research, for teacher education programs and for teacher development programs were discussed in light of these findings.

CONTENTS

TABLES

CHAPTER I

INTRODUCTION

Research about the preparation of effective teachers has shown that "student learning of science depends on teachers having adequate knowledge of science" (NRC, 2007, p. 296). "Knowledge of science," in this sense, is more than just understanding science content. Only when teachers become more comfortable with both science content and the processes through which claims to scientific knowledge are produced and validated, will they be able to endorse the vision of the science education reforms. That is, science teachers need to develop pedagogical content knowledge (PCK) for teaching, which addresses both the substantive and syntactic dimensions of their disciplines (Shulman, 1986). Indeed, the strongest predictor of how well a student performed on a national assessment was the percentage of well-qualified teachers—those who were fully certified and had majored in the subjects they taught (Darling-Hammond & Youngs, 2002). If teachers have misconceptions, it is likely that they will pass inaccurate content on to their future students. The result of persistent wrong conceptions about scientific phenomena is an ill-informed citizenry and a reduced probability of suitable preventive actions by these citizens against future environmental issues such as pollution.

Several studies have suggested that teachers do not feel they have the knowledge or abilities to teach environmental education due to lack of training (Elder, 2003). The pedagogical content knowledge which teachers draw on in their work with students is significantly important in determining the nature of classroom practice and the opportunities for students to develop understandings related to environmental education

and hence the necessity of teacher education as a key factor in the development of the teachers' knowledge base for teaching environmental issues. When teaching concepts, such as pollution, the representations, instructional strategies, and assessments are aimed specifically for that content and are, therefore, topic-specific. However, the knowledge needed to teach these concepts depends upon more than knowledge of content and topic-specific representations, instructional strategies, and assessments; teachers must also understand students as learners and be aware of students' misconceptions and potential learning difficulties associated with content. Thus, PCK is a necessary component of a knowledge base for effective teaching of pollution (Jones, Harlow, & Cowie, 2004; Magnusson, Krajcik, & Borko, 1999; Park & Oliver, 2007; Shulman, 1987; Van Driel, Verloop & De Vos, 1998).

Before Shulman, the rhetoric regarding the knowledge base for professional teaching rarely specified the characteristic domains or components of such knowledge. In fact, it was assumed that teachers' knowledge comprised two domains: knowledge of content and knowledge of pedagogy. However, Shulman was dissatisfied with this conceptualization because, as such, it failed to offer answers to many relevant and fundamental questions such as: "How does the successful college student transform his or her expertise in the subject matter into a form that pre-college school students can comprehend? What are the sources of analogies, metaphors, examples, demonstrations, and rephrasing?" (Shulman, 1986, p. 199). In resolving this conflict, Shulman (1987) suggested that

> the key to distinguishing the knowledge base for teaching lies at the intersection of content and pedagogy, in the capacity of a teacher to transform the content

> knowledge he or she possesses into forms that are pedagogically powerful, yet adaptive to the variations in abilities and backgrounds presented by students (p. 237).

He argued that a new domain of knowledge, the content knowledge for teaching also labeled Pedagogical Content Knowledge (PCK), must be included in the knowledge base; a separate domain of teachers' knowledge that is most distinctive of teaching and that is solely the territory of the expert teacher. Indeed, this emphasis on PCK as necessary to professional teaching was later explicitly recognized in the National Science Education Standards (National Research Council, [NRC], 1996) statement which defined PCK as a special kind of understandings and skills that allow science teachers to "tailor learning situations to the needs of individuals and groups" (p. 62). Viewing the knowledge base for professional teaching from this new perspective has major implications on the traditions of teacher preparation and teacher examinations. Indeed, credentials would need to reflect not only deep knowledge of the content of a subject-matter and general pedagogical knowledge, but also topic-specific pedagogical knowledge.

In Lebanon, there has been no study investigating experienced and novice science Lebanese teachers' PCK involving environmental science topics such as pollution, specifically, the greenhouse effect and global warming. Globally, most studies explored the PCK held by prospective teachers in the knowledge about different environmental issues (Boyes, Chambers, & Stanisstreet, 1995; Çakir, Irez, & Doğan, 2010; Dove, 1996; Groves & Puch, 1999; Khalid, 2003; Michail, Stamou, & Stamou, 2007; Papadimitriou, 2004; Summers, Kruger, Childs, & Mant, 2001; Taylor, Doff, Jenkins, & Kennelly, 2007). However, only two studies explored the PCK of the greenhouse effect and global warming

held by experienced primary science teachers (Chordnork, Yuenyong, & Hume, 2012; Chordnork & Yuenyong, 2014) but none was done for secondary level teachers. Therefore, the purpose of this study is to explore the pedagogical content knowledge held by secondary Lebanese teachers who teach about pollution. Characterizing the extensive knowledge needed for good teaching of pollution can have vital implications for the assumptions that guide curriculum developers of teacher education programs. Moreover, it would narrow the gap between the environmental education 'intended' in Lebanon's curriculum and that which is taught and received in the classroom.

Research Problem

According to Anderson (1987), for teachers to be able to transform their knowledge and understandings of science into forms that are attainable by their students, they should be highly literate in science. Therefore, for teachers to transform their understanding of the national and global environmental issues, they should be highly literate in issues such as ozone depletion, water pollution, and soil degradation. In Lebanon, Environmental Education was introduced in 1997 for the first time into the general education curriculum with the aim of preparing 'an environmentally literate generation' (National Center for Educational Research and Development [NCERD], 1997–98). At the lower secondary level (Years 7–9), the science curriculum includes an ecosystem unit, a geology unit which includes soil conservation, and units in chemistry which include pollution. Topics like "pollution" were integrated with the national examination chemistry syllabus at the grade 9 level. Since topics on environmental issues are addressed in national examinations, this necessitates a preparation of competent teachers in Environmental Education. The acquisition of a robust PCK on environmental issues should be one of the goals of teacher

preparation programs in Lebanon. This new curriculum was developed without any solid research regarding Lebanese students' and teachers' environmental knowledge (Makki, Abd-El-Khalick & BouJaoude, 2003). Teacher education institutions are crucial for equipping teachers to address environmental education. They include numerous courses in general and professional education, leaving little room for specialty areas (BouJaoude, 2000) such as environmental education. It should be noted that to enhance teachers' disciplinary knowledge is to replace the general, content-free science methods courses currently emphasized in science teacher preparation programs with distinct, content-specific methods courses in the various disciplines (Gess-Newsome & Lederman, 1993). Moreover, it is the responsibility of these programs to provide student teachers with the knowledge base for professional teaching together with the opportunity to practice such skills. Thus, PCK being a central component of the science teachers' knowledge base is assumed to be learned by certified teachers who pass the courses of the teacher education program and manifested in their experience during their mentoring period. However, evidence in the literature repeatedly portrays an image of science teachers who have taken such programs but having poor or no PCK whatsoever (Abd-El-Khalick & BouJaoude, 1997; De Jong & Van Driel, 2001). Another study conducted by Rizk (2009) in Lebanon shows that pre-service secondary science teachers' PCK profiles varied along a continuum ranging from poor to proficient. Additionally, student teachers' were found to have moderate knowledge of their students' conceptions of various topics in science. Therefore, it is doubtful whether teacher education programs are actually conveying to pre-service science teachers the required knowledge base (and of special concern for this study, PCK) which entitles them to teach about environmental issues.

In summary, it would be fruitful in Lebanon to explore and describe the PCK held by teachers that implement environmental education in their classroom and determine whether their teacher preparatory training equipped them with the necessary robust PCK. Moreover, since PCK is a topic-specific construct which can also be developed through experience in teaching (Shulman, 1986), it would also be fruitful to know whether experience in teaching a topic on pollution impacts Lebanese teachers' PCK.

Research Questions

The purpose of this study is to explore and portray the PCK in pollution of a group of experienced and novice in-service secondary school chemistry teachers. For this purpose, the study investigated these teachers' PCK using three different methods to provide a thick and detailed description of their PCK. Additionally, it investigated aspects of PCK that are most or least mastered by those teachers in an effort to identify the potential strengths and weaknesses of teacher preparation programs in promoting PCK on pollution. Specifically, this study attempted to answer the following questions:

1. What is the pedagogical content knowledge of experienced and novice secondary level chemistry Lebanese teachers of pollution?
2. How do secondary chemistry teachers' PCK of pollution differ between those that hold a teaching diploma degree from those that do not?
3. How do secondary chemistry teachers' PCK of pollution relate to their years of teaching experience?

Rationale

Following the conceptualization of PCK by Shulman in 1986, researchers have investigated its sources, how it develops, and how components of PCK interact with each

other. This research has asserted that PCK is a topic-specific construct (Van Driel, et al., 1998). Some research studies on topic-specific PCK held by prospective teachers were conducted. These topics included heat and temperature (Magnusson et al., 1994), chemical equilibrium (Van Driel et al., 1998), and acid-base chemistry (Drechsler & Van Driel, 2008). However, this research is limited in scope and has not shown how teachers develop PCK for teaching many specific topics (Abell, 2008; Van Driel et al., 1998) - especially those related to environmental issues - within the complexity of the classroom to determine how teachers' use their PCK in transforming their subject matter knowledge into pedagogically powerful representations to support student learning (Abell, 2008; Loughran et. al.., 2006; Magnusson, Borko, & Krajcik, 1994; Van Driel, Verloop, De Vos., 1998).

Even though a number of researchers have asserted that teachers' PCK develops as a result of teaching experience (Van Driel et al. 1998; Van Driel & Verloop, 2002), their results are not conclusive and more studies that focus on the PCK held by experienced teachers for teaching specific concepts or topics in science should be done. In Lebanon, a study conducted by Abd-El-Khalick and BouJaoude (1997), assessed the PCK held by a group of experienced Lebanese science teachers on topics like digestion; the chemistry of compounds, elements, and atoms; and heat energy and temperature. The teachers' knowledge base was found to be lacking in terms of their discipline's structure, function and development. Moreover, research demonstrated that Lebanese secondary school students had inadequate knowledge of basic environmental concepts and issues such as recycling and soil degradation (Makki, Abd-El-Khalick & BouJaoude, 2003) which might indicate that secondary science teachers are not preparing the students adequately for developing scientifically acceptable conceptions of environmental issues. Thus, in an

attempt to gain an in-depth understanding of why secondary Lebanese teachers could not transform their environmental knowledge into a form attainable by their students, there is a need to investigate their PCK in pollution.

Significance

It is often argued that, in their current form, teacher education programs do not always offer student teachers sufficient opportunities to transform the knowledge they attain into PCK; it being a tedious and time-consuming endeavor. Moreover, because different types of knowledge such as subject matter and pedagogy are often taught separately, student teachers inadvertently find themselves in situations whereby they need to find ways, on their own, of transforming their various knowledge domains into appropriate and significant forms within a given context of teaching (Nilsson, 2008). Therefore, it seems that the knowledge base that teachers hold remains mostly undocumented and far of reach for research purposes. Hence, there is significant benefit in exploring how teachers explicate their understanding of, and reason for their actions while tapping on various knowledge domains, an exploration with possible benefits to research and practice.

Science teacher preparation programs in Lebanon include post-graduate programs that prepare secondary teachers with significant amount of science background. Moreover, most of the science teacher preparation programs' efforts are directed to content-free domains of pedagogy, classroom management techniques and field experience (BouJaoude, 2000). Shulman's (1987) knowledge base model may serve as a sound theoretical framework for characterizing the extensive knowledge base needed for good teaching of environmental issues. Understanding teacher's PCK of environmental issues,

has the potential to provide important insights for curriculum designers of teacher education programs. It would help curriculum designers to come up with a curriculum that upgrades student-teachers' PCK of the content of their disciplines. Therefore, the aim of this study is to shed light on the gaps found in teachers' PCK in pollution so that the teacher educators' efforts are better directed into challenging pre-service teachers' understanding of their environmental PCK. In other words, the focus of the teacher preparation programs when addressing Environmental Education should equally balance "what to teach" and "how to teach".

Using Shulman's model for the knowledge base for teaching to describe secondary Lebanese teachers' PCK on pollution may have many useful implications for theory. The results of this study would further validate the topic-specific nature of PCK. It would also further validate the utility of Shulman's model in guiding curricula designers to tapping topic-specific PCK held by prospective teachers.

Limitations

There are two sources of limitations to this research. First, because this study adopts qualitative methods, the scope of generalization of the results is narrow. However, the purpose of the study is not to create generalizations in as much as it is to shed light on a particular phenomenon and understand and document in-service experienced and novice secondary chemistry teachers' PCK in pollution. Second, there is the possibility of data misinterpretation. However, the triangulation of findings from several sources enhances the credibility of the results. Additionally, the analysis will be performed by two researchers working together then independently; a situation which reduces bias and adds more validity to the findings. Moreover, teachers will be consulted for discussion of particular

topic-specific issues. Particularly, when considering the lesson plans' content, the sequencing of ideas and the addition or deletion of some ideas, the teachers were asked to examine these for possible flaws.

CHAPTER II

LITERATURE REVIEW

This chapter provides a review of recent literature on pedagogical content knowledge (PCK) and its relation to environmental education. First, a brief history on the conceptions and the nature of PCK is presented followed by a summary of recent research done on topic specific PCK held by teachers. Following this, I present a description of the various conceptualizations of teachers' PCK from which a framework for the current research is derived. Next, empirical research concerning methods of portraying and documenting PCK is briefly explored. Finally, the last section deals with teacher preparation programs for environmental education, a summary of research done in Lebanon on environmental education and a summary of the research done worldwide on teachers' and students' misconceptions about pollution.

Models of the Knowledge Base for Professional Science Teaching

Several researchers set out to explicate the components that constitute a knowledge base for professional teaching in order to adopt the argument urging for a reform in teacher education and preparation programs. Shulman and his colleagues (1987) were among the first to embrace the reform of science teacher education while explicitly proposing a structured model that depicts the several domains of knowledge that teachers refer to when planning instruction and taking decisions. In Shulman' seminal publication titled ''Knowledge and teaching: foundations of the new reform'' (1987), PCK is included in a knowledge base for teaching that consists of seven categories: (1) content knowledge which is defined as the knowledge of the substantive and syntactic structures of a

discipline; (2) General pedagogical knowledge which include knowledge of the theories and principles of teaching, and strategies of classroom management (Shulman, 1986); (3) Curriculum knowledge which is defined as knowledge of the "programs designed for the teaching of particular subjects" (Shulman, 1986, p. 10) and knowledge of different curriculum materials; (4) Knowledge of learners' characteristics, cognition, motivation, and development. This is due to the close relationship between these characteristics and the design of the curriculum; (5) Knowledge of educational contexts. These include the knowledge of the classroom settings, the governance and financing of schools, the community and the culture of the school; (6) Knowledge of educational purposes, ends, and values, and their philosophical grounds; and (7) Pedagogical content knowledge. Its original definition is mentioned in Shulman's 1987 publication as follows:

> [PCK] represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction (p. 8).

Shulman (1986) identified two key dimensions distinctive to teachers holding PCK: knowledge of wide-ranging representations of content and knowledge of content-related learning difficulties. Knowledge of content-related learning difficulties is rooted in a scholarship in cognitive research and is necessarily related to teachers' understanding of students' misconceptions in specific topics. Knowledge of content representations encompasses

> the most regularly taught topics in one's subject area, the most useful forms of representations of those ideas, the most powerful analogies, illustrations, examples,

> explanations, demonstrations – in a word, the ways of representing and formulating the subject that makes it comprehensible to others (Shulman, 1986, p. 203).

Shulman argued that such knowledge is necessary, for it equips teachers with the prerequisite multifaceted comprehension necessary to teach a concept in alternative ways. Knowledge of content-related learning difficulties is ingrained in a scholarship in cognitive research and is necessarily related to teachers' understanding of students' misconceptions in specific topics. The importance of this PCK aspect is apparent in light of the cognitive research that is repeatedly suggesting that students' prior knowledge interferes with their conceptual understanding. In particular, professional teachers concerned with long lasting and meaningful learning must account for students' initial conceptions and misconceptions while planning their teaching.

A large number of scholars have tried to refine Shulman's concept of PCK (e.g. Cochran, Deruiter, & King., 1993; Grossman, 1990; Hashweh, 2005; Loughran et al., 2006; Magnusson et al., 1999; Park & Oliver, 2008a; Van Driel, Verloop, & de Vos, 1998). For example, Cochran et al. (1993) defined PCK as "the manner in which teachers relate their pedagogical knowledge to their subject matter knowledge in the school context, for the teaching of specific students" (p. 1). After further scholarly refinements, PCK became a way of understanding the intricate relationship between teaching and content through the use of specific teaching approaches (Loughran, Milroy, Berry, Gunstone, & Mulhall, 2001). Moreover, it can be developed through a process embedded in classroom practice (Van Driel et al., 1998). PCK then refers to a teacher's combination of subject matter knowledge (SMK) and pedagogy in ways intended to improve student learning (Nilsson, 2008). Although PCK has been defined in slightly different ways, the

transformation of content knowledge by the teachers for the purpose of effective teaching and enhanced student learning lies at the center of PCK (Park & Oliver, 2008a).

Identifying the components of PCK and viewing it as an integration of those components was another prevalent way for conceptualizing PCK (Park & Oliver 2008a). In terms of the features integrated, the concept of PCK has been further elaborated by several scholars. Grossman (1990) identified three main domains–subject matter knowledge, Pedagogical knowledge, and Context knowledge–that influence teachers' PCK. Magnusson et al. (1999) proposed that the concept of PCK could be described as a "synthesis" of five different types of knowledge: (a) orientation toward science teaching, (b) knowledge of science curriculum, (c) knowledge of science assessment, (d) knowledge of students' understanding, and (e) knowledge of instructional strategies. Magnusson et al. (1999) referred to the term "orientation" to refer to both the goals of science instruction as well as the characteristics of the corresponding methods espoused by the teacher in achieving those goals. According to the authors, it is the use of a certain strategy in relation to the goals intended is what distinguishes teachers' PCK during science instruction and not the use of that strategy. An example of an orientation they named 'activity-driven' with the goal of having the students to be active with materials; "hands-on" experiences (one of the corresponding strategies used in this case is to engage the students in hands-on activities used for verification of discovery. Another orientation is 'inquiry', with the goal of representing science as inquiry. The rest of the orientations, described by Magnusson et al. (1999), together with the goals they comprise as well as some instructional strategies that can be well related with these orientations are summarized in Appendix 1. Park and Oliver

(2008a, 2008b) elaborated Grossman's conceptualization further by identifying the fifth component which is the "knowledge of assessment of student understanding."

However, a new and latest conceptualization—teacher pedagogical constructions (TPCs)—is offered by Hashweh (2005) to address some of the problems associated with PCK. Hashweh presented seven assertions that encompass the new conceptualization. First, PCK represents personal and private knowledge. Second, PCK is a collection of basic units called teacher pedagogical constructions. Third, teacher pedagogical constructions result mainly from planning, but also from the interactive and post-active phases of teaching. Fourth, pedagogical constructions result from an inventive process that is affected by the interaction of knowledge and beliefs from different categories. Fifth, pedagogical constructions are topic-specific. Sixth, pedagogical constructions comprise both a generalized event-based and a story-based kind of memory. Seventh, pedagogical constructions are labeled in multiple interesting ways that connect them to other categories and subcategories of teacher knowledge and beliefs. According to Hashweh (2005), viewing PCK as a collection of TPCs, more precisely defines it, clarifies its relations to other knowledge and beliefs entities, and attempts assists in future investigations of PCK.

Other lines of research on teaching have stressed on the critical role of PCK in teachers' planning and actions when dealing with subject matter teaching (Loughran et al. 2006; Van Driel et al. 1998), influencing student learning (Carpenter, Fennema, Peterson & Carey, 1988) and outlining teachers' learning of new instructional strategies (Borko & Putnam 1996). Therefore it can be reasonably concluded that PCK is fundamental to effective science teaching and that science teachers should possess PCK to aid student learning. Lee, Brown, Luft, and Roehrig (2007) interviewed five teachers who had more

than ten years of teaching experience, analyzed the interviews, and used the results of analysis to develop a framework that included seven aspects of PCK. Their model comprised the following dimensions, all of which are content-bound: (1) knowledge of science (including knowledge about "the nature of science, science processes, and relationships among various areas in science" (p. 53); (2) knowledge of the different representations and instructional strategies; (3) knowledge of students' learning and students' conceptions; (4) knowledge of science curriculum organization and media; (5) knowledge of the resources available other than the curriculum; (6) knowledge of the purpose of instruction; and (7) knowledge of assessment. The model presented by Lee et al. (2007) seems to assimilate all of the other components characteristic of the other models presented earlier in this section. It is exactly because of its inclusive nature that this model will be implemented with some alterations, proposed by Rizk (2009), as a framework for the current study.

Topic-specific pedagogical content knowledge. According to Baxter and Lederman (1999), PCK is composed not only of what a teacher knows but also by what a teacher does, and the reasons for the types of actions that he/she takes in relation to teaching a specific topic. Shulman (1987) further argues that PCK involves teachers

> from being able to comprehend subject matter for themselves, to becoming able to expose subject matter in new ways, reorganize and partition it, clothe it in activities and emotions, in metaphors and exercises, and in examples and demonstrations, so that it can be understood by students" (p. 13).

Teachers must have knowledge of what students know about a topic and areas of likely difficulty to employ PCK effectively.

Pre-service science teachers often have a hard time converting their content knowledge into PCK. Therefore, many studies investigated pre-service science teachers' PCK and the development of PCK in in-service teachers. Due to the fact that pre-service teachers have little experience in real classroom context, their PCK is not robust (Van Driel et al., 1998). Although teaching experience does not guarantee having rich PCK (Friedrichsen, Lankford, Brown, Pareja, Volkmann, & Abell, 2007), research showed that teaching experience is one of the important sources of PCK development (Grossman, 1990; Shulman, 1987) and that it leads to more integration among its components (Friedrichsen, Lankford, Brown, Pareja, Volkmann, & Abell, 2009). Many research studies were conducted on topic-specific PCK held by prospective teachers. These topics included rotational motion and gravity (Berg & Brouwer, 1991), isotopes (Geddis, Onslow, Beynon, & Oesch, 1993), heat and temperature (Magnusson et al., 1994), chemical equilibrium (Van Driel et al., 1998), density and air-pressure (Clermont et, al., 1993), and acid-base chemistry (Drechsler & Van Driel, 2008).

In summary, all aforementioned research studies on teachers' PCK and topic-specific PCK offered rich and valuable information regarding the influence of subject matter knowledge on teachers' PCK and how PCK components interact. However, studies investigating the nature of knowledge held by experienced teachers for teaching specific topics in science are largely absent from the literature.

Veal and MaKinster (1999) suggested a taxonomy of PCK to provide a scheme for future studies of PCK development in teacher education. It addresses the hierarchical relationships of three levels of teacher knowledge: (a) discipline-specific PCK (e.g., English, history, or science), (b) domain-specific PCK (e.g., physics, chemistry, or

biology), and (c) topic-specific PCK (e.g., genetics or environment). The model indicates that PCK is unique and specific for each topic. For instance, PCK necessary for teaching mathematics is different from that necessary for teaching science. The nature of PCK for teaching chemistry is different from that necessary for teaching physics. Teaching specific topics within a domain of science demands a PCK that includes knowledge of student learning difficulties as well as knowledge of the most effective instructional approaches, representations, curricular resources, and assessments for teaching this specific topic.

A call for solid science content. Research on student and teacher (pre-service and in-service) misconceptions about scientific phenomena is a dynamic field of study. Students and even teachers develop misconceptions as a result of either personal experience, from other people, or through the media (Driver, Guesne, & Tiberghien, 1985). In teacher education, it is vital to evaluate the conceptions held by pre-service teachers. If they have misconceptions, it is likely that they will pass the inaccurate content on to their future students. The result of persistent wrong conceptions about scientific phenomena is an ill-informed citizenry and a reduced probability of suitable preventive actions by these citizens against future problems (Boyes, Chamber, & Stanisstreet 1995). This is a cascading effect that has not been widely tackled. For example, an analysis of survey data showed that many secondary pre-service teachers hold several misconceptions about the causes and effects of acid rain (Khalid, 2003) and the greenhouse effect and ozone depletion (Boyes, Chamber, & Stanisstreet 1995). The problem grows more complex due to the mismatch between the content of the curriculum and student developmental levels. Inaccuracies in textbooks, inaccurate information provided by instructors, and student memorization of prior concepts without meaningful understanding of the central concepts

magnify the problem. Ultimately, a lineage of perplexed science concepts and perplexed students is created. Both pre-service and in-service teachers need to know the possible misconceptions that students can have in examining environmental education**.**

The Framework Used in this Study

The framework that will be used in this study is a framework used by Rizk in her 2009 study, "Examining pre-service non-experienced secondary science teachers", which is a modified version of Lee et al.'s (2007) PCK framework. This model presents PCK as a separate domain of knowledge with a number of indicators that determine whether a teacher has PCK or not. Lee's (2007) model has seven dimensions of PCK while this model which was modified by Rizk (2009) has six. The fifth element in Rizk's (2009) model: "Orientations toward science teaching" which was adopted from Magnusson et al.'s (1999) model combines 'teachers' goals and their use of a parallel strategy included in Lee's model. According to Rizk (2009), offering a rational judgment for their pedagogical action is more indicative of the teacher's PCK. The framework comprising the six main categories with their definitions is presented in Table 1. The first element of PCK is the knowledge of the science content that is pertinent for instruction. This dimension includes both the academic knowledge in the discipline and the knowledge about the nature and processes of science and the relationships among different ideas within the topic. The knowledge about topic-specific instructional strategies and representations is the second dimension of PCK. Teachers who possess this dimension should be able to represent their material for instruction in different ways with reasoned pedagogical judgment for using or not using a particular representation (analogy, metaphor, text, etc…). The third dimension comprises knowledge of students' learning and students' conceptions including knowledge

about students' common misconceptions and teachers' ability to expect some potential misconceptions. The teachers' knowledge of specific science curriculum organization, vertical progression and horizontal progression is the fourth dimension of PCK. In other words, teachers should be able to teach in a way helpful to integrated learning and informed by their knowledge of the materials taken and other yet to be taken at later stages. The fifth dimension of PCK is teachers' orientations toward science teaching which was adopted from Magnusson et al.'s (1999) model and was included in this framework. The last dimension in this framework is teachers' knowledge and use of suitable assessments – both formative and summative. The alignment between orientations and assessment is a measure of teachers' PCK since teachers that possess a robust PCK would reproduce their orientations in a specific instructional setting. (Rizk, 2009)

Portraying Teachers' PCK

Research on unpacking teachers' PCK has mainly been concerned with reporting how the different aspects of PCK were or were not portrayed by teachers. As shown by Abel (2008, p. 1407), "teachers not only possess PCK, they employ the components of PCK in an integrated fashion as they plan and carry out instruction". Therefore, research should look more at how the dimensions of PCK come into play during instruction to produce a qualified act of teaching rather than one or another dimension of PCK. This is evident in recent conceptualizations of PCK which suggests that researchers need to look at the synergistic nature of PCK because it comprises more than the sum of its constituents.

Table 1

Framework for Science Teachers' PCK

Dimension	**Definition**
1. Knowledge of the content in science	This dimension not only includes scholar knowledge in the discipline, but also knowledge about the nature and processes of science and the relationships among various ideas within the topic
2. Knowledge about topic-specific instructional strategies and representations	Teachers who have this dimension should be able to represent their material for instruction in various ways with reasoned pedagogical judgment for using or not using a particular representation (analogy, metaphor, illustration, text, simulations, videos…).
3. Knowledge of student' learning and students' conceptions	Teachers' ability to tap into students' prior knowledge to initiate instruction, to anticipate some potential misconceptions and to deal with spontaneous instances of students' misconceptions is illustrative of their PCK.
4. Knowledge of specific science curriculum organization	(both vertical progression and horizontal progression); teachers' effort to instruct in a way conducive to integrated learning must be informed by their knowledge of the materials taken and other yet to be taken at later stages.
5. Orientations toward science teaching.	When teachers argue for orientations, they are presenting a reasoned judgment for their pedagogical action in relation to their intended goals.
6. Knowledge and use of adequate assessment	Assessment – both, formative and summative – prepared by teachers with high PCK should reflect their orientations in a specific instructional setting. Therefore, alignment between orientations and assessment is also a measure of teachers' PCK.

Abd-El-Khalick and BouJaoude (1997) described the PCK of a group of Lebanese science teachers using a combination of methods including a modified version of the VOSTS questionnaire (Views on Science -Technology-Society), clinical interviews and concept maps. Teachers were assessed in terms of their understanding of the structure, function and development of their disciplines. Their study revealed that science teachers' knowledge base was lacking in all aspects, irrespective of teachers' years of experience and that teacher preparation programs were not promoting teachers' professional

knowledge base. In another study examining teachers' knowledge, Halim and Meerah (2002) used interviews to describe Malaysian physics teachers' PCK. Their study revealed that teacher trainees not only lacked the ability to transform their knowledge of some physical concepts, but also were unable to employ effective teaching strategies adequately. Using pilot year data, Lee et al. (2007) developed a rubric to document secondary science teachers' PCK while focusing on two particular domains: knowledge of instructional strategies and knowledge of students' learning. Tracking the development of these teachers' PCK throughout their first year of experience, the authors found that all 24 teachers participating in the study had either limited or basic levels of PCK.

In an attempt to document science teachers' PCK but also portray it to others, Loughran, Mulhall, and Berry (2004) devised two approaches: CoRe (Content Representation) and PaP-eRs (Professional and Pedagogical experience Repertoire) to capture the dimensions of science teachers' PCK. While stressing that CoRe provides a tool for accessing science teachers' PCK, the authors argued that the tool can also be very useful as an interviewing technique in research. A detailed description of the instrument is provided in the methodology section (Chapter 3). Using CoRe matrices with chemistry teachers, the authors found that teachers' approaches to describe their understanding of chemical reactions were different. Their response in framing this topic was somewhat bimodal. One framing response was of chemical reactions as identifiable ''common'' types of reactions and the associated reasons for these categorizations; a second response was through chemical reactions as requiring a specialist language that was helpful in explaining events. Noting that no single approach is more valuable than the other, Loughran et al.

(2004) argued that the CoRe approach offers opportunities to access the various aspects and manifestations of teachers' PCK.

Chordnork, Yuenyong, and Hume (2012) examined the PCK of 15 primary Science teachers when delivering a topic like global warming. This study used CoRe design as a framework to illustrate aspects of the teachers' PCK. Moreover, the researchers used questionnaires, document analysis and interviews in data collection. The results of this study indicated that the current teaching practice lacked sophisticated PCK in the knowledge of topic specific instructional strategies, knowledge of students' understanding of global warming and knowledge of assessments. On the other hand, the teachers demonstrated an understanding of the purposes and the socio-cultural role that influenced science teaching and learning, concluding that there is a need for professional development support for teachers to enhance their understanding about teaching and student learning in topics relevant to environmental education. In another study that involved the use of a CoRe matrix, Chordnork and Yuenyong (2014) explored how four primary science teachers interpreted, used and developed their understanding of teaching global warming before and after taking part in a workshop on the use of a CoRe matrix. Data collection also involved using open-ended questionnaires and semi-structured interviews. The findings revealed that all teachers valued the use of the CoRe matrix in planning for the lesson and reflection about their instruction. Moreover, the teacher's CoRe matrices revealed that they do not have a robust PCK in the knowledge of students' misconceptions and current understanding of the topic, knowledge of teaching strategies for instruction and knowledge of the curriculum. As a consequence, their CoRe offered a meaningful way for them to come to understand PCK and its influence on science teaching and it provided

insight for teacher professional developers on how to prepare teachers for an efficient instruction of issues relevant environmental education.

Rizk (2009) examined the PCK of pre-service non-experienced secondary science teachers. Four teachers were involved in the study, all of whom were finishing their teacher education program at a university in Lebanon. Three instruments were used for data generation: (1) a unit plan followed by a semi-structured interview, (2) a peer teaching lesson followed by a guided case analysis and a semi-structured interview and (3) a CoRe matrix followed by a semi-structured interview. Rizk (2009) adopted a modified version of Lee et al.'s (2007) model. Each teacher had a profile that contained descriptions of his/her PCK in planning, PCK in action, and PCK in reflection. Tracking the development of these teachers' PCK throughout their teacher education program. Rizk (2009) found that that non-experienced secondary science teachers' PCK profiles varied along a continuum ranging from poor to proficient PCK profiles. The study also revealed that the teachers demonstrated consistently the same level of proficiency across the domains 'knowledge of topic specific instructional strategies', 'knowledge of orientations to teach science', and 'knowledge of assessment'. Moreover, comparisons between different teachers' profiles showed that student teachers' PCK proficiency while planning affected their proficiency level while reflecting on their teaching and planning . On the other hand, teachers' actual teaching did not influence their ability to reflect on their teaching.

Teacher Preparation for Environmental Education

With the addition of the North American Association for Environmental Education (NAAEE) environmental education standards to the National Council for Accreditation of Teacher Education (NCATE) teacher preparation accreditation standards (NAAEE, 2000)

and the frequent occurrence of environmental issues in the news, science educators who prepare teachers are facing an ever growing challenge as they design the scope and sequence of topics in their courses. Researchers suggest that teacher preparation has a powerful influence on whether teachers implement environmental education in their own instruction (Tilbury, 1992; Cutter, 1998 as cited in Miles & Cutter-Mackenzie, 2006). However, Miles and Cutter-Mackenzie, (2006) found that "despite national and international policy rhetoric about the importance of pre-service teacher preparation in environmental education, pre-service teachers' preparedness for teaching environmental education is overwhelmingly low" (p. 140). They further contemplate that environmental education in pre-service teacher education has remained unchanged for the past 2 decades. However, environmental education must be clearly addressed in teacher preparation programs if we are to meet "the priority of priorities" for environmental education (UNESCO-UNEP) and expect environmental education to find its way into K-12 classrooms (McKeown-Ice, 2000). But, there are 3 problems to overcome before environmental education is incorporated in teacher education programs: (a) teacher self-efficacy in addressing environmental education topics; (b) lack of pre-service and in-service teacher training in environmental education; and (c) unavailability of classroom resources (Stepath, 2004; Miles & Cutter-Mackenzie, 2006).

Teachers are known as important agents of change in society. They can play an important part in enhancing human capacity in environmental awareness and problem-solving. Teachers require the knowledge, skills, and commitment to "environmentalize" their curriculum and produce environmentally educated students (Tilbury, 1992). Classroom teachers are the ultimate source of environmental education implementation in

schools. It is, therefore, not just logical, but essential to incorporate environmental education in the preparation of teachers. Furthermore, ministry of education participants from around the globe in UNESCO conferences has consistently emphasized the establishment of good courses for pre-service teachers as a response to an urgent need for environmental education (Dominguez & MacDonald, 2010).

According to Tilbury (1992), environmental education requires special training and commitment because it needs a different focus and outlook that many prospective teachers have not experienced in their own education. Teachers cannot effectively address the goals and aims of environmental education solely by learning information about environmental issues and concerns. Thus, it is unrealistic to expect teachers without expertise to explore environmental concepts with students to foster holistic, regional, and global thought about the environment, rather than treating each topic or idea as an isolated, discrete entity (Dominguez & MacDonald, 2010). Environmental education should be a part of science methods courses in teacher preparation programs since many of these programs do not have a separate environmental education methods course. Although the basic principle of environmental education calls for an interdisciplinary approach, the reality of resource availability for pre-service preparation may require a single subject approach. Therefore, the most reasonable alternative would be the use of science methods courses for environmental education preparation delivery (Dominguez & MacDonald, 2010).

Environmental Education in Lebanon

As Lebanon strives to achieve sustainable economic and social development, it faces numerous environmental challenges, such as water and air pollution and solid waste management. Uninformed environmental decisions and behaviors could be very costly at

the ecological, economic, and social levels. To manage this state of affairs, environmental education was incorporated in 1997 for the first time in the Lebanese general education curriculum with the aim of preparing "an environmentally literate generation" (Center for Educational Research and Development [CERD], 1997–98). An environmental education module was integrated into selected topics within disciplines such as life sciences, physics, biology, chemistry, and social studies. However, according to Haidar-Makki, Abd-El-Khalick, and BouJaoude (2003), this new curriculum was developed without any solid research regarding student's or teachers' environmental knowledge. So far, only six studies were implemented in Lebanon that are relevant to environmental education. These studies surveyed students' environmental knowledge and attitudes (Haidar-Makki, Abd-El-Khalick, & BouJaoude, 2003), explored the effects of teaching an environmentally-oriented science unit related to water on Grade 7 students' achievement in science and their attitudes toward the environment(BouJaoude & Youssef, 2004), investigated pre-service and in-service teachers' conceptions of nature and environment and the values that determine these conceptions (Khalil, Clément, & Laurent, 2007), identified international environmental education trends in science textbooks (Khalil, 2008), compared environmental knowledge and attitudes of Lebanese prospective teachers with those of Australians (Vlaardingerbroek & Taylor, 2007), explored the geographical effect on teachers' environmental conceptions independent from the effect of religion, language of instruction and the goals of the lesson being taught (Khalil, Clément, & El Hage, 2008), and described the incorporation of environmental education in the school curriculum in formal and non-formal contexts and examined its impact on the knowledge, skills, attitudes, and behavior of grade ten students (Bouzeineddine, 2012).

Haidar-Makki, Abd-El-Khalick, and BouJaoude (2003) assessed Lebanese secondary school students' environmental knowledge and attitudes, and explored the relationship between participants' knowledge and attitudes, biographical and academic variables, and commitment to environmentally friendly behavior. Results showed that participants had favorable attitudes toward the environment but were lacking in their environmental knowledge. Environmental knowledge was significantly related to parental education level, and to participants' environmental attitude, beliefs, affect, and behavioral commitments. By comparison, participants' scores on the behavior subscale were considerably correlated with their environmental affect and intentions suggesting that environmental intentions and affect might serve as good predictors of commitment to environmentally friendly behavior.

The purpose of the study conducted by BouJaoude and Youssef (2004) was to investigate the effects of teaching an environmentally-oriented science unit related to water on students' achievement in science and on their attitude toward the environment. Two units on water, one experimental and one control were prepared for the purposes of the study. The two units covered the same topics (molecular structure of water, solubility, states of water, heat conduction in water, physical properties of water and their significance to life on earth, hydrological cycle, water purification techniques, water pollutants, water conservation, solutions to water pollution, water treatment and water treatment plants, and artificial and natural water purification systems) and contained the same laboratory sessions but differed in the teaching approach. Results indicated that students in the experimental group achieved significantly higher and developed

significantly more positive attitudes toward the environment than students in the control group.

Khalil, Clément, and Laurent (2007) analyzed the conceptions (anthropocentric, ecocentric or sentimentocentric) of preservice and inservice Lebanese teachers about nature and environment while seeking to identify the value systems that determine these conceptions. Results demonstrated a diversity of conceptions among participants whereby biology majors seemed to be rather ecocentric, being the most sensitive to environmental problems and the most equipped with scientific knowledge related to the ecosystem. Geography teachers were for the most part sentimentocentric, whereas prospective teachers were anthropocentric. This diversity of conceptions among teachers involved in environmental education could be a source of difficulty for students. In another study, Khalil, Clément and El Hage (2008) studied the conceptions held by science teachers in different regions of Lebanon: Beirut, Bekaa, Mount Lebanon, North and South. One was on an environmental conception known as Genetically Modified organisms. The results showed that unlike teachers from the North, teachers from the South and Bekaa were not against the use of transgenic plants. The authors explained this result by the fact that these are the two regions where agriculture is mostly evolving.

Khalil (2008) analyzed Lebanese Grade 7-12 biology and chemistry textbooks and Grades 1-6 geography and science textbooks published by the Lebanese Center for Educational Research and Development to find out if they included international trends in environmental education. Findings showed that that the textbooks were not aligned with the curriculum. More importantly, topics related to the environment did not even appear in the textbooks. The textbooks were typified with the predominance of information

dissemination, a participative pedagogy at the elementary level, and a participative, imperative, and persuasive style at the secondary level. Finally, results showed that more environmental topics were addressed at the elementary than the secondary level. It is worth noting that pollution was the most common theme at all levels in chemistry and geography in contrast to biodiversity, which was almost absent at the elementary level.

Vlaardingerbroek and Taylor (2007) gauged the environmental knowledge and attitudes of 87 final-year primary and secondary prospective teachers in Lebanon in two universities on the threshold of their careers using an equivalent Australian cohort as a reference group (N = 169). Results showed that the Lebanese prospective teachers lagged behind their Australian counterparts with respect to their knowledge of global environmental issues and displayed a narrower awareness of national environmental issues. Despite higher scores on the environmental attitudes scale that was administered in the study, the Lebanese teachers were more skeptical about the potential of school environmental education to instill environmentally responsible attitudes and behavior.

Bouzeineddine (2012) described the integration of environmental education in the school curriculum in formal and non-formal contexts and examined its impact on the knowledge, skills, attitudes, and behavior of forty five students in grade ten. Qualitative data from interviews, a teacher's questionnaire, and the school's curriculum and teaching documents showed that students learnt about global and local environmental topics (such as Pine Forest) in languages, biology, chemistry, social studies, sociology, and economics. Quantitative results from students' pre- and post-assessments showed that the environmental education program s improved students' environmental knowledge and skills and reinforced their positive attitudes and behavior.

In summary, Lebanese students, in general, had positive attitudes toward, but low levels of knowledge about environmental issues; learned about global and local environmental topics in languages, biology, chemistry, social studies, sociology, and economics; biology teachers were ecocentric whereby they have a serious concern for the environment while teachers of other subjects were mostly sentimentocentric whereby they did not care about the human impact on the environment; Lebanese teachers had more positive attitudes but less environmental knowledge than their Australian counterparts, and students' attitudes and achievement can be positively influenced through instruction. Finally, results indicated that environmental topics were almost absent from textbooks and that there was a prevalence of information dissemination in textbooks that addressed environmental issues.

Teachers' and Students' Misconceptions about Pollution

The problem of air pollution has local, regional and global dimensions. Smog, photochemical pollution, the greenhouse effect exacerbation, ground level ozone, the ozone layer depletion and acid rain are all considered forms of air pollution (Cunningham & Cunningham, 2008). Each of these problems has specific consequences on human health, on flora and fauna, on biochemical cycles, on life in ecosystems, on non-living matter and on cultural monuments (Mason & Hughes, 2001; Cunningham & Cunningham, 2008). For these reasons, the action taken to control air pollution should be a priority, because it has both short-term and long-term consequences for life on Earth. Consequently, it is important to investigate teachers' conceptions about pollution as it is likely that, if uninformed about the topic, they will pass inaccurate content on to their future students which in turn, reduces the probability of suitable preventive actions by these citizens

against pollution. Most studies on teachers' content knowledge concerning environmental issues have been based on an assumption that having strong content knowledge of environmental issues might encourage teachers to implement environmental education in schools (Boyes, Chambers, & Stanisstreet, 1995; Khalid, 2003). The literature review also revealed that in-service and pre-service teachers from various cultural contexts hold misconceptions about several environmental issues and limited knowledge in some cases. Many researchers revealed that prospective teachers do not possess the desired knowledge and understanding and have misconceptions regarding complex environmental issues such as the greenhouse effect, ozone layer depletion and acid rain (Boyes, Chambers, & Stanisstreet, 1995; Çakir, Irez, & Doğan , 2010; Dove, 1996; Groves & Puch, 1999; Khalid, 2003; Michail, Stamou, & Stamou, 2007; Papadimitriou, 2004; Summers, Kruger, Childs, & Mant, 2001; Taylor, Doff, Jenkins, & Kennelly, 2007). For instance, prospective teachers held the misconceptions that emissions from motor vehicles are responsible for ozone depletion and holes in the ozone layer are a direct cause of global warming (Boyes et al., 1995; Dove, 1996; Summers et al., 2001); also, they associate the ozone layer depletion with the greenhouse effect (Boyes et al., 1995; Michail et al., 2007; Summers et al., 2001). The results of these studies have indicated that teachers hold prevalent misconceptions on these particular topics and most are the same as their students' misconceptions. The studies revealed a widespread confusion between greenhouse effect and ozone layer depletion. Over half of the participants from all of these studies held the misconception that ozone layer depletion directly increases global warming by letting in more sunrays. The most common misconceptions identified in these previous studies included the following: (a) global warming will cause skin cancer; (b) carbon dioxide is

the main contributing factor towards these environmental problems; (c) the ozone layer helps to keep the earth warm, and (d) Acid rain occurs because of ozone layer depletion or greenhouse effect. Moreover, studies have indicated interlinked misconceptions between global warming, greenhouse effect, and ozone layer depletion (Boyes & Stanisstreet, 1992; Boyes, Chuckran, & Stanisstreet, 1993; Groves & Pugh, 2002); global warming and acid rain (Boyes et al., 1993); and ozone layer depletion and acid rain (Pekel & Ozay, 2005).

CHAPTER III

METHODOLGY

The purpose of this study is to investigate the pedagogical content knowledge of non-experienced and experienced secondary science teachers who are teaching about pollution, the greenhouse effect and global warming in specific, to grade 9 students. The intention of the researcher is to unpack an important component of the knowledge base for professional teaching, PCK, on pollution in order to find out whether teacher education programs are adequately preparing their students in teaching about environmental issues. The study provides descriptions of teachers PCK in relation to preset dimensions. The descriptions are specifically concerned with both strengths and weaknesses of teachers' PCK dimensions. Potential impediments to the development of PCK are also discussed in relation to the data obtained from the study.

In particular, this study addressed the following questions: What is the pedagogical content knowledge of experienced and novice secondary chemistry Lebanese teachers of pollution? Does secondary chemistry teachers' PCK of pollution differ between those who hold a teaching diploma degree from those who do not? Does secondary chemistry teachers' PCK of pollution relate to their years of teaching experience?

Research Design

This study used a qualitative design because it aims to characterize student teachers' PCK and gain in-depth understanding of chemistry teachers' PCK of the greenhouse effect and global warming. The methodology followed in this study was adopted from Rizk's (2009) study. Crucial to the value in using such an approach are the depth and breadth of

data to be collected, data that are used to generate thick descriptions of non-experienced (novice) and experienced secondary chemistry teachers' PCK in Lebanon in an effort to enrich the literature with case-studies that could be used to inform both research and practice.

Participants

The sample of chemistry teachers for this study was taken from private schools in Beirut and its suburbs that provide basic education (up to grade 9) and prepare their students to sit for the Lebanese Intermediate Certificate (Brevet) national examination. Also, only schools where the language of chemistry instruction is English were chosen. Chemistry teachers who teach Grade 9 level were chosen since pollution is incorporated into this grade level's national curriculum of chemistry and Brevet national examination. For the purpose of this study, purposeful sampling was used to select the teachers, consequently, a sample of six chemistry teachers who teach greenhouse effect and global warming in grade 9 was selected. The selected teachers had to have a bachelor's degree in chemistry. Since the second question entails investigating differences between those holding a teaching diploma and those who do not, and thus the teachers were selected in such a way that half of them held a teaching diploma or had taken courses in pedagogy. However, the sample had only one experienced and one novice teacher holding a teaching diploma as it was difficult to find other holders of a teaching diploma who would accept to be part of the study. Concerning the third research question which entails investigating years of experience and PCK), the six teachers were divided into two groups according to their years of teaching experience. The length of teaching experience was either short (less than six years), or long (more than six years). Six years of experience or less was defined

as novices in contrast to a competent professional with more than six years of experience. This purposive sampling (Bogdan & Biklen, 1992) was used because it best serves the purpose of this study. It is worth noting that this sample is not intended to be representative of a larger population of chemistry teachers in Lebanon.

When dealing with the participants, the researcher followed the Institutional Review Board's (IRB) basic ethical principles. Consent forms were given to all the participants in the study and they were given the freedom to withdraw from the study or not answer any questions they would not like to answer. Table 2 below presents background information about the six teachers, each of which was given a code for confidentiality.

Table 2

Background information of participants

Code	NT1	NT2	NT3	ET1	ET2	ET3
Gender	Female	Female	Female	Female	Female	Female
Education	B.S./ MS	B.S. / MS	B.S./TD	B.S.	B.S.	B.S./MS/TD
Science background	Chemistry	Chemistry	Chemistry	Biology	Biology	Chemistry
Teaching subjects	Chemistry	Chemistry	Chemistry	Chemistry	Chemistry	Chemistry
Teaching years	1	4	6	8	11	12

NT: Novice teacher ET: Experienced teacher

Instruments

Three instruments were used in this study to generate data: a lesson-planning assignment followed by a semi-structured interview; a video-taped teaching session followed by a self-evaluation and a guided case analysis; and CoRe matrices (Loughran et al., 2004) followed by semi-structured interviews.

Unit-planning assignment followed by a semi-structured interview. The chemistry teachers presented a written document comprising a lesson plan on pollution that addresses the greenhouse effect in specific; the lesson plan contained assessment material. This lesson plan was the basis on which semi-structured interviews were developed. The interviews revolved around the several dimensions of PCK hypothesized in the adopted framework, and more importantly, they were content specific. As such, these tools helped extract from teachers their hypothetical pedagogical reasoning regarding the topic of pollution. Each of the six interviews was audio-taped, then transcribed and analyzed.

A teaching session followed by self-evaluation and a guided case analysis. The chemistry teachers conducted the lessons on the greenhouse effect in the classroom. Each of these lessons lasted about 45 minutes. After that, teachers wrote a self-evaluation to reflect critically on the various decisions that they had to make; in particular, two planned and two unplanned decisions that they made during their teaching while providing reasons for their actions and decisions. In response to Shulman's claim for incorporating case studies as a method for eliciting teachers' knowledge within a context, and attempting to unfold further teachers' PCK, the researcher videotaped the lesson each of the six teachers taught, followed by a stimulated recall discussion/interview with every teacher in what relates to and reflects on the implementation of the planned unit. Before conducting the

interviews, the researcher watched the movie ahead of time and divided it into several subsections each of which constituting a subject for discussion with the teachers. During the interview, the teachers were asked to summarize the content of different sections of the video in terms of events so that the researcher can witness what particular events were of importance to the teacher. The questions developed by the researcher were mainly about why particular strategies were used and what kind of alternatives could have been done and why. Discussions were thus initiated, based on the guiding framework of PCK and guided by the researcher to engage the teachers in reflecting on their PCK in action. The discussions were tape recorded, transcribed and analyzed at a later stage.

CoRe matrices followed by a semi-structured interview. Content representations (CoRe) matrices, developed by Loughran et al. (2004), are essentially conceptual tools that can be used to elicit teachers' knowledge about the various dimensions of PCK relative to a particular content (topic) and context (grade level). As such, they provide an overview of how teachers conceptualize the content in a particular subject matter for the purpose of meaningful learning. Appendix II represents a CoRe matrix as presented by Loughran et al., (2006). A CoRe matrix is developed by teachers while thinking about what they consider to be the big ideas associated with teaching a given topic for a particular grade level. These big ideas are then probed and queried through eight prompts so that specific information about them that has impact on the manner in which the content is taught can be made explicit. Below is the set of eight questions as they appear in the CoRe matrix:

1. What do you intend for the students to learn about this idea?
2. Why it is important for students to know this?

3. What else do you know about this idea that you do not intend students to know yet?

4. What difficulties/limitations are connected with teaching this idea?

5. What knowledge about students' thinking influences your teaching of this idea?

6. What other factors influence your teaching of this idea?

7. What are the teaching procedures and particular reasons for using these to engage students with this idea?

8. What specific ways of ascertaining students' understanding or confusion around this idea will you use? (Loughran et al., 2004)

Teachers participating in this study were invited to complete a CoRe with regards the material they planned and taught earlier. It is hypothesized that CoRe matrices can provide a structure for teachers to organize their ideas and knowledge. The prompts used in the CoRe matrix relieve teachers from the burdens of organization while still showing researchers what these teachers know and do not know with regards to a specific science topic. What is interesting about these CoRes is that the teachers were invited to evaluate their content for teaching while making reasoned judgments about what ideas they believed were essential to instruction but also about others that were considered as nonessential. Upon completion (at home) of the matrices, the chemistry teachers were interviewed for the last time so that the researcher is able to represent their PCK especially that the CoRes link the how, why, and what of the content to be taught with what teachers argue to be vital in modifying students' learning and teachers' teaching.

Data Collection Procedure

All participants were asked to submit their lesson plan on the greenhouse effect and then participate in an interview with the researcher to discuss their work. The teachers' sessions about pollution were video-taped and, together with the reflections written by the teachers, they were used to probe PCK through planned and guided case study interviews with the researcher. Finally, the teachers were interviewed individually upon completing a CoRe matrix. The semi-structured interviews used for discussing the resulting CoRe matrices were the last source of data used. Peripheral notes in all of these interviews were taken so as to keep an eye opened to any emerging themes.

Pilot Testing

The researcher pilot tested all of the semi-structured interviews prior to data collection. The first interview was pilot tested using a chemistry lesson plan prepared by an expert chemistry teacher. Questions were reshaped so as to be as clear as possible and any additional ones were added to target all six dimensions of PCK. The second sets of interviews were developed by the researcher, and for each video-taped episode the corresponding interview was discussed with another researcher to conduct a reliability check. A pilot testing of the third instrument was conducted with an expert chemistry teacher to develop an expert chemistry CoRe on pollution for grade 9. Appendix III represents the expert CoRe matrix that was generated for this topic.

Data Analysis

Description of the domains of PCK . The researcher in this study used Rizk's (2009) modified framework of Lee et al.'s (2007) model in an attempt to elicit experienced and novice secondary chemistry teachers' PCK on pollution from a holistic perspective.

There are six domains of PCK that are considered in this study. The coding scheme used was developed prior to the analyses and modified throughout through a process of constant comparison. A description of the domains and their respective codes are presented in Table 3. The first dimension, knowledge of the content that is relevant for instruction, includes scholarly knowledge in the discipline, knowledge about the nature and processes of science and the relationships among various ideas within the topic. The second dimension includes knowledge about topic-specific instructional strategies and representations as well as the reasoned pedagogical judgment for using or not using a particular representation (analogy, metaphor, illustration, text, etc…). The third dimension comprises knowledge of students' learning and students' conceptions including some scholarly knowledge about students' common misconceptions; this domain also encompasses teachers' ability to anticipate some potential misconceptions and to deal with spontaneous instances of students' misconceptions. The fourth dimension is teachers' knowledge of specific science curriculum organization including both vertical and horizontal progression. This domain also encompasses teachers' knowledge about salient ideas in the unit and about what ideas can be added or removed so as to facilitate learning. The fifth element of PCK is teachers' orientations toward science teaching. This dimension includes teachers' reasoned judgment for their pedagogical action in light of their teaching goals and objectives. The sixth dimension is knowledge and use of adequate assessment reflecting orientations in a specific instructional setting.

Table 3

Description of the Six Domains of PCK

Categories of knowledge	Descriptors
Domain 1: Knowledge of content	
Scholarly knowledge in the topic Nature of the topic	• Concepts, theories, laws; Knowledge about some general principles within the topic like the micro/macro differentiation; Knowledge of the history of the topic when applicable; Knowledge about applications of the topic to real life; Knowledge about the processes of science generation and validation .
Domain 2: Knowledge of topic specific instructional strategies	
Types of teacher/student activities Characteristics of instruction Types of and reasons for using illustrative devices	• Teachers' activities (Challenge students' thinking, guide students' thinking, convince and negotiate, explain and explore explanations, lecturing, asking questions, engaging students, relate ideas and make connections, summarize…) • Students' activities (Thinking individually, problem solving, predicting, explaining, working in group…) • Instruction is Teacher centered /student centered; Reasoned use of instructional approach (Cooperative learning, exploration, investigation, inductive/deductive, discrepant events…); Using alternative approaches • Using appropriate illustrative tools (Analogy, text, handout, picture/ /diagram, example, simulation/movie, stimulating question, story …)
Domain 3: Knowledge of students	
Knowledge of students' learning Building on prior knowledge Dealing with misconceptions and learning difficulties	• Knowledge of some theories of learning and their underlying assumptions; knowledge of students' thinking patterns; accounting for the motivation/interest/backgrounds of students as well as their cognitive level • Relate to students' daily life experiences and link to previous lessons • Anticipating misconceptions and learning difficulties but also dealing with emerging student misconceptions/thoughts/challenges
Domain 4: Knowledge of the curriculum	
Knowledge of horizontal and vertical progressions Curricular saliency	• Knowledge of the structure of the unit and understanding the place of a topic in the curriculum (structure of the topic) • Knowledge of vertical progression and establishing links for future learning • Making informed decisions to leave out some aspects of the topic

	• Making appropriate content elaboration in relation to the curriculum
Domain 5: Knowledge of orientations	
Goals of the lesson (reflecting orientation)	• Formulating realistic objectives that emphasize students' learning of desired outcomes; Developing a coherent teaching sequence reflective of the intended objectives;
Domain 6: Knowledge of assessment	
Knowledge of assessment types and techniques	• Formative, summative, diagnostic / Questioning, paper and pencil, summarizing, quiz; Understanding the role of assessment in the context used; Appropriate use of assessment in terms of time and place of its administration in the sequence

Data analysis procedures. It is important to note that data analysis required a thorough knowledge of the content given in the teaching session, content matter knowledge in biology and chemistry, as well as of the different elements of PCK. Consequently, to assure that data analysis was accurate the following issues were addressed as advised by Rizk (2009):

1. The researcher attended almost all sessions on pollution to insure familiarity with the unit content.
2. The researcher had a thorough knowledge about issues related to PCK since in preparation for her research she wrote a paper on the topic and received feedback from a science educator on this paper even before she wrote the literature review.
3. The researcher received help in determining the quality of content matter knowledge (specifically in biology and chemistry) from and experienced biology teacher and an experienced chemistry teacher both of whom have master's degrees in science.

The data consisted of three sets: the taped interviews discussing teachers' lesson planning, the video case analysis transcriptions and the self-reflections, and the CoRe matrices with the corresponding interviews. Analysis of data from the three sources was carried out for each teacher so as to generate profiles for these teachers. First of all, a rubric (Table 4) was prepared by the researcher that contains all six dimensions of PCK together with their descriptors (codes) that were mainly derived from the literature but also from preliminary readings of the interviews. These codes were discussed with another coder for any possible modifications to be made. All of the data sources were coded, and quotes for each teacher were placed under one of three categories: PCK in planning, PCK in action, and PCK in reflection. Each of the quotes was then categorized as either poor, moderate, or proficient based on the rubric (Table 4) that described these categories. The rubric (Table 4) was the result of amalgamation of three other rubrics that are found in the literature (Friedrichsen et al., 2009; Park et al. 2010 & Rizk, 2009). For the first dimension of PCK, knowledge of the content, the researcher analyzed the competency/ proficiency/ knowledgeability of teachers' understanding of the concept and evaluated the teachers' ability to relate content to everyday life. For the second PCK dimension, instructional strategies, the researcher analyzed the type of approach (teacher vs. student centered), integration of student prior knowledge during instruction, and usage of a valid reasoning for the selection of the strategies. For the third dimension, knowledge of students, the researcher analyzed the teacher's' ability to focus on student's difficulties, conceptions, misconceptions, prior knowledge, and real-life experiences prior to and during instruction. As for the knowledge of curriculum, the fourth dimension, the researcher analyzed the vertical and horizontal progression in alignment with the objectives of the national

curriculum. Concerning the fifth dimension, knowledge of orientations, the researcher focused on the appropriateness of the teaching sequence design and its alignment with the objectives of the national curriculum. Finally, the researcher assigned the level of performance in the knowledge of assessment based on how well the teacher selected appropriate tools to assess student understanding including its time and place of its administration in the sequence and on how well the teacher incorporated action verbs from Bloom's taxonomy at various levels one - six (knowledge, comprehension, application, analysis, synthesis, and evaluation). Next, for each teacher and for each dimension, a frequency count was calculated for every form of knowledge (PCK in planning, PCK in action and PCK in reflection). If, for a given dimension and a given form, a candidate's quotes were all poor, the candidate was labeled as having poor PCK for that dimension in that form. If their quotes were all coded as proficient, they were labeled as having proficient PCK for that dimension in that form; otherwise they were labeled as having moderate PCK. If there was a slight difference between any two levels, more evidence (quotes) would be collected until more than 60% of the quotes are coded as one of the two levels. In addition, for each level of performance, the researcher assigned a score (Poor = 1; moderate = 2; Proficient =3) so that the overall PCK level of performance, for all dimensions, can be generated for each teacher. The higher the overall PCK score, the more robust the teacher's PCK for the teaching about the greenhouse effect.

For the interview coding part of the analysis, and to insure reliability, the researcher and a teacher who holds a Master's degree coded a part of an interview together after discussing the background information of the study and the instruments. Then the teacher and the researcher coded a whole interview independently and then met to compare the

results of the coding. Any disagreements were discussed and clarified until consensus was reached. After that, the researcher and the teacher independently coded the rest of the interview and then discussed the results of the coding. The teacher coded 10 % of the researcher's findings which represents the data set of one of the six teachers (the taped interviews discussing teachers' lesson planning, the video case analysis transcriptions and the self-reflections, and the CoRe matrices with the corresponding interviews). A reliability check was performed using inter-coder reliability based on the application of the descriptors related to the various dimensions of PCK. The inter-reliability score initially yielded 70% but increased to 90% following the discussions. At this stage the researcher decided to continue the coding individually because the reliability was sufficiently high. Later, the researcher summarized all findings in a table for every teacher. Finally, the six teachers were grouped according to the variables of interest: the attainment of a teaching diploma and their years of teaching experience. Two groups were selected to reflect the level of education: Teaching Diploma and no Teaching Diploma. Next, the PCK profiles of the experienced and novice teachers that were generated earlier were used to seek relationships with the aforementioned variables of interest.

Table 4

PCK Rubric for the Greenhouse effect

Elements of PCK	**Level of performance**		
	Poor	**Moderate**	**Proficient**
Knowledge of the content	Demonstrating no appropriate understanding of the concepts (greenhouse effect and global warming). Not giving enough applications of the topic to real life (less than three).	Demonstrating an appropriate understanding of the concepts (greenhouse effect and global warming). Giving some applications of the topic to real life (four-six).	Demonstrating a deep understanding of the concepts (greenhouse effect and global warming). Giving enough applications of the topic to real life (more than seven).
Knowledge of the topic specific instructional strategies	Using a teacher-centered approach. Not using appropriate illustrative tools. Not giving reasoned use of instructional approach. Not integrating understanding of the student's prior knowledge into instructional strategies. Not giving valid reasoned uses of instructional approach.	Instructing in a semi-student centered manner. Using the strategy in an inefficient way. Integrating the understanding of the student's prior knowledge into instructional strategies in a restricted way (Ex: using the greenhouse analogy in restricted way). Giving poor reasoned uses of instructional approach.	Using a variety of instructional student-centered approaches that includes multimedia or technology (e.g. PowerPoint) to express the concept of subject. Integrating the understanding of the student's prior knowledge into instructional strategies in an effective way. Giving appropriate and reasoned uses of instructional approach.
Knowledge of students	Not describing any students' difficulty in understanding the subject. Not taking into account student's prior knowledge and not relating the lesson to their daily life experiences and linking it to previous lessons.	Giving details about students' difficulties in understanding the subject and alternative conceptions (at least two). Taking into account student's prior knowledge and relating the lesson to their daily life experiences.	Giving details about students' difficulties in understanding the subject and alternative conceptions (at least four). Explaining how and why students may have learning difficulties or develop alternative conceptions. Taking into account student's prior knowledge.

Table 4 (Cont'd)

Elements of PCK	**Level of performance**		
	Poor	**Moderate**	**Proficient**
Knowledge of the curriculum	Unknowledgeable of the national content curriculum. Viewing curriculum as dictated to the teacher by textbook or subject-coordinator. No understanding of the topic or its objectives in the curriculum. Not establishing links for future learning. No modification done to the content in relation to the curriculum.	Sufficient understanding of the topic's objectives in the curriculum. Equating the curriculum with the textbook. Knowing that the topic was covered before in middle school and it would not again be encountered in the future. Making content elaboration in relation to the curriculum or leaving out some aspects of the topic without a valid reason.	A proficient understanding of the place of the topic and its objectives in the curriculum. Viewing curriculum as being negotiated and written by teachers in the school with national standards as guidelines. Making appropriate content elaboration in relation to the curriculum. Making informed decisions to leave out some aspects of the topic. Knowing that the topic was covered before in middle school and it would not be given again in the future.
Knowledge of the orientations	Presenting clear and defined goals but not tailoring them to foster conceptual understanding of the topic. Misusing the strategies. Sequencing is not conducive to reach lesson goals.	Developing the teaching sequence in alignment with the goals of teaching science content but fails to manage the transition from one objective to the next.	Developing the teaching sequence in alignment with the goals of teaching science content. Managing a smooth transition from one objective to the next. Sequencing is conducive to reach lesson goals
Knowledge of the assessment	Missing an appropriate and aligned with objectives assessment tool. No appropriate use of assessment in terms of time and place of its administration in the sequence. Questions were based on Bloom's taxonomy at level one (knowledge).	Using one assessment tool that is aligned with the national curriculum and lesson objectives. Appropriate use of assessment in terms of time and place of its administration in the sequence. Questions are based on Bloom's taxonomy at levels one & two (knowledge and comprehension)	Using several appropriate assessment tools that are aligned with the national curriculum standards and lesson objectives. Relies heavily on on-going informal assessment to determine what is needed to be taught or re-explained. Appropriate use of assessment in terms of time and place of its administration in the sequence. Questions are based on

	Bloom's taxonomy at levels one-six. (knowledge, comprehension, application, analysis, synthesis, and evaluation)

CHAPTER IV

RESULTS

Data from interviews with teachers, from their reflections on their teaching on the greenhouse effect and global warming, the videotapes and from their CoRe matrices were coded and analyzed according to the six dimensions presented in Table 3 in Chapter 3. The findings are presented in the form of teacher profiles that portray each teacher's level in each domain of PCK. Each detailed description of the teacher PCK profile is followed by a table that summarizes findings.

Analysis of Experienced Teacher 1 (ET1) (non-TD holder)

Teacher ET1 has a total of eight years of teaching experience. Her educational background includes a bachelor degree in Biology. She started her lesson with a video that depicts the harmful effects of pollution on the environment. Next, she listed the lesson objectives on the white board and tried to elicit from the students what they know about the greenhouse effect. She used the greenhouse analogy later on to explain the role of the greenhouse gases. Then, the teacher used a PowerPoint presentation that she had already prepared for a project that was presented in a science fair organized during the previous year. The PowerPoint presentation showed slides of several real-life implications of the greenhouse effect. Moreover, it showed a diagram that depicts the process behind the greenhouse effect. The teacher explained what was being portrayed on all of the slides. After that, the students were asked to recall what was being explained and to come up with ways that they know of which will help to reduce the greenhouse effect. Finally, a worksheet was distributed that comprised questions from previous national Brevet exams.

Some of the questions were answered by the students in class, others were assigned for homework. The answers to the questions were discussed to check for student understanding. Even though the teacher had passion for the content of instruction as she worked with a group of students on the same topic in a former science fair, it was apparent in action, the teacher's lack of passion for engaging the students in the discussion. The level of interaction was very low for only the high achievers were participating.

In general, teacher ET1 has a proficient knowledge of the first domain of PCK, knowledge of the content related to instruction, as she demonstrated in her planning to have a moderate or an appropriate understanding of the greenhouse effect and global warming concepts and she listed up to five examples of real life implications as illustrated in the excerpt below:

> *The greenhouse effect is the trapping of some of the heat radiated back from the earth and warm the air. Without it, life on earth is impossible. The atmosphere keeps the planet warm due to the presence of the greenhouse gases such as CFCs, NO_2, CH_4 and mainly CO_2. Upsetting the balance of these gases will cause an increase in the greenhouse effect which leads eventually to global warming. All of this is the result of air pollution. The consequences of global warming include: change in climate, flooding, droughts, extinction of some animals, and migration of animals. (Teacher ET1, Int.1).*

In addition, she stressed on the importance of this topic in relation to real life applications, an indicator of scientific literacy and proficient PCK:

> *[…] Even though it is not covered much in the official national Brevet exams… I think it [this topic] is important because the students should be prepared how to*

face this phenomenon in the future when it gets worse. I will expose them to the various solutions that are found now so that they start applying even right now in their daily lives (Teacher ET1, Int. 3).

In her PCK in action and reflection, teacher ET1 showed a proficient level at the content knowledge level as she used her own extensive research for her science fair project and a video to expose the students to more than seven real-life implications of global warming.

In the second domain of PCK, Teacher ET1 seemed to have an inadequate knowledge of the topic specific instructional strategies. In her planning, she decided to use a "semi-student centered" approach. The students' role was only to watch the video at the beginning of the session and then tell the teachers what they already know about global warming or the greenhouse effect. They were expected to be involved in discussion on how to help reduce this effect. Even though the teacher planned to use a video, an analogy and PowerPoint presentation, she did not plan to involve the students in deducing the meaning or relating the two concepts of greenhouses and greenhouse effect as indicated in the following excerpt:

Researcher: what will your role be and what will the student's role be during the entire session?

ET1: at first, I will ask them questions to see what they know about this topic so that I fill any gaps they have….all they need to do is to focus on the video memorize some ideas and after I am done with my explanation about the process behind this phenomenon… I will explain to them the analogy so that they better understand the meaning of the greenhouse effect…I will also use the diagram in the ppt. that

depicts process behind the greenhouse effect and at the end, I will check the students' understanding using the worksheet that I prepared (Teacher ET1, Int.1)

In terms of PCK for action, the teacher showed a poor PCK level in the knowledge of instructional strategies as the strategy was mainly teacher-centered. Even though the teacher asked the students to state what they know about pollution and the greenhouse effect, and to suggest ways to reduce it, student contributions were mainly "not really allowed" for the purpose of not wasting time. All they had to do was to sit there and listen! In terms of PCK for reflection, ET1 also demonstrated a poor PCK as she stated that she is knowledgeable enough, so she wanted to give them the correct answers. She also reflected on why she used video, but her explanation reflects an inefficient use of technology. Moreover, she did not give a valid reason as to why she elicited students' prior knowledge before she started instruction. She also reflected on the idea that when a lesson is easy, there is no need for much interaction between teachers and students.

I am responsible for the knowledge that I give to the students so I have to make sure that they get the right information from me… I like to drill the information so that it sticks to the students' minds… The video is a good visual aid as it reminds them of what they see in their daily life and it gives them more knowledge but a lot of time was taken to install the projector… at the beginning … so I might not use it next year and waste my session time. (Teacher ET1, Int. 3)

Teacher ET1 seemed to have a poor knowledge of students. In her PCK in planning, she showed a poor level of PCK as she only planned to elicit students' prior knowledge from questions at the beginning of the session and she mentioned three entrance abilities that the students should already have. These abilities include: 1) Students

must know the concept of greenhouses whose nylon walls prevent heat from escaping, 2) Students must know complete combustion reactions that release CO_2 into the air, and 3). Students must know that air pollution is the result of human actions (Teacher ET1, lesson plan). Moreover, she only mentioned two misconceptions that the students might have. These include: greenhouse effect only affects the earth negatively and greenhouses are the ones that lead to the greenhouse effect (Teacher ET1, CoRes matrix). Although she thought about initiating the lesson by building on the students' prior knowledge, she was not knowledgeable enough as to why this step is important for the teacher:

> *I asked them what they already know about this topic because if they knew so much then I do not have to do a lot of explaining …this helps me to finish the lesson faster (Teacher ET1, Int.1)*

Nor did she anticipate appropriate ways to handle the students' misconceptions. When asked how she would handle misconceptions, she answered:

> *When you drill the information into the students' minds throughout the whole session … re-iteration helps the students to memorize the right information and ignore the misconception that they might have (Teacher ET1, Int. 1)*

Although when discussing her planning, teacher ET1 asserted that she would make use of students' peer teaching to help in any emerging difficulty; in fact, when the students proved to have difficulties in explaining how the greenhouse effect occurs, she decided to deal with it herself without involving the class. Hence, the class was really passive and quiet. When asked why the class was quiet most of the time. ET1 replied:

"They understood from my explanation …it was more than enough… plus my constant re-iteration of ideas helps a lot… they don't need to ask" (Teacher ET1, Int.2)

In her PCK in action, ET1 showed poor knowledge of the students as she did not work towards correcting student misconceptions, and did not answer questions that she considered "irrelevant" to the topic of discussion. When a student asked: "does the greenhouse house effect make holes in the ozone layer?" (Teacher ET1, Int.2), the teacher replied "The ozone layer is not related to the lesson. We will address it in the coming sessions" (Teacher ET1, Int.2). She did not attempt to address misconceptions right away. For her PCK in reflection, ET1 showed poor knowledge of students as she asserted that taking student misconceptions into consideration and working to correct them will take up the class time (i.e. is not of great importance). She indicated that she knows all about their misconceptions, however, she did not identify them or take them into consideration in the flow of the lesson.

Researcher: one of the students wanted to discuss the consequences of the greenhouse effect but you stopped him to explain to him the process behind the effect. Why did you that?

ET1: He won't fully understand the consequences without understanding the cause behind this effect. I wanted to organize his ideas (Teacher ET1, Int.2)

Moreover, she did not realize that students have varying learning styles as shown in the following excerpt:

Only the smart students and those who are interested will understand my explanation...some might not focus because they are not interested... I am sure that

with the video and all the re-iteration of the ideas that I have done… there shouldn't be any student who would find this lesson to be difficult…those who were quiet either they were shy or they understood the lesson fully (Teacher ET1, Int.3)

Concerning the knowledge of the curriculum, ET1 showed poor level of PCK in general. In her PCK in planning, she showed moderate knowledge. She was knowledgeable of the objectives of the national curriculum and aware of the vertical and horizontal progressions:

Pollution, its definition, types and its effects is taken at the elementary and middle school level (grade 7) but they don't know the definition of the greenhouse effect or global warming…it is only given in grade 9. They won't encounter this topic again in the future unfortunately.

Even though she strictly abided by what the curriculum says, she equated it with the national textbook and not by what is mentioned in the national curriculum itself. Moreover, she did not write down the objectives found in the curriculum in her lesson plan. When asked for the reason behind this, she replied:

The objectives related to this lesson are few and unclear for the teacher. They do not specifically tell us what to teach the student in terms of content and skill…it is very brief whereas the national chemistry book gives me a better idea of what the student is required to learn (Teacher ET1, Int. 1)

Moreover, in her planning, she decided to only talk about the role of CO_2 in the greenhouse effect. She did not want the students to learn about other greenhouse gases because the "national examinations only ask about CO_2" (Teacher ET1, Int.1).

In her PCK in action, the teacher showed moderate understanding of the curriculum as she started her lesson by referring to what the students learned before about pollution. Moreover, she listed on the board the objectives of the lesson from the content of the chemistry national textbook which is supposed to be based on the national curriculum. During instruction, the teacher decided to leave out some aspects of the explanation that were impeding students' understanding. The student could not understand how reflection or re-radiation of heat by the greenhouse gases could heat up the earth. She decided in her reflection:

> *I don't want to go into the details the role played by the greenhouse gases. The idea of absorbing the heat radiated by the earth and re-radiating it back by the greenhouse gases will confuse the students. It is not mentioned in the curriculum nor in the book the details behind this process…even in the national examination, questions does not require the student to be really knowledgeable about the process… it's enough to say that these gases trap heat (Teacher ET1, Int.3)*

The teacher did not want the students to achieve deep understanding of the process and that is why in her reflection she did not want to change the structure of the lesson. Her excuse was based on the fact that the national curriculum and the textbook offer shallow content related to this topic. When reflecting on the lesson, teacher ET1 appeared to have a poor PCK as she simplified the lesson in ways that simplify the process of the greenhouse effect which might obstruct students' conceptual understanding:

> *In the official exams, the student has to be careful how to answer the questions. He should stick to the content found in the Chemistry national book. He will be*

penalized for any extra information given in the official Brevet exams (Teacher ET1, Int. 3)

In her knowledge of orientation to teach about the greenhouse effect, ET1 showed a moderate PCK level in general. In her lesson plan, the strategies used were aligned with her teaching objectives which were: "define the greenhouse effect; identify the main cause of the greenhouse effect (CO_2); Identify the consequences of global warming; List solutions to reduce the greenhouse effect" (Teacher ET1, Lesson plan), however they were not planned to foster deep understanding but only for the students to memorize and recall what they saw in the video or the PowerPoint presentation. In her PCK in action, even though the teacher emphasized these aforementioned objectives in an attempt to make the most important ideas clear to the students, however, she strictly abided by the order she put on the board rather than answering student questions as they come. Activities were tailored mainly to memorization. While reflecting on her teaching sequence episode, she noted:

I am very well experienced…I followed my plan as it is … my plan will help me fill any gaps the students have… I would not change anything about the sequence….maybe I would remove the video as it took some time…I can use this time to move on with the curriculum and address other environmental issues (Teacher ET1, Int.2)

This reflects a poor PCK in the knowledge of orientation as the teacher does not seem to take into account student answers to modify the sequencing of the lesson.

Moreover, ET1 has a poor knowledge of the assessment, the sixth dimension of PCK. In terms of PCK for planning, she shows a moderate level of knowledge of

assessment as two assessment tools were planned to be used (classroom discussions and a worksheet). When examining the worksheet which was based on former national Brevet exams, the type of questions belonged to Levels one and two of Bloom's Taxonomy (Knowledge and comprehension). Questions include: State one consequence of global warming; Justify why carbon dioxide is considered a pollutant according to the graph; referring to the text and the diagram, give an explanation of the greenhouse effect. In her PCK in action, the teacher did not rely heavily on formative assessment (e.g. questioning and asking for summarizing) while she progressed through the lesson especially at the juncture where she moved from using the analogy to focusing on the real-life consequences of the greenhouse effect. She stated: "this lesson does not need much interaction because it is really easy" (Teacher ET1, Int. 3). This shows a poor PCK in action because even though she used a worksheet that is aligned with curriculum objectives, she asked only few questions to monitor the student understanding during the session and only a few participated. Moreover, there was no appropriate use of assessment in terms of time and place of its administration in the sequence. Upon reflection, ET1 demonstrated a poor reflection on the knowledge of assessment. She believed that all students understood the concepts although only one to two students seemed to participate during the session as she believed the reason was shyness. Even though she stated: "I believe that assessment should be done at the end of the lesson after all the explanation is done" (Teacher ET1, Int.1), she did admit however, that for next year, "I would ask for more participation and let the students do most of the talking to know if they really understood or not" (Teacher ET1, Int. 3). A summarized profile ET1's PCK is presented

below in Table five. The overall PCK (taking into account the horizontal and vertical levels) puts ET1 in the poor category.

Table 5

PCK Profile for ET1

PCK Element	PCK in Planning	PCK in Action	PCK in Reflection	PCK Category
Knowledge of the content	**Moderate** Adequate understanding, from lesson plan and core	**Proficient** Explanation based on video and her own knowledge	**Proficient** She was knowledgeable as was evident in her responses. Moreover, she was engaged in a science fair where she had to do an extensive research on the greenhouse effect.	**Proficient**
Knowledge of the topic specific instructional strategies	**Moderate** Semi-student centered approach was implemented, however, student prior knowledge was to be elicited from questions only at the beginning of the session concerning pollution and a video was to be used for explanation	**Poor** Teacher- centered was mainly implemented. Used video inefficiently. Student contributions were mainly "not really allowed". All they had to do was to sit there and listen!	**Poor** Teacher-centered approach. Reflected on why she used video, but her explanation reflects an inefficient use of technology although she elicited students' prior knowledge before she started instruction. She also reflected on the idea that when a lesson is easy, there is no need for much interaction between teachers and students.	**Poor**
Knowledge of students	**Poor** Student prior knowledge was to be elicited from questions at the beginning of the session however, only mention 2 misconceptions.	**Poor** The teacher did not work towards correcting student misconceptions, and did not answer questions she found were "irrelevant" to the topic	**Poor** Teacher reflected that taking student misconceptions into consideration and working to correct them will take up the class time (i.e. is not of great importance). She says that she knows all about their misconceptions,	**Poor**

		of discussion.	however, she did not identify them. Moreover, she didn't realize that students have varying learning styles and that	
Knowledge of the curriculum	**Moderate** Knowledgeable about the objectives of the curriculum and aware of the vertical and horizontal progressions. She realized that students took it before in prior instruction, but strictly abided by what the curriculum says. She deduced the objectives of the lesson from the content of the chemistry national book.	**Moderate** She started her lesson by referring to what the students learned before about pollution. She deduced the objectives of the lesson from the content of the chemistry national book.	**Poor** Simplify the lesson to exclude any difficult concept such as the idea of re-radiation of heat by the greenhouse gases.	**Moderate**
Knowledge of the orientations	**Moderate** Activities were aligned with the objectives; however they were not tailored to foster deep understanding (Memorize…)	**Poor** She wanted the objectives to be addressed smoothly during the lesson, however, she strictly abided by the order she put rather than answering student questions as they come. Activities were tailored to memorization.	**Poor** She reflected that it was of great importance to follow objectives as were written in her plan, and not taking into account student answers to modify the sequencing of the lesson.	**Poor**
Knowledge of the assessment	**Moderate** Two assessment tools were	**Poor** Even though she used a	**Poor** She believed that all students understood the	**Poor**

	used but only one will be done after teacher explanation is complete; there's also a worksheet for assessment (Level one & two Bloom's Taxonomy)	worksheet that is aligned with curriculum objectives, the teacher asked a few questions to monitor their understanding during the session and only a few students participated.	concepts although only one-two students seem to participate (she believed the reason was shyness). Her proposed questions were not really conducive to deep understanding (Bloom's taxonomy level one).	
PCK Category	**Moderate**	**Poor**	**Poor**	**Poor**

Analysis of PCK for Experienced Teacher 2(ET2) (non-TD holder)

Teacher ET2 has a total of 11 years of teaching experience. Her educational background includes a bachelor degree in Biology. She started her lesson by writing the lesson's objectives on the board and then engaging the students in a group activity that elicited what they knew about pollution, its causes, and its effects on the environment. A student from each group presented the answer to each question. The teacher summarized all the students' answers and wrote the summary on the board. Next, the teacher used the students' answers on the effects of pollution to introduce the concept of global warming. She asked the students to explain what they already know about it. Then, she introduced the concept of the greenhouse effect to explain what causes Global warming. She later used an analogy between greenhouses and the greenhouse effect to clarify the role played by the greenhouse gases. The teacher reiterated the aforementioned concepts by drawing a diagram depicting the process behind the greenhouse effect. One last reiteration was also done right after showing the students a video about the consequences of global warming and the process behind the greenhouse effect. A discussion followed the video to check what the students understood and to recall what was shown. Additionally, the teacher engaged her students in a brainstorming activity about ways to reduce this problem. Finally, a worksheet that comprised questions from previous national Brevet exams was given to the students to be solved individually. Corrections to the answers of the worksheets were to be done in the following session. It was apparent that the teacher made sure to engage all of the students in discussion and group activities. Moreover, she checked on every group during the classroom activity and made sure they understood the questions mentioned in the worksheet.

In general, teacher ET2 showed a moderate level in the knowledge of the content, the first dimension of PCK. In PCK planning, she demonstrated an appropriate understanding of the greenhouse effect and only gave four real-life examples about the consequences of the greenhouse effect:

> *The greenhouse effect is important for nature as it is responsible for warming up the earth. It is caused by several greenhouse gases such as CO_2, CH_4 and water vapor…the upsetting of the balance in the greenhouse gases leads to an increase in the greenhouse effect and thus leads to global warming… global warming will result in flooding, change in climate, melting of the polar ice caps, and destruction of animal's habitats…The role of humans is to reduce the emission of these gases (Teacher ET2, Int.1).*

She also planned to show an informative video to provide additional information about the real-life consequences of the greenhouse effect. Her PCK in action also showed a moderate level on the knowledge of content as she showed a deep understanding of the concepts. However, she did not elaborate enough on the real-life implications of the greenhouse effect (less than 4 examples). ET2's PCK in reflection was poor, as she did not reflect on her knowledge of the content.

In the second dimension of PCK, the knowledge of instructional strategies, ET2 showed a moderate level in PCK of planning, action and reflection. Concerning her PCK in planning, although the teacher planned to use a semi-student-centered approach where students would be engaged in discussion, watch a video, and work in groups, she planned to do most of the explanation of the main ideas and present the students with the "correct answers" to all the questions asked. She also planned on using several

approaches explore students' explanations and guide their thinking so as to facilitate the comprehension of concepts:

> *Researcher: What will the students do during the whole session?*
>
> *ET2: At the beginning, they will work in groups in order to answer questions about what they know about effects and types of pollution, and then they will discuss the idea of the greenhouse with me after I explain it…. because maybe they already know about it…. They are going to copy the information onto the copybook after I write the correct answers on the board….I'll give them the analogy of greenhouses for them to understand how the greenhouse effect works (Teacher ET2, Int.1).*

In her PCK in action, the teacher followed her plan efficiently. Although the teacher engaged the students through group discussion on pollution and its effects in general, wrote a summary of their answers on the board, and gave feedback, she was the one who still did most of the work in terms of explanation. She did not engage the students in any thought-provoking activities. The students were simply asked to recall what they had learned from the video and in her lecture. Upon reflection on her PCK of knowledge about instructional strategies, ET2 showed a moderate level by saying that she successfully made the students interact during the session (group activity and discussions) and that the choice to explain the lesson to her students was the correct one. However, she admitted, "After watching myself now, I realized that I haven't given time for students to elaborate on their explanations…I guess I was worried about the time" (Teacher ET2, Int.3). Moreover, when asked about the benefit of using this particular video after a second reiteration of the ideas, she said, "The video is a good visual aid; it grabs the students' attention and motivates them to stay focused" (Teacher

ET2, Int.2). Next, when asked why the video was shown after her second explanation and not before, to allow students to understand better the meaning of the greenhouse effect, she replied:

> *The students might get confused from the video if I don't explain the greenhouse effect myself first…also, I did not want to play the video with sound because that it would be difficult for students to understand some of the ideas mentioned…some ideas that were mentioned were not part of the curriculum (Teacher ET2, Int. 3)*

Even though ET2 implemented several instructional strategies during the session, she gave poor reasons for using them and she did not use these instructional strategies in a way that fostered deep understanding of the concepts. This indicates a moderate level of performance in PCK.

In the third dimension of PCK, the knowledge of students, ET2 also showed a moderate level in PCK of planning, acting, and reflecting. In her PCK of planning, the teacher showed a moderate level of PCK as she mentioned several students' entrance abilities in her lesson plan that included: knowledge of the role of greenhouses, the definition of pollution, the causes of pollution, and the type of bonding in greenhouse gas molecules. This indicates that she planned to take the students' prior knowledge into account when introducing the lesson in class. She did not, however, provide an extensive list of difficulties or misconceptions students might have during instruction. She stated, "I don't think the students will face any difficulty in this lesson because they learned about it at the elementary level and from their geography lesson" (Teacher ET2, Int.1). She anticipated only one misconception. She claimed, "Many students might think that the greenhouse effect can only affect the earth negatively and that it is

not necessary for the survival of living things" (Teacher ET2, Int.1). However, she planned to deal with it by reiterating the correct explanation. This was also evident in her instruction during the session.

Researcher: How did you overcome the students' misconception about the role of greenhouse effect?

ET2: I repeated several times the true meaning of the greenhouse effect throughout the session…also I pointed out to the students that such misconceptions is frequently found in most of the students…this way they will watch out and not have such a misconception in the future (Teacher ET2, Int.2).

Even though ET2 explained the misconception clearly to the students, she did not effectively deal with it. Moreover, although, in action, the teacher started with refreshing students' prior knowledge about pollution through the group activity, she did not encourage students to portray their prior knowledge about the greenhouse effect, since she believed they knew nothing about it. Assuming her students knew nothing about the topic puts her at the moderate level of performance in PCK of students. In her PCK in reflection, even though the teacher reflected on the importance of starting from students' prior knowledge, she was unable to showcase misconceptions and difficulties and tried to justify this deficit by saying she would deal with any emerging misunderstandings from instruction in upcoming sessions (or to be answered in different subjects).

Researcher: A student said that deforestation can help reduce the greenhouse effect…you did not correct his misconception nor gave him feedback…why didn't you decide to guide him to overcome it?

ET2: I don't know...I guess I was worried about the time…there are many things that I need to tackled in the next session. I memorized his face… I will explain it to him again…I usually do a lot of re-iterations… (Teacher ET2, Int.2).

Moreover, she thought that one way to avoid misconception would be to ask the students to ignore complex explanations. She stated: "There were some explanations in the video that I told the students to forget about in order to avoid having any misconceptions" (Teacher ET2, Int.2).

In general, ET2 showed to be proficient in the fourth dimension of PCK, the knowledge of the curriculum. In her PCK in planning, she demonstrated a proficient level of performance as mentioned in her lesson plan where the topic was covered in middle and elementary school (Grades five & seven), and so based her lesson on this fact and she knew that this topic is covered in the future at the secondary level. This shows that she is knowledgeable of the vertical and horizontal progression. She also made appropriate content elaboration to the national curriculum by adding learning objectives and action verbs that would help achieve lesson goals. Her lesson objectives included: define pollution and list some pollutants, list the causes and effects of air pollution, and describe the greenhouse effect and list its consequences. In her PCK in action, the teacher showed to be moderate. She explained concepts in relation to the curriculum and what would be on the exams. She also related the specific lesson objectives to what the students had already learned and would learn during instruction. However, she gave explanations without adding any ideas that transcended the levels of conceptual understanding to ensure deeper understanding.

Researcher: Why did you decide to avoid explaining how the chemical structure affects the heat trapping ability of the greenhouse gases? Don't you think that if the students don't understand the process well then it would hinder their understanding and lead to a misconception?

ET2: I wanted to avoid going into details so that we don't waste time on something that is not required in their curriculum… (Teacher, ET2, Int.3).

Moreover, when asked why she did not use the audio when playing the video, she replied, "It contained additional ideas that I didn't want the students to know about since it is not in the curriculum" (Teacher ET2, Int.2). In her PCK in reflection, the teacher showed a proficient level of performance. When asked to reflect on the current Chemistry content curriculum for the lesson on air pollution and the greenhouse effect, she replied:

The verb "recognize" in this objective [to recognize the effects of pollution] is not clear at all… I feel this is not enough for the students at this level to know about only…. I t should be written as "describe" or "list" or "compare" for instance. These action verbs are not even found in bloom's taxonomy. The objectives need modification so that the teacher knows exactly what to teach the student for the national examinations. (Teacher ET2, Int.3).

She reflected on the fact that in grade 9, she only needs to explain concepts that are aligned with the curriculum. She said that she left the difficult concepts out of the topic since they were not included in the curriculum to begin with.

In the fifth dimension of PCK, knowledge of the orientations, the teacher demonstrated a proficient level in general in all of the three PCK categories. In her PCK while planning, it was apparent that design of the lesson was aligned with the

lesson goals. Moreover, and during instruction, whenever she came across any of the concepts of the greenhouse effect and global warming, she emphasized them to indicate their importance to her students. By the end of the lesson, students were expected to have covered all objectives smoothly. In her PCK in action, she demonstrated proficiency through her smooth transition between objectives and her organized and connected ideas. Moreover, her questions during class discussion were conducive to reaching the lesson goals. In her PCK in reflection, she reflected on the design of her plan to achieve the goals (related to the greenhouse effect vs. pollution), but thought that time is the only factor that could guarantee a smooth transition from one objective to the other.

> *Researcher: Was there a smooth transition from one objective to the next? How would you change the sequencing of your lesson for next year?*
>
> *ET2: Yes to a certain extent…If I had more time I would have let the students elaborate more on their answers to the worksheet. I would also be able to give them more feedback and address their misconceptions right away….for next year, I would place group activity to be revolved on the greenhouse effect and not on pollution to focus more on the new concepts (Teacher ET2, Int. 3).*

For the knowledge of the assessment the sixth dimension of PCK, the teacher showed in general a moderate level of performance. In her PCK in planning, although she wanted to resort to two types of assessment (oral/discussion and written worksheet) that were aligned with the lesson goals, the questions did not assess deep understanding of the concepts as they belonged to Level one and two of Bloom's Taxonomy (Knowledge and Comprehension). For instance, one of her questions in the worksheet was to describe the process of the greenhouse effect in the students' own words. When

asked why she did not incorporate questions from a higher level of Bloom's taxonomy, she replied: "The type of questions, in the national Brevet exams, that asses the ideas in this lesson are not critical thinking questions so the student is only required to know the causes of pollution and its consequences" (Teacher ET2, Int.1). In her PCK in action, the teacher expressed a poor performance level. Even though the class discussion was vibrant and involved a lot of student interaction, the teacher's questions belonged to the first level of Bloom's taxonomy (Ex. list, define, describe…etc.). Moreover, the students were not asked to summarize or deduce the content in the video they watched. Instead, they were only asked to recall what they had seen, without giving any deep explanation. Upon construction of the CoRe matrix, the teacher argued for using several assessment methods (formative and summative), but she mentioned that she would not incorporate many questions on this topic since it is not well covered in the high-stake Brevet assessment. She showed a moderate level in terms of her PCK in reflection as well. Although she reflected on the importance of assessing student understanding, by stating that "the students' abilities can force you to do changes such as putting a different assessment" (Teacher ET2, Int.3), she did not suggest questions that would involve the students' deep comprehension of the concepts. A summarized profile of ET2's PCK is summarized below in Table six. The overall PCK (taking into account the horizontal and vertical levels) puts ET2 in the Moderate category.

Table 6

PCK Profile for ET2

PCK Element	PCK in Planning	PCK in Action	PCK in Reflection	PCK Category
Knowledge of the content	**Moderate** Although she demonstrated an appropriate understanding of the greenhouse effect and gave only 4 real-life examples about the greenhouse effect consequences, she provided a list of solutions to decrease such effects and used a video for additional information.	**Moderate** Although she showed a deep understanding of the concepts, she did not elaborate enough on the real-life implications of the greenhouse effect.	**Poor** No reflection was provided	**Moderate**
Knowledge of the topic specific instructional strategies	**Moderate** Although the teacher used a semi-student-centered approach where students engage in discussion, watch a video, and work in groups, she was the one who gave the explanation and presented them with the "correct answers". She planned to start from their prior knowledge (pollution) and then explain the analogy…etc.	**Moderate** A semi-student-centered approach was implemented. Although the teacher engaged the students through group discussion on pollution and its effects in general, wrote answers on the boards, and gave feedback, she was the one who still did most of the work in terms of explanation.	**Moderate** Although the teacher reflected on students working in groups, she saw that she did it the right way when she was the one doing the explanation. Additionally she did not play the video with sound, fearing that the background narration would be too difficult for her students to understand, since it contained "difficult ideas".	**Moderate**
Knowledge of students	**Poor** Although the teacher mentioned	**Moderate** Although the teacher started with	**Moderate** Although the teacher reflected on	**Moderate**

	students' prior knowledge (ex. they already know about pollution), she did not provide an extensive list of difficulties or misconceptions students might have.	refreshing students' prior knowledge about pollution through the group activity, she did not encourage students to demonstrate their prior knowledge (show misconceptions about *greenhouse effect*, since she believed they know nothing about it). She took it for granted that they know nothing about the topic.	the importance of starting from students' prior knowledge, she was unable to showcase misconceptions and difficulties and tried to justify by saying she'll deal with any emerging ones due to instruction in upcoming sessions (or to be answered in different subjects). Moreover, she thought one way to avoid misconception was to ask the students to forget about it.	
Knowledge of the curriculum	**Proficient** The teacher knew that the topic was covered in grades five & seven, and therefore based her lesson on this fact (vertical) and horizontal transgression. Made appropriate content elaboration by adding learning objectives and action verbs that would help achieve lesson goals.	**Moderate** She only explained things in relation to the curriculum and what would be on the exams, without adding any ideas that transcend the levels of conceptual understanding and ensure deeper understanding. She did relate the objectives explicitly of the lesson to what students have learned/will learn during instruction.	**Proficient** She reflected on the fact that in grade nine, she only needs to explain material that is aligned with the curriculum. She only left out difficult concepts that are not included in the curriculum to start with. Made appropriate content elaboration as the existing national curriculum objectives are very vague.	**Proficient**

Knowledge of the orientations	**Proficient** The design of the lesson was aligned with the goals. By the end of the lesson, students were expected to have covered all objectives smoothly.	**Proficient** The transition between the objectives was smooth, as her ideas were organized and connected. Her questions during class discussion were conducive to reaching the lesson goals.	**Proficient** She reflected on the design of her plan to achieve the goals (related to greenhouse effect vs. pollution), but thought that time is the only factor that guarantees a smooth transition from one objective to the other.	**Proficient**
Knowledge of the assessment	**Moderate** Although she wanted to resort to two types of assessment (oral/discussion and written worksheet) that are aligned with the lesson goals, the questions/objectives did not assess deep understanding of the concepts (Level one & two Bloom's Taxonomy)	**Poor** Although the discussion was vibrant, involving a lot of student interaction, the questions asked by the teacher belong to the first level of Bloom's taxonomy (Ex. List, define, describe…etc.)	**Moderate** Although she reflected on the importance of assessing student understanding, she did not reflect on administering other types of assessment (other than discussion) in upcoming sessions to reach her goals and a high level of understanding (Bloom's Taxonomy one & two).	**Moderate**
PCK Category	**Moderate**	**Moderate**	**Moderate**	**Moderate**

Analysis of PCK for Experienced Teacher 3 (ET3) (TD holder)

Teacher ET3 has a total of 12 years of teaching experience. Her educational background includes a bachelor degree in Biology, a master's degree in biochemistry and a teaching diploma. ET3 started her lesson about the greenhouse effect by orally listing the objectives of the lesson. Next, she asked the students to follow a 3 minute video that shows how humans are currently negatively affecting the environment through their daily activities. Then, she asked the students to work in groups and write down what they already know about global warming and greenhouses on a t-chart that she had already prepared. Later on, she asked one group to present what they had written on the cardboard to the whole class. After that, she asked them to pay attention to the second video that explains the process behind the greenhouse effect and illustrates several real-life implications of this environmental issue. She made several stops throughout the video to explain each concept that was being depicted. After that, the teacher asked the students to explain what they understood from the video. This was followed by a lecture-based approach, where the teacher drew a diagram on the board to explain the greenhouse effect in her own words. Also, she listed several real-life implications that are currently occurring in Lebanon and the nearby countries. Finally, she asked the students to go back to the t-chart and write down what they understood about global warming and the greenhouse effect post-instruction. She then asked a different group to come up and compare their knowledge pre- and post-instruction. Even though the teacher tried to implement a student-centered approach, she did not encourage other groups of students to participate in class discussions. She was not even passionate about engaging the students in reflecting on whether they changed their current conception about the greenhouse effect and global warming. Moreover, she did

not make sure while checking each group's work whether they are filling the t-chart correctly or whether the term "greenhouses", mistakenly used in the t-chart, hindered their understanding of the greenhouse effect.

For the first PCK dimension, the knowledge of the content, in general, ET3 shows a moderate level of performance. In her PCK in planning, the teacher showed a moderate PCK performance level as she demonstrated an appropriate understanding of the greenhouse effect by mentioning both its negative and positive aspects but only giving four real-life consequences of the topic that included: extreme weather incidents, a rise in sea level, flooding and frequent droughts. However, when the researcher asked her about the type of radiations involved in this environmental issue, she replied: "This is not part of the chemistry subject…it is part of physics and I am not a specialist in physics" (Teacher ET3, Int. 1). This shows that the teacher does not have a deep understanding of the mechanism that leads to the greenhouse effect Moreover, when she was asked why is it important for the students to learn about these concepts, she answered, "It is related to our lives…and it is good for our general knowledge" (Teacher ET3, Int.1). It appeared that teacher ET3 could not appreciate the meaningfulness of the content of her lesson in relation to real-life applications. In her PCK in action, the teacher also demonstrated a moderate knowledge level as her explanation was based on video and her own knowledge and more than eight real-life applications were presented to the students. However, she did not demonstrate a deep understanding behind the consequences of the greenhouse effect she only listed them as to the students without explaining the relation between the rise in the earth's temperature and the extreme climate shift. In her PCK in reflection, the teacher mentioned that there are some concepts related to physics and geography that she can't

explain as she is not a specialist (i.e. climate change); therefore she will only list them to the class without any explanation. When asked why she limited herself to this amount of knowledge in class, she replied: "It is enough for the students…even the curriculum tells us that we don't have to explain more than this" (Teacher ET3, Int. 3).

In the knowledge of the topic specific instructional strategies, the second PCK dimension, the teacher shows a moderate level of knowledge. In her PCK in planning, however, she proved to be proficient as she planned to divide students into groups and engage them in discussion, filling in the T-chart, correcting their and others' ideas, and acting as a guide by interfering whenever necessary. This implies that she planned to implement a student-centered approach as the students will themselves work in groups to construct their own meaning of the greenhouse effect and global warming. Even though ET3 proved to be proficient in planning, her PCK in action only reached the moderate level of performance. Her approach was basically semi-student-centered. Even though students were engaged and the discussion was vibrant in their groups as they filled in the chart to elicit any prior knowledge/misconceptions, and correct their own knowledge, the rest of the time was left for the teacher's explanations and re-iteration of the concepts. Some students still found the video to be confusing, so the teacher had to reiterate what the video said by drawing a diagram on the board to explain how greenhouse gases trap the heat energy in the atmosphere. ET3 gave appropriate and reasoned uses of her instructional approaches when interviewed before and after her session plan:

> *This T-chart will help explore the students' prior conceptions or misconceptions to tackle them during the lesson (Teacher ET3, Int.1) this video helps the*

students to understand the relationship between the greenhouse effect and global warming as the diagram is very simple and audio is clear….the t-chart helped to compare their conceptions before the lesson and after…they realized that they learned something new… (Teacher ET3, Int. 2).

However, in action, she did not use these approaches in an efficient manner. Whenever she asked the students to reflect on the videos, she did not elaborate on their answers and rushed into the second part of the lesson where she asked them to finish filling the t-chart and adjust their current conceptions. Moreover, the t-chart was confusing as the title had "greenhouses" instead of the "greenhouse effect". Her lesson plan did mention that she was planning to check what the students know about the greenhouse effect. This could have possibly led to a misconception where the students might think that global warming is caused by greenhouses and not by the greenhouse effect. The teacher could not spot her mistake during the session when she was roaming around the different groups. However, in her PCK in reflection, ET3 showed a moderate level of knowledge in instructional strategies. Although the teacher planned that the students themselves construct their own meaning through a group work activity, and started from what the students know to design her lesson, she still believes that the student can understand the lesson better through re-iteration or when she does most of the explanation at the beginning of the lesson. She claimed, "I did not stress enough on the meaning of global warming and the greenhouse effect…I should have removed one of the videos to use the extra time for more re-explanation" (Teacher ET3, Int.2). Moreover, despite the large class size, the teacher wanted to encourage students to explicitly state their views on the topics as a first step in designing her lesson. She

learned about the meaning of student-centered approaches while she was earning her teaching diploma.

She noted: “I took several courses in AUB when I was earning my TD on several student-centered approaches and their importance” (Teacher ET3, Int.3). Moreover, she believed that such activities can only work if enough time is given in the curriculum as she stated:

> *[…] Next year… I would disregard the t-chart because it needs a lot of time…I cannot ask all groups to come up and present to the whole class. …I have done many workshops on how to do group activities but sometimes I worry about the time especially if I always give the floor for students to build their own meaning” (Teacher ET3, Int. 3).*

Moreover, Teacher ET3 did admit that she used the wrong title in her t-chart and she should have asked the students to change the title "greenhouses” to “greenhouse effect”. She said, “I realized now that the students are still confused between the meaning of greenhouses and greenhouse effect” (Teacher ET3, Int. 3).

As for the third domain of PCK, teacher ET3 appears to have a moderate knowledge of students’ learning in general as she showed moderate level of knowledge in all PCK categories: planning, action and reflection. In her PCK in planning, although the teacher mentioned students’ prior knowledge, for example: they should already know about pollution; the role of greenhouses greenhouse effect is related to plants (Teacher ET3, lesson plan) and explained possible origins (news), she did not provide an extensive list of difficulties or misconceptions students might have. Her Core matrix included: global warming and greenhouse effect are the same thing; greenhouses lead to the greenhouse effect. Indeed, teacher ET3 acknowledged the necessity of building

on students' prior knowledge. This was evident in her decision to address a common misconception in her t-chart, thus recognizing the fact that instruction must be initiated from where the learners are. However, she only addressed two misconceptions that the students might have, which indicates that she has a moderate knowledge of her students' learning. In her PCK in action, although the teacher started her lesson by refreshing students' memories (prior knowledge), she did not address misconceptions the students might have developed before or during instruction. Though she did refer to one group's explanation to initiate her discussion, she did not attempt to address the explanations written by the other groups so as to challenge their misconceptions (if they had any). Furthermore, whenever she noticed students were struggling to understand the greenhouse effect, she only kept reiterating her explanation of the concept throughout the whole session. Teacher ET3 showed a moderate level of knowledge in terms of PCK in reflection for even though she reflected on a few difficulties the students had that hindered understanding (e.g. using greenhouse vs. greenhouse effect), she did not address possible misconceptions (e.g. related to ozone layer) right away, due to the lack of time:

> *I realized that the students were confused… some put down the role of greenhouses in farms and not a description of the greenhouse effect which is affecting our earth* [...] *I didn't want to waste time on something [ozone layer] that is not directly related to the greenhouse effect (Teacher ET3, Int.3).*

Moreover, she was not able to understand why her students struggled with the lesson during the session. She believed the problem was due to a lack of reiteration. . When asked how she handled these misconceptions during the session, she answered, "I

believe when you provide the correct explanation several times, it would change the students' misconceptions" (Teacher ET3, Int.2).

Teacher ET3 has a moderate knowledge of the curriculum in general. In her PCK in planning, she showed a proficient level, as she was very knowledgeable about the horizontal and vertical transition to a certain extent across the disciplines:

> *It is an interdisciplinary topic…students have learned about it in their English language class in grade 7…grade 6 students took about the definition of pollution, its effects and its causes in Science… In geography, grade 8 take about the effects of global warming, however at the secondary level, they only learn about it in grade 9 only (Teacher ET3, Int.1).*

Moreover, she views the curriculum as something to be entirely dictated by the coordinator and the national chemistry textbook. However, the current national curriculum is very shallow in terms of content and therefore she does not refer to it when formulating her lesson plans.

> *The national Brevet curriculum of grade 9 is very big but shallow at the same time. I rarely refer to it…I know what to teach from my coordinator and from the national textbook…even the national textbook does not mention any objectives for the teacher (Teacher ET3, Int. 1)*

While developing the CoRe for this lesson, teacher ET3 demonstrated proficient PCK as she decided to anchor her lesson around two major ideas. The first was to "define the greenhouse effect" (CoRe). The second was focused on the comparison between the greenhouse effect and global warming, with the aim of addressing a frequent misconception. Informed by her session, she argues that this idea is important as she noticed that, "students will not understand global warming without understanding first

how the greenhouse effect occurs" (Teacher ET3, Int.3). Therefore, she made appropriate content elaboration in relation to the curriculum. However, she did leave out some aspects of the lesson that could impede the students' understanding, such as the role played by ozone gas in the atmosphere, which shows a moderate level of PCK in action. No data was given by the teacher in reflection on the knowledge of the curriculum which categorized her as having a poor PCK in that aspect.

In general, teacher ET3 has a moderate knowledge of the orientation to teaching about the greenhouse effect global warming. The goal of her lesson as it figures in the lesson plan was to teach about the process of the greenhouse effect. However, her planning sequence revealed that her goal was two-fold; she wanted to address a misconception about global warming and the greenhouse effect in addition to introducing new content. She explained that addressing the misconception was a minor goal, as the main purpose of the teaching is the explanation of the process of the greenhouse effect and its several consequences. Her sequence was based on using a group activity that actively engages the students in alignment with her objective to challenge students' thinking. She also planned to use students' explanations as a place to initiate instruction of the new content; as such, her planning sequence was aligned with her goals and she proved to have proficient PCK. Nonetheless, while teaching, she was struggling with time needed to complete the whole activity and she failed to smoothly manage the transition from the first part of the group activity discussion to the video that explains the greenhouse effect (the new content), an act which portrays a moderate PCK. In her PCK in reflection, even though the transition from one objective to the next was not particularly smooth, the teacher was able to identify what went wrong during the group work activity. She noticed that students were disoriented and

could not change their conceptions even after instruction and the t-chart activity. She still thinks that such activity is less beneficial to the student than her direct explanation of the concepts as the t-chart activity did not help her reach lesson goals. ET3, however, was able to reshape her goals and acknowledge that each of the lesson goals would need to be tackled separately. As such, she restructured her lesson while focusing on addressing the misconception which shows a moderate PCK performance level in terms of reflection.

> *I set so many goals for the lesson which is only a 45 minute period…I should have made sure that the students understood what the greenhouse effect means by guiding their thinking before asking them to fill the t-chart…I must give them more time to elaborate on their answers (Teacher ET3, Int.3).*

Teacher ET3, in general, has a moderate level of knowledge about assessments, the last dimension of PCK. In her PCK in planning, the teacher planned to use two assessment tools that include classroom discussion and group work activity t-chart. The tools were planned to be administered at the proper time and place of instructional sequence of events, which shows moderate PCK level of performance. However in her PCK in action, having students participate in discussion and actively write their conceptions on the t-chart cardboard was not sufficient to measure or correct student understanding and many students were still confused after the lesson. Only one group out of six was asked to present to the class, less than a quarter of the class. Moreover, the teacher's questions were mainly about recalling what was being shown in the videos. There were no questions that led to critical thinking, as they were mainly based at the knowledge and comprehension level of Bloom's taxonomy. In her PCK in reflection, although the teacher believed that the students themselves should correct

their own misconceptions, she acknowledged that she needs to check the responses for the other groups that were involved in the activity and further assess whether the students understood the concepts through a quiz or test. Still, she did not suggest tools that ensure deep understanding for students by using questions that include higher levels of Bloom's taxonomy.

> *[…] …of course… only those who participated understood but I cannot know if each one in the class understood. I don't have the time. I can't depend entirely on it [t-chart] I need to assess the students in other ways too. I guess I rushed through it because I was worried about the time. Hopefully, in the following sessions, I will ask more questions in class and maybe give them a drop quiz (Teacher ET3, Int. 3*).

A summarized profile of ET3's PCK is summarized below in Table seven. The overall PCK (taking into account the horizontal and vertical levels) puts ET3 in the Moderate category.

Table 7

PCK Profile for ET3

	PCK in planning	**PCK in action**	**PCK in reflection**	**PCK category**
Knowledge of the content	**Moderate** She mentioned both positive and negative aspects to the greenhouse effect, its multidisciplinary nature, and only 4 consequences on daily life.	**Moderate** Explanation was based on video and her own knowledge, with more than 8 applications to real life presented to the students. However, she did not show deep understanding behind the consequences of the greenhouse effect as they were only listed to the students.	**Poor** The teacher mentioned that there are some concepts related to physics and geography that she can't explain as she is not a specialist (e.g. climate change) therefore she will only list them to the class without any explanation.	**Moderate**
Knowledge of the topic specific instructional strategies	**Proficient** Student-centered approach, as the students will themselves work in groups to construct their own meaning of the greenhouse effect and global warming by filling a t – chart that takes into account their prior knowledge. Moreover, the teacher planned to engage the students in discussion through the type of questions that she will ask by referring to 3 videos.	**Moderate** Semi-student-centered. Even though one group of students presented the change in their conceptions to the whole class, she did not share their answers to the t-chart; the rest of the time was left for the teacher explanations and re-iteration of the concepts.	**Moderate** Although the teacher planned that the students themselves construct their own meaning through a group work activity, and designed her lesson based on what the students already knew, she still believes that the student can understand the lesson better through reiteration or when she does most of the explanation at the beginning of the lesson. Moreover,	**Moderate**

			she believed that such activities can only work if enough time is given in the curriculum. She acknowledged the t-chart misuse.	
Knowledge of students	**Moderate** The teacher mentioned only two misconceptions that the students might have. She took into consideration the student's prior knowledge while planning for the lesson.	**Moderate** Although she explained to the students as to why she was using these specific instructional tools, and tried to uncover the students' prior conceptions of the greenhouse effect consequences, she did not use it to build her explanations. Moreover, even though she noticed students were having difficulties in understanding the greenhouse effect, her response to this perceived gap was to continue to reiterate her explanation throughout the whole session. She used illustrative tools but not efficiently.	**Moderate** Although the teacher reflected on a few difficulties the students had that hindered understanding (e.g. using greenhouse vs. greenhouse effect) she didn't address possible misconceptions (e.g. related to ozone layer) right away, due to the lack of time.	**Moderate**
Knowledge of the curriculum	**Proficient** Although she was knowledgeable about the horizontal and the vertical transition to a certain extent, because the national curriculum is very shallow,	**Poor** She started her lesson by referring to what the students had previously learned about pollution. She verbally mentioned the objectives that	**Poor** No reflection was given by the teacher.	**Moderate**

	content-wise, she understands the curriculum as something to be entirely dictated by the coordinator. She made appropriate content elaboration by adding the objective of comparing between greenhouse effect and global warming, since it's a frequent misconception held by students.	were supposed to be aligned with those of the curriculum but she did not relate the objectives explicitly of the lesson to what students have learned/will learn during instruction.		
Knowledge of the orientations	**Proficient** The design was aligned with the lesson goals. There was a smooth transition between the objectives.	**Moderate** Although the teaching sequence was aligned with the lesson goals, the strategy behind the t-chart was not handled correctly (rushed through it) as many of the students did not change their original conceptions after instruction.	**Moderate** Even though there was a smooth transition from one objective to the next and the teacher could identify what went wrong during the group work activity, she continues to think that such an activity is less beneficial to the student than her direct explanation of the concepts as it didn't help her reach lesson goals.	**Moderate**
Knowledge of the assessment	**Moderate** Used several assessment tools that include classroom discussion and group work activity t-chart. The tools were planned to be administered at the proper time and place of instructional sequence of events. Questions based on	**Moderate** Although two assessment tools (class discussion and t-chart) were used to assess the students understanding, they still were not enough to ensure that all students achieved a deep understanding of the concept. This is because only	**Moderate** Although the teacher believed that the students themselves should correct their own misconceptions, she acknowledged that she needs to check the responses for the other groups that were involved in the activity and further assess	**Moderate**

	Bloom’s level one & two.	one group out of six was asked to present to the class. Moreover, the teacher's questions were mainly about recalling what was being shown in the videos. There were no questions that lead to critical thinking.	whether the students understood the concepts through a quiz or test. Still, she did not suggest tools that ensure deep understanding by using questions that include higher levels of Bloom’s taxonomy.	
PCK Category	**Proficient**	**Moderate**	**Moderate**	**Moderate**

Analysis of PCK for Novice Teacher 1(NT1) (non-TD holder)

NT1 has only one year of teaching experience. Her educational background includes bachelors and a master's degree in Chemistry. NT1 started her lesson by mentioning that the lesson will address an issue related to air pollution that is jeopardizing our life on earth. Then, she asked the students to pay attention to the video being shown without stating either the specific lesson's objectives or the purpose of the video. She made two stops during the screening of the video to ask the students to explain what they understood about the greenhouse effect. The level of participation was very low, which forced the teacher to explain the process behind the greenhouse effect herself, using the diagram depicted in the video. Next, she addressed the sources of greenhouse gases by first referring to Carbon Dioxide to make students participate in a familiar topic. She elaborated on a couple of students' answers and tried to use these responses to build her explanation and to move from one objective to the next. After that, she reiterated the main ideas once more by using the analogy between greenhouses and the greenhouse effect. She moved back and forth between the ideas while trying to encourage her students' participation. Later, she tried to elicit real-life consequences from the students that would result from such a phenomenon that are occurring in Lebanon. After, she tried to explore what the students knew about different ways to reduce the greenhouse effect. Finally, after she summarized the main points of the lesson, she asked the students to imagine that they were part of an awareness campaign and would want to present to the class a short summary about the dangers of the global warming and the different ways to reduce it. It was apparent that the teacher was determined to engage the students in class discussion and encourage them to participate

as she tried to target most of the students in the class. Moreover, she frequently kept asking whether the students understood her explanation throughout the lesson.

Teacher NT1 has a moderate knowledge of the content in general. In her PCK in planning however, she showed a deep understanding of the greenhouse effect:

> *Radiant energy coming from the sun is absorbed by the Earth's surface and not reflected… this absorbed energy is re-radiated outwards from the Earth in a different form … no longer as light, but as thermal radiation. The CO2 molecules and other greenhouse gas molecules absorb the heat radiation and release it again in all directions…Thus they slow down the escape of the heat energy into space. The increase in concentration of the greenhouse gases due to human daily activities leads to an issue known as global warming…this phenomenon has several life-threatening implications (Teacher NT1, Int.1).*

Moreover, she listed more than 6 real-life examples in her lesson plans which include: flooding, redistribution of rainfall over various continents, melting of polar ice caps, frequent droughts, plant and animal extinction, and soil erosion (Teacher NT1, lesson plan). When asked how she knew about the aforementioned information, she responded, "We took a course in college called Environmental Science when I was majoring in chemistry back in university" (Teacher NT1, Int.1). NT1's PCK in action also showed a proficient knowledge level as her explanation was based on a National Geographic video (a very reliable resource) and her own knowledge. However, she did not reflect on her knowledge of the content, which showed that she has a poor PCK in reflection on her knowledge of the content to teaching the greenhouse effect.

Teacher NT1 has a poor knowledge of the topic-specific instructional strategies (domain two) in general. Her PCK in planning seemed to be at the moderate level of

knowledge as she planned a semi-student-centered approach where even though she will lead all class discussions it is the student who will come up with his explanation based on the video. However, although she mentioned some entrance abilities for the students in her lesson plan, her lesson plans' procedure did not reflect this which puts her in the moderate category. Her PCK in action showed a poor knowledge of instructional strategies as her approach was entirely teacher–centered. Although she used multimedia to engage the students and enhance their understanding, she did not use it as a cognitive tool or give a valid reason to the students for the purpose of its use as she stated, "I want to change the students' mood since I am always the one giving them the information" (Teacher NT1, Int. 2). However, in action, the student participation was very low when the video was over. When asked for the reason for the passive student behavior, NT1 could not give a valid reason, as she claimed that the students are not used to watching videos and in chemistry they participate more when there are application questions. Even when she used the analogy between greenhouses and the greenhouse effect, it was handled in a restricted way. She did not give the students a chance to deduce the relationship between the concepts. She preferred to the do the explanation herself when using it. Moreover, even though she made an instant decision to incorporate a presentation by the student to increase their participation, only one volunteered as the rest seemed to be unmotivated to be mentally engaged. When asked why the students looked lost after 20 minutes of her explanation and use of video, she replied:

> *I think they did not understand the content of the video though I am sure they have no language barrier…the video was really simple…I do not know actually why they were not participating…Maybe I should have told them that there will*

be graded questions related to my explanation and the video…I should have prepared a worksheet or any other activity related to the lesson (Teacher NT1, Int. 2).

Even though NT1 was planning to help the students deduce the meaning themselves from the video and elicit their ideas to build on them, she did not provide them with meaningful cognitive activities and instead used the video as a display tool. She did not even provide them with a worksheet that would engage their thinking or help them relate the concepts that they are exposed to in the session. Moreover, she did not orally mention or write on the board the lesson's objective, which made the students feel lost and caused their thoughts to be unorganized. Her planned approach tended to go towards a teacher-centered strategy in action. Teacher NT1's PCK in reflection on her teaching episode portrays a poor knowledge of how to use instructional strategies effectively for she was not able to take a critical stance toward her teaching and correct it adequately:

Some talked about the ozone layer…later I went back to this idea when M. told me she wasn't convinced…but the role of the ozone I did not explain because initially I did not understand what she meant…but I did not ask her to elaborate on her answer as I did not want to waste time… (Int.2); I should have helped her come up with the correct explanation…but I think it is better to re-explain the lesson again in the coming session just to make sure that those students understood the lesson and give them a worksheet to solve (Teacher NT1, Int.3).

In summary, although teacher NT1 realized that she needs to engage the student's thinking by preparing a worksheet and asking more questions, she still insisted on

doing the explanation herself instead of the students which put her at the poor level of PCK in reflection.

As for third domain of PCK, teacher NT1 appears to have, in general, a poor PCK in the knowledge of students' learning. Her PCK while planning seemed to be poor because although she related the lesson to real-life examples and only mentioned one misconception - the difference between the greenhouse effect and global warming (Teacher NT1, CoRe) - she did not describe any student difficulties or take potential difficulties into account while planning the lesson. Additionally, she did not anticipate the underlying reasoning such misconception, stating "The students hear about these two phenomena a lot and they fail to separate between both" (Teacher NT1, Int.1). Correspondingly, she was not aware of the many ways to overcome this misconception: "I would ask a student to explain it to his fellow student or I will re-explain the difference between the two phenomena again" (Teacher NT1, Int. 1). Her PCK in action also showed to be poor as her approach was completely teacher-centered and she did not give enough reasons to the students as to why she was using the video. Even though she did identify one misconception that the students might have, she kept reiterating her explanation throughout the whole session. In addition, although she tried to uncover the students' prior conceptions of the greenhouse effect consequences, she did not use it to build her explanations. Upon reflection of her knowledge of the students' learning though, NT1 appeared to be at the moderate level. Even though she realized the importance of immediately addressing misconceptions, she was able, to a certain extent, to explain why students had difficulty understanding the lesson even after incorporating an engaging activity (She asked them to present a small speech about the dangers of global warming) that was unplanned:

> *I think the students were lost as the ideas given by me were not connected or organized and might have confused them…I also did not give the students enough time to comprehend the concepts well…I kept moving back and forth in my ideas thinking that this way they would understand it better through re-iteration (TeacherNT1, Int.3).*

When asked why she decided to include an activity towards the end of the lesson, she replied, "I was frustrated how the students were not participating and I wanted to come up with something instantly to engage them more" (Teacher NT1, Int. 2). This implies that NT1 did realize during the session that she needs to further involve the students' thinking and she later reflected that she should have planned this involvement from the beginning. This puts her at the moderate level in PCK reflection.

Teacher NT1 has a poor knowledge of the curriculum in general. Her PCK in planning appeared to be poor as she was knowledgeable about the objectives of the curriculum but she was not aware of the vertical and horizontal progressions. She said, "I am not sure when they took the definition of pollution and its effect, but I think somewhere in the elementary level" (Teacher NT1, Int.1). Moreover, she did not make appropriate content elaboration in relation to the curriculum, as she reasoned that the type of questions that address this topic in the Brevet examinations require a shallow understanding of this topic. Therefore, she determined that she does not need to add to or change the content found in the chemistry books. In her PCK in action, she appeared to have poor knowledge. Even though she started her lesson by referring to what the students learned in middle school about pollution, she did not verbally mention the objectives that were supposed to be aligned with those of the national chemistry

curriculum, or write them on the board. Moreover, she did not provide any reflection on her knowledge of the curriculum, which puts her at the poor knowledge level.

Overall, teacher NT1 has a moderate knowledge of the orientations to teaching about the greenhouse effect. She appeared to have moderate knowledge in her PCK while planning as although she presented clear and defined goals and her sequencing was conducive to the lesson goals, she was not able to clarify how she would smoothly move from one objective to the next. In action, her PCK appeared to be poor as she misused the incorporation of technology and she did not mention the lesson objectives verbally or in writing. As a result, she failed to foster conceptual understanding which was evident in the students' level of participation. In her reflection, she noticed that the students were disoriented and could not follow the link between the video screening and the later explanation of the ideas later. Upon reflection, she suggested developing a more meaningful teaching sequence to reach her goals; however, the objectives were stated in a way that did not help the students completely achieve a high level of understanding:

> *I would start this lesson in a different way…first I would make the students watch a Lebanese news report about one of the consequences of global warming to grab their attention and make it more relevant to them…I would also state the lesson objectives on the board so that it is clear to them what they are supposed to achieve by the end of the lesson…I will put down a summary of notes for them to copy it down …I will ask them to write down a description of the greenhouse after I explain it to them to force them to pay attention and engage in discussion instead of sitting passively and listening to me (Teacher NT1, Int.3).*

Teacher NT1 has a moderate level of knowledge about assessments, the last dimension of PCK, in general. While discussing her lesson plan, she appeared to have a moderate level of understanding as she planned to rely heavily on using informal assessment (questioning through class discussion) and showed appropriate use of it in terms of time and place of its administration in the sequence. However, this was not enough to show that students' changed their current conceptions. Accordingly, her PCK while instruction of the session also showed a moderate level. While she heavily relied on using informal assessment as planned, she did not focus on assessing the one misconception (the failure to differentiate between greenhouse effect and global warming) that she mentioned in her CoRe and her lesson plan interview. Moreover, her questions (ex: list, describe, compare …etc.) were based only on levels one and two of Bloom's taxonomy which do not challenge the students' currently held misconceptions or even unveil traces of other misconceptions. Upon modifying her CoRe matrix, NT1 also reflected a moderate PCK as she suggested adding a quiz and a worksheet, aligned with the lesson goals to a certain extent, right after the video and her explanation. However, when asked the purpose behind these added assessment, she responded,

> *I want to see if they got the video…if I tell them that it is a graded worksheet or there will be a quiz by the end of the session, they will be more attentive…also it will help me check if they understood my explanation (Teacher NT1, Int.3).*

Additionally, when asked to suggest examples of questions that are the most important for her to ask the students, she replied, "I would ask them for instance to summarize what they saw in the video" (Teacher NT1, Int.3). NT1 did not realize the importance of taking into account students' prior knowledge or their misconceptions about the topic in her assessment tools. In addition, her questions are only based on Bloom's taxonomy

at the knowledge and comprehension levels which do not measure the students' deep understanding of the concepts. Therefore, this is indicative of a moderate level of PCK in the knowledge of assessments. A profile NT1's PCK is summarized below in Table eight. The overall PCK (taking into account the horizontal and vertical levels) puts NT1 in the moderate category.

Table 8

PCK Profile for NT1

	PCK in planning	**PCK in action**	**PCK in reflection**	**PCK category**
Knowledge of the content	**Proficient** Deep understanding of the concepts and listed more than four real–life examples.	**Proficient** Explanation based on video and her own knowledge. She stressed on real-life implications of the topic.	**Poor** No reflection was given.	**Moderate**
Knowledge of the topic specific instructional strategies	**Moderate** Semi-student-centered as she mentioned that even though she would lead the discussion, the students would come up with his or her explanation based on the video. Although she mentioned some entrance abilities for the students, she didn't use to build her lesson plan.	**Poor** Teacher–centered approach as she was doing most of the talking. Although she used multimedia to engage the students and enhance their understanding, she did not use it as a cognitive tool or give a valid reason to the students for the purpose of its use. Moreover, an instant decision was made to incorporate a presentation by the students to increase their motivation.	**Poor** Although she realized that she needed to engage the student thinking by preparing a worksheet, she insisted in doing most of the work as it guarantees complete student understanding of the concepts.	**Poor**
Knowledge of students	**Poor** Although she related the lesson	**Poor** Completely teacher-centered	**Moderate** Even though she	**Poor**

	to real-life examples and mentioned one misconception that she had during her education, she did not describe any student difficulties or take it into account while planning the lesson.	and did not sufficiently explain why she was using these tools to the students. Although she tried to understand the students' prior conceptions of the greenhouse effect consequences, she did not use it to build her explanations. Moreover, even though she noticed students were having difficulties in understanding the greenhouse effect, she only kept reiterating her explanation throughout the whole session. She used illustrative but not efficiently.	realized the importance of addressing misconceptions right away, she was unable to explain why students had difficulty understanding the lesson even after incorporating engaging activities that were unplanned.	
Knowledge of the curriculum	**Poor** Knowledgeable about the objectives of the curriculum but unaware of the vertical and horizontal progressions.	**Poor** She started her lesson by referring to what the students learned before about pollution but she did not verbally mention the objectives that were supposed to be aligned with those of the curriculum, or write them on the board. Or by writing on the board the objectives.	**Poor** No reflection was given.	**Poor**

Knowledge of the orientations	**Moderate** She presented clear and defined goals. Her sequencing was conducive to the lesson goals, but she was not able to clarify how she would smoothly move from one objective to the next.	**Poor** She misused the incorporation of technology. She did not mention the objectives of the lesson verbally or in writing. As a result she failed to foster conceptual understanding. This was evident in the students' level of participation.	**Moderate** Although she reflected on developing a more meaningful teaching sequence to reach her goals, the objectives were stated in a way that did not help the students fully achieve a high level of understanding.	**Moderate**
Knowledge of the assessment	**Moderate** Although she relied heavily on using informal assessment (questioning through class discussion), it was not enough to show that students' changed their current conceptions.	**Moderate** Although she relied heavily on using informal assessment (questioning through class discussion), she did not focus on assessing the misconception. Her questions were based only on levels one & two of Bloom's taxonomy.	**Moderate** Although she mentioned that short quizzes and worksheets could be added to assess the students' understanding right after her explanation, she did not mention questions that engage the students in critical thinking.	**Moderate**
PCK Category	**Moderate**	**Poor**	**Moderate**	**Moderate**

Analysis of PCK for Novice Teacher 2 (NT2) (non-TD holder)

The teacher, NT2 has a total of four years of teaching experience. Her educational background includes a bachelor and a master's degree in Chemistry. She started her lesson with a brainstorming activity on the definition of pollution and its effects on our environment. This was followed by a short video on the definition of the greenhouse effect and its consequences. A discussion followed the screening of the video to check for student comprehension of the process behind the greenhouse effect. Later, the teacher divided the students into three groups based on their academic performances and assigned different worksheets for them to solve. She wanted to implement differentiated instruction. Each group received a worksheet with questions that match the students' academic performance. The low achievers had a worksheet with questions in which they pick information from a diagram and a text. The second worksheet which was prepared for the next higher academic level group, posed questions about how Lebanon has been affected by global warming in the past decade and ways to reduce this phenomenon. The third worksheet, prepared for the highest achiever group, asked them to prepare a news report about the process behind the greenhouse effect, the definition of global warming, and real-life harmful effects of the aforementioned phenomena. All three worksheets had the same diagram and text that explained about the greenhouse effect, its causes, and its effects. Each group received a tablet to play the video again, in case they missed out something. A discussion followed to answer the worksheets' questions whereby a student from each group presented the answers that they came up with. Finally, the teacher provided a summary of the lesson's main points to the students. It was apparent throughout the session that the teacher was not passionate about using a new and different strategy (differentiated

instruction) as she was rushing when implementing it and she did could not see the benefits of letting the student construct meaning on their own.

Regarding the first dimension of PCK, knowledge of the content, the teacher showed an overall moderate level. In planning, the teacher demonstrated an appropriate understanding of the greenhouse and global warming concepts:

> *The greenhouse gases such as CO_2, CFCs, and NO_2 are causes of this effect. An increase in the concentration of these gases will cause a rise in the earth's temperature resulting in global warming. Global warming is the main consequence of such an effect which will lead to droughts, changes in climate and melting of the polar ice caps (teach NT2, Int.1).*

The teacher did not plan on addressing the positive effect of the greenhouse effect nor mentioned more than three implications of the greenhouse effect. She planned to refer to the video for real-life implications of the greenhouse effect and provoke class discussions. Moreover, her PCK was also moderate at the action level as she relied mainly on the video, her own knowledge, and class discussions, to illustrate the process and give numerous real-life implications (four-six examples) of the greenhouse effect. In action, teacher NT2 appreciates the meaningfulness of her lesson content in relation to its real-life applications. She mentioned in her CoRe matrix and pre-instruction interview several important reasons for studying this topic:

> *These gases are the result of activities done by humans…Students need to gain awareness of their role as future citizens on how to help reduce emissions of these gases. Some of these gases are found in our products that we use in our everyday life. Therefore, they need to understand the process behind this effect. Moreover, students need to know all the consequences because they are*

observable and a living proof of this effect which is the result of human action (Teacher NT2, Int.1)

Teacher NT2 showed poor PCK at the reflection level as she did not reflect, post instruction, on her knowledge of the content or its importance.

Teacher NT2 has in general a poor knowledge of the topic specific instructional strategies. In her PCK in planning she demonstrated a moderate knowledge level as she planned to use a student–centered approach that involved differentiated instruction. In action, she handled this approach inefficiently. Her plan was to use a tiered worksheet through which all learners could work with the same important understandings and skills, but proceed with different levels of support and complexity. However, the type of questions for the low achievers was not designed to engage their critical thinking. Even for the other groups, the tasks requested were not complex enough to challenge the conceptions they held about the greenhouse effect, its causes, and its consequences. Moreover, in her lesson plan, she did not take into account prior knowledge even though it was mentioned in the plan. She planned to use the video, but not as a cognitive tool as the students were only going to write down what was being mentioned. Even the diagram in the worksheets was used for the same reason. She claimed, "I want the students to extract the information in the video without my interference" (Teacher NT2, Int.1). In her PCK in action, NT2 demonstrated a poor level of knowledge as she gradually implemented a teacher-centered approach, in which she did most of the talking, especially right after showing the students the video. The way she used the video did not let the students construct their own meaning. The students were aware of the importance of the video, although she did not clarify it

sufficiently for them. When asked about the reason behind implementing differentiated instruction, she did not give a valid reason as she replied:

> *The coordinator is asking us to implement it …she showed us once how to implement it…this is only the second time that I tried it out with the students… it helps students from different levels to be engaged in their thinking (Teacher NT2, Int. 1).*

Moreover, she sat with the low achievers most of the time to re-teach all the ideas without trying to extend their thinking. The other groups were completely ignored. The following dialogue portrays how this teacher did not fully understand the reason behind differentiated instruction:

> *Researcher: If you were planning to give critical thinking questions only to the high achievers group, won't the groups be missing out something that can extend their thinking?*
>
> *NT2: maybe I can give them [other groups] the answers to the critical questions as additional information…as long as they all achieve the lesson objectives it is fine by me. I took into consideration their limited abilities (Teacher NT2, Int. 1).*

Even though the teacher did not to follow a "one size fits all" approach and wanted to adjust teaching and learning methods to accommodate each child's learning needs, she could have prepared the worksheet questions in a way that was more engaging and more challenging to the student's conceptions. In her PCK in reflection, NT2 also showed a poor level. Even though she suggested using heterogeneous groups instead of homogenous groups of the same academic level to allow for more efficient peer work, the teacher insisted that it was better to repeat elements of the lesson over and

over to make sure everyone understood. Moreover, she was not convinced that this method was appropriate for the students in this school as:

> *The system is built on spoon-feeding the students with knowledge so they are used to being so dependent on me…plus this is our second attempt to incorporate differentiated instruction so I think it will take time for the students to be able to work on their own and construct their meaning using a video or a worksheet …so it is just better when I do all explanation (Teacher NT2, Int.3).*

Regarding the knowledge of students, the fourth PCK dimension, NT2 has poor knowledge in general. In planning however, she showed a moderate knowledge level as she planned to do some brainstorming at the beginning of the session to assess students' prior knowledge and she mentioned two misconceptions in her CoRe matrix: that student might think that global warming is localized and that students might think that the greenhouse effect damages the ozone layer. In her PCK in action, NT2 showed a poor knowledge level because although she did some brainstorming to assess prior knowledge and connected it to previous lesson on types of pollution, she did not immediately address the misconception about ozone with one student. When asked the reason behind her actions, she replied, "I didn't want to waste time plus I wanted to stay focused on the objectives. The ozone layer depletion is not part of the lesson's objectives" (Teacher NT2, Int. 2). Even though she predicted in her CoRe matrix that students might have misconceptions about the ozone layer depletion and the greenhouse effect, she did not take into account students' prior conceptions nor did she dedicate time in her lesson to address this potential misconception. Even in her PCK reflection, the teacher showed a poor knowledge level as she did not acknowledge the

importance of addressing misconceptions right away. Moreover, she did not anticipate ways to handle students' misconceptions when she said:

> *I guess they weren't paying attention enough to the video or my explanation in class...so I have to repeat the ideas next session.... I will re-explain again in the following session to make sure everyone understood (Teacher NT2, Int. 3).*

Teacher NT2 has a moderate knowledge of the national curriculum in general. In her PCK in planning, she demonstrated an understanding of the topic within both the vertical as well as the horizontal curricula:

> *Students must have learned about air pollution, its causes and effects in elementary and middle school level especially in grade 8…they did not take however how the greenhouse effect happens…also, I am sure they took about global warming in the geography lesson… in grade 9, the students have to recognize the effects of pollution such as global warming, acid rain, and ozone depletion as mentioned in the curriculum…this is the whole curriculum for grade 9… they will not see it again in the higher levels (Teacher NT2, Int. 1).*

When asked if she modified any objectives in the curriculum and what her rationale was behind any modification, she replied:

> *I did not delete anything because the information in the curriculum is already shallow. I added a couple of objectives which is to describe the greenhouse effect and to list the its many consequences… the student would not understand why global warming is occurring without understanding first the greenhouse effect so I elaborated the content for this reason(Teacher NT2, Int. 1).*

NT2 made appropriate content elaboration in relation to the curriculum, which puts her at the proficient level in terms of planning. However, in action, even though she started

her lesson by referring to what the students had previously learned about pollution, she did not elaborate enough at a conceptual level to make the ideas more meaningful to the students. This indicates a poor PCK. In her PCK in reflection, NT2 showed a moderate level by saying:

> *The objectives in the national chemistry curriculum are confusing to the teacher and they are not skill-specific. The coordinator tells me what the students should learn in each lesson so I do not need to check the objectives in the curriculum especially that they are vague (Teacher NT2, Int.1).*

This means that NT2 views the curriculum as dictated to her by the subject coordinator and not as negotiated and written by teachers with the national curriculum as a guideline.

In general, teacher NT2 showed moderate orientations to teach the greenhouse effect (fifth dimension of PCK). In her PCK in planning, she was proficient as she planned to use differentiated instructions to cater to the needs of achievers at different academic levels. The lesson's design was aligned with goals and the sequence was conducive to reach the lesson goals. In her PCK in action, however, she showed a poor knowledge of orientation. This was evidenced by two main observations. First, her goals, although clear and defined, required low cognitive demands and thus were not tailored to foster a conceptual understanding of the topic. Indeed, implications of the greenhouse effect and the concept of global warming were not discussed in ways that made sense to students, even after discussing the answers on the worksheets given. Ultimately, students were supposed to memorize these for recalling in a quiz or a test. Second, she misused the differentiated instruction strategy. Although the sequence was ultimately conducive to reaching her goals, it was not a coherent structure as the

transitions from one activity to the next were hardly related (e.g. moving from the video to the group work activity). Her ideas were not organized and kept moving back and forth between objectives. In her PCK in reflection, NT2 proved to have a moderate knowledge of orientations. Although she emphasized the importance of the student understanding one objective before moving to the next, she failed to re-design her lesson plan to match the goals effectively.

Teacher NT2 has a poor knowledge of the assessment, the sixth dimension of PCK, in general. Regarding her PCK in planning, NT2 revealed a moderate knowledge of assessment. Even though she used two ways to assess the students (classroom discussion and a guided group work activity), the questions prepared for each group did not assess a deep understanding of the concepts and were based on the first two levels of Bloom's taxonomy (knowledge and comprehension). For example, the highest achieving students were asked to write a news report about the harmful effect of global warming and ways to reduce it using an online website which is basically asking them to rephrase the information found online. Had it been a "Q&A" conference then the class would not have been so passive during group presentation of the answers and the students would have been cognitively engaged in constructing meaning of the information found online. When asked why the students were so passive throughout the session, especially during the group activity, she replied: "I really think they didn't want to put any effort… they were passive and were only serious when I sat with them [low achievers group]... (Teacher NT2, Int. 2). For the other groups, the questions were not appropriate to their cognitive level as they did not require critical thinking. All the questions were based on levels one and two of Bloom's taxonomy (knowledge and comprehension), as they included action verbs such as list, define, explain, and

describe. In her PCK in action, NT2 showed a poor knowledge of assessment as the teacher was spoon-feeding the answers, particularly to the low achievers, instead of guiding them to construct meaningful responses. Class discussions involved questions that were addressed in a way to put words in the students' mouth. In her PCK in reflection, the teacher demonstrated a poor knowledge of assessment because even though she recognized that the worksheet was insufficient to measure student understanding, she did not offer alternative efficient assessment tools. When asked how she could change the worksheet for next year, she replied with a vague answer, "I would ask the questions in a different way…maybe I would ask the students to put in more details about what they understood" (Teacher NT2, Int. 3). This shows that the teacher had wanted to assess the quantity of the conceptions held by the students' rather than the quality, hence a poor PCK reflection on the knowledge of assessment. A summarized profile of NT2's PCK is summarized below in Table nine. The overall PCK (taking into account the horizontal and vertical levels) puts NT2 in the poor category.

Table 9

PCK Profile for NT2

	PCK in planning	**PCK in action**	**PCK in reflection**	**PCK category**
Knowledge of the content	**Poor** Appropriate definition because there was no mention of positive aspect. She will refer to the video for real-life implications of the greenhouse effect and through class discussions. She is only knowledgeable of only three real life implications.	**Moderate** She referred to the video and her own knowledge to illustrate the definition of the greenhouse effect, its causes, and its consequences.	**Poor** No reflection was given.	**Poor**
Knowledge of the topic specific instructional strategies	**Moderate** Student-centered approach/differentiated learning activity. She planned to integrate the students' understanding into instructional strategy but in a restricted way. Used the video for vague reasons.	**Poor** Teacher-centered approach as she did most of the talking. The questions were addressed in a way to put words in the students' mouth. The way she used the video did not allow the students construct their own meaning. The students were aware of the importance of the video (not sufficiently clarified).	**Poor** Even though she suggested using heterogeneous groups, the teacher kept emphasizing to keep on doing most of the explanation to ensure all students understood the concepts.	**Poor**
Knowledge of students	**Moderate** Brainstorming to assess prior knowledge. She mentioned two misconceptions (global warming is localized and	**Poor** Brainstorming to assess prior knowledge and connect it to previous lesson on types of	**Poor** Even after a student asked about the relation of the ozone layer to the	**Poor**

	confusion about ozone layer).	pollution. She did not immediately address a student's misconception about the ozone.	greenhouse effect, she did not give it much importance and she did not acknowledge the importance of addressing misconceptions right away.	
Knowledge of the curriculum	**Proficient** She was knowledgeable about the horizontal and the vertical transition to a certain extent. Also, she accounted for the objectives in the national curriculum, as evident in the lesson.	**Poor** She started her lesson by referring to what the students had previously learned about pollution.	**Moderate** The teacher showed good understanding of the curriculum even though the objectives were vague.	**Moderate**
Knowledge of the orientations	**Proficient** She planned to use differentiated instructions to cater for the needs of low achievers. Her lesson design was aligned with goals and sequence is conducive to reach goals.	**Poor** The teacher misused the strategy. Moreover, even though she stated the objectives on the board, her ideas were not organized and moved back and forth between objectives.	**Moderate** Even though she emphasized the importance of the students understanding one objective before moving to the next, she failed to re-design her lesson plan to match the goals effectively.	**Moderate**
Knowledge of the assessment	**Moderate** Even though she used two ways to assess the students (classroom discussion and a guided activity), the questions did not assess deep understanding of the concepts,	**Poor** The assessment tools were not implemented well as the teacher was spoon-feeding the answers to her students, especially to the	**Poor** Even though the teacher recognized that the worksheet was not sufficient to measure	**Poor**

	as they were just a reiteration of the text found in the sheet. For the moderate level students, the questions were not appropriate to their cognitive level, as they did not require critical thinking.	low achievers, instead of guiding them to construct meaning themselves.	student understanding, she did not offer alternative efficient assessment tools.	
PCK Category	**Moderate**	**Poor**	**Poor**	**Poor**

Analysis of PCK for Novice Teacher 3 (NT3) (TD holder)

Teacher NT3 has a total of six years of teaching experience. Her educational background includes a bachelor degree in Biology and a teaching diploma. NT3 introduced her lesson by asking the students how our planet is in danger and what role humans have in negatively affecting their planet. After, she asked the students to pay attention to a video that explained how the greenhouse effect occurs so that they summarize what they understood by the greenhouse effect. At first, the teacher struggled to unpack what the students understood from the video. Therefore, she gave the explanation herself, and asked some students to reiterate what she said. Next, she asked the students to watch the second video that addressed the consequences of this phenomenon. After that, she asked the students to refer to the two videos and compare between global warming and the greenhouse effect, which was one of her lesson objectives. Later, she asked the students to use the video and list real-life consequences that were relevant to them. Later, the students were asked to suggest solutions to reduce this phenomenon. Finally, the teacher used the board to draw a diagram explaining the process behind the greenhouse effect and then she used the analogy between the greenhouse effect and greenhouses to summarize all main ideas of the lesson. It was apparent that the teacher was determined to engage the students in class discussion and encourage them to participate as she tried to target most of the students in the class. The teacher showed passion for student interaction as she would refer to their answers when moving from one idea in the lesson to the next.

Teacher NT3 has, in general, a moderate level of PCK with regards to the first dimension: knowledge of the content relevant for instruction. Her PCK while planning her

lesson plan appeared to be moderate as she showed an appropriate understanding of the greenhouse effect:

> *This phenomenon is necessary for the survival of living things on earth…The greenhouse gases trap the needed amount of heat around the earth to maintain a constant temperature…however, if the concentration of these gases increases…due to harmful human activities…it becomes a problem as it will lead to global warming and many other life-threatening consequences (Teacher NT3, Int.1).*

Also, she did not give more than four real-life consequences about the greenhouse effect: floods, climate change, melting of the ice caps and frequent droughts (Teacher NT3, lesson plan). When asked why is it important for the students to understand the mechanism of the greenhouse effect and to know its consequences, she replied, "They should know because first it is required in the national curriculum… also it is a universal issue due to human action and many of them think it is a problem…it has a positive role too" (Teacher NT3, Int. 1). This shows that NT3 does not seem to stress significantly on this topic's importance in relation to real life applications, which does not indicate scientific literacy and proficient PCK. In action, however, her PCK of the knowledge of content seems to be proficient as she used an informative video along with her own knowledge. Upon reflection, she did not give any reflection of her knowledge about the content, which shows that is at the poor level of PCK in reflection

Teacher NT3 has a moderate knowledge of the topic-specific instructional strategies, the second dimension of PCK, in general. She showed to be moderate in her PCK while planning as she planned to engage the students in post-video discussions through types of questions like "compare between the greenhouse effect and global

warming as shown in the two videos." Also, she wanted her students to overcome one known misconception (the failure to differentiate between global warming and the greenhouse effect) about this topic, and to come up with solutions to reduce this phenomenon on their own. At the same time, she was planning to explain the greenhouse effect herself by drawing a diagram on the board and summarizing the main ideas towards the end of the lesson:

> *At the beginning, I will tell them the objectives (we will discuss the greenhouse effect and how it becomes a problem due to pollution.... I will show them one video at a time because there are two videos…I will discuss and ask questions right after every video... then the students will propose solutions to reduce this phenomenon… At the end, I will summarize everything that was discussed during the session. That is: what is the definition, the difference between global warming and the greenhouse effect and the consequences of this phenomenon (Teacher NT3, Int. 1).*

This implies that the teacher wanted a semi-student centered approach to be used, which puts her at the moderate level. In her PCK in action, there was a balance of roles between the teacher and the students as planned. The students were actively engaged in explaining what they had understood from the two videos. Additionally, the teacher asked many questions regarding what the students already knew about each of the lesson concepts. When asked why it was important to know this, she responded, "to know where to start my explanation from and to focus on the difficulties that the students might have regarding any idea" (Teacher NT3, Int.2). This shows that NT3 integrated the students' prior knowledge into her instructional strategies. Moreover, when asked why it was important for her to include a summary towards the end of the lesson, she replied, "I do this in every lesson…I

like to reiterate all the important points in case some students did not pay attention and to overcome any misconception that they have" (Teacher NT3, Int. 2). In her PCK in reflection, teacher NT3 demonstrated a proficient level, as she wanted to design her lesson based on what her students already knew, and use this starting point to move from one objective to the next during the session. She said: "I did not start discussing ways to reduce the greenhouse effect before exploring what solutions do students have in mind to reduce the effect of heat trapping around the earth" struggled. Moreover, even though NT3 truly understands the benefit of using analogies, she realized that she did not use it in an efficient way:

> *I should have resorted to the analogy between greenhouses and greenhouse effect right after the first video… there are many new concepts that the students will be exposed to in the video…using the analogy after that video reduces the effort of knowing something new because it is supposed to be about something that the student already know…after watching the session now… I realized that there are some students who did not get the greenhouse effect even after class discussion and my explanation on the board…rushing to explain the analogy in the last five minutes of the session is not enough to let it sink in the student's minds (Teacher NT3, Int.3).*

Teacher NT3 has a moderate knowledge of students' learning, the third dimension of PCK in all PCK categories: planning, action, and reflection. While discussing her planned actions, teacher NT3 emphasized the importance of taking into consideration the students and their ideas as she reasoned that:

Each class is different, it's unique: the way they think, the way they interact, their level; you can't just plan a lesson and teach it wherever you go… people have different… you don't know how they think, respond and interact one should consider prerequisite knowledge in order to define misconceptions in case there are any (Teacher H, Int.1).

Moreover, she listed two main misconceptions that the students usually have for this lesson. First, the students will think that the greenhouse effect is only negatively affecting the earth. Second, the students will think that the greenhouse effect and global warming mean the same thing. Therefore, she purposefully designed her lesson objectives to allow the students to compare between the greenhouse effect and global warming. In action, her instruction was mainly centered on the discussion of the misconception (15 minutes out of 30). In addition, she talked about the aforementioned misconception explicitly in class. When asked for the reason behind this, she replied, "I need the students to identify them and be aware that most students have them if they don't understand the lesson well so that they are convinced to change their current conceptions" (Teacher NT3, Int.2). Talking about misconceptions can help the students to overcome it, but is not the only guaranteed way for this way to happen. Teacher NT3 also brainstormed with the students to assess prior knowledge and connect it to previous lesson on types of pollution. Hence, teacher NT3 has a moderate PCK in action. In reflection, she realized the importance of addressing misconceptions right away and she was able to identify one misconception that a student developed during the instruction, which she later added to her CoRe matrix:

I used to think that if I tell the student that his explanation is wrong, it would demotivate him to participate again…so I listen to all misconceptions and explain

my ideas several times to help the students overcome any misconceptions that they have…however, I realized now that students do not give up easily their current conceptions…Ahmad still thinks that holes in the ozone layer are the ones that heat up the atmosphere…even after I told him that this lesson has nothing to do with the ozone layer (Teacher NT3, Int.2).

However, she could not explain why students face such a difficulty or develop alternative conceptions during instruction. Thus, this indicates a moderate PCK in terms of reflection.

With regard to teaching about the greenhouse effect, Teacher NT3 has a moderate knowledge of the national chemistry curriculum for the Brevet. Her PCK while planning showed to be poor, as she was only knowledgeable about the horizontal and the vertical progression to a certain extent:

I am sure that the students took about pollution in science at the elementary level…they know the types of pollution and its effects on the environment…unfortunately this topic won't be encountered after grade 9…though it is a global issue (Teacher NT3, Int.1).

Moreover, she was not acquainted with the objectives of the national curriculum. While writing down her lesson objectives, she equated the curriculum with the textbook. Her lesson plan objectives included: students should define pollution, describe the greenhouse effect, explain how air pollution leads to the greenhouse effect, compare between global warming and the greenhouse effect, and list ways to reduce global warming (Teacher NT3, lesson plan).When asked for the reason behind using the book as a guideline to formulate the objectives, she replied:

This is my 6th year in teaching and honestly…I scanned real quick through its pages but when I started putting down my lesson plans, my coordinator told me what to teach in each lesson… It is easier for me to deduce the lesson objectives from the national chemistry books… sometimes in the official exams, some questions address global warming and ask students to describe… without even mentioning it in the curriculum which surprises us teachers...the curriculum is not well detailed and it is not a good guide so I do not refer to it (Teacher NT3, Int.1).

In action, her PCK was moderate. Even though she started her lesson by referring to what the students had previously learned about pollution and she modified the lesson objectives in a way to focus on a misconception that is commonly held by the students, she removed an aspect of the lesson that impeded students' understanding during her instruction. When asked during her lesson plan interview which part would she delete from the curriculum, she replied:

I do now want to discuss how the earth radiates infra-red radiation back to space after absorbing UV radiation of the sun…I don't want the students to know about this…I think it will confuse them…I just want them to know that the greenhouse gases form like a blanket that trap heat around the earth (Teacher NT3, Int.1).

However, right after drawing on the board and explaining the mechanism of the greenhouse effect superficially during instruction, she identified a difficulty in student learning that formed during her instruction. When she asked one of the students to summarize the main points behind this phenomenon to his friend, he had difficulty in viewing the earth as radiating body of heat as he expressed that the earth is like a mirror that reflects heat coming from the sun. NT3 commented, "I did not realize that student

might think of it this way" (Teacher NT3, Int.2). Then she added, "I think I need to explain the whole concept again but in details" (Teacher NT3, Int.2). No reflection was given post-instruction concerning her knowledge of the curriculum and as a result she was labeled poor in that area.

Teacher NT3 has a proficient knowledge of the orientations to teach this topic (fifth dimension of PCK) in general. In her planning, her PCK was proficient as this was evident in her lesson plan. She planned to use the greenhouse analogy where heat is maintained by trapping warm air inside, in order to relate the greenhouse effect to something that is familiar to the students. Her teaching sequence is aligned with the goal she planned for and conducive to fulfilling her teaching objectives: "Define air pollution; Describe the greenhouse effect; List all the greenhouse gases; Explain how pollution leads to Global warming; Compare between the greenhouse effect and global warming; List ways to reduce the greenhouse effect" (Teacher NT3, lesson plan). During instruction she stressed on these aforementioned ideas whenever she came across any of them during the lesson so as to make their importance clear for the students and she organized her ideas in the lesson plan well. However she struggled with the time needed to complete the whole sequence and she rushed in her explanation of the greenhouse effect and incorporated the use of analogy towards the last few minutes of the session, which affected the smoothness of her transition from one objective to the next and impeded the students' understanding to a certain extent. Thus, putting her at the moderate level for her PCK while action. Acknowledging that she had set unrealistic objectives for a 35-minute teaching episode, and upon reflecting on her teaching sequence, teacher NT3 was able to reshape her goals and acknowledge that each of the aforementioned goals would need to be tackled

separately. Therefore she restructured her lesson while focusing on addressing the misconception. Thus showing a proficient PCK while reflection. This was evident when she noted:

> *I thought the lesson is easy and does not need more than 35 minutes…now after I watched the videotaped session…I realized I was rushing to finish my long list of objectives in one session…I think I need double the time for the students to achieve all the lesson goals…I should have used the analogy at the beginning of the lesson to foster a deep understanding of the greenhouse effect mechanism followed by the video that illustrates the process using animations…then I would give time for students to elaborate in their explanations to know if I can move on to the next objective …solutions to reduce the greenhouse effect can be given in the next session so that I make sure that the students understood fully the cause behind these consequences… this way I will have less students who might face difficulties or formed misconceptions during my instruction…(Teacher NT3, Int.3).*

Teacher NT3 has in general a moderate knowledge of the assessment, the sixth dimension of PCK. In planning, NT3 proved to be moderate in the area of assessments as even though she understands the importance of when, for what and which type of assessment to be used, she noted,

> *Assessments can be of different types…must important thing that they are aligned with the lesson's goals so that we are fair to the students… In the beginning of the chapter, the discussions in class are really important for assessing the student's thinking and for exploring what they already know... Later on, when the students have gained the knowledge required, I would choose a different type of assessment*

such as quiz or a group work activity…it has to be on going… for me to check also that my strategy for that particular lesson was effective (Teacher NT3, Int.1).

However, she relied heavily on a questioning assessment. Even in action, she only assessed the students using questions, especially at junctures when they were conducive to the lesson goals like when she moved from explaining the first video to explaining the second. However, the questions asked belonged to levels one and two of Bloom's taxonomy (knowledge and comprehension), which do not sufficiently measure the students' deep conceptual understanding. Moreover, using only one assessment tool is not enough to ensure that all students achieved a deep understanding of the concept. Hence, this is an indication of moderate knowledge of assessment in terms of action. Upon reflection, teacher NT3 realized that the students who did not participate in the discussion may not have understood the concepts. She also modified her CoRe matrix by implementing different type of assessment to ensure that all of the students understood the concepts. She said:

I will incorporate a group activity sheet for sure…this way I can observe better if most of the students engaged their thinking…at the end of the lesson I will ask students to summarize the lesson instead of me…maybe also I can use the analogy as assessment tool…asking the students to explain the analogy by themselves after watching the video… (Teacher NT3, Int.3).

However, when asked what type of questions she might ask in the group worksheet, she said,

I will ask questions that asses if the students achieved the objectives such as listing 3 or 4 consequences of the greenhouse effect…I might bring them a diagram and ask them to describe it in their own words" (Teacher NT3, Int.3).

Again, these questions do not engage the students' thinking even if they were conducive to the lesson goals. This implies that she is also moderate in her PCK while reflection. A summarized profile NT3's PCK is summarized below in Table ten. The overall PCK (taking into account the horizontal and vertical levels) puts NT3 in the moderate category.

Table 10

PCK Profile for NT3

	PCK in planning	PCK in action	PCK in reflection	PCK category
Knowledge of the content	**Moderate** She demonstrated an appropriate understanding of the greenhouse effect. However, she did not give enough real-life examples about the greenhouse effect consequences.	**Proficient** Explanation based on video and her own knowledge. Stressed on the importance of the topic in relation to real life applications.	**Poor** No reflection was given.	**Moderate**
Knowledge of the topic specific instructional strategies	**Moderate** Semi-student-centered approach was planned to be used. The students would be engaged in discussion through the type of questions that she asked, such as being asked to compare between the two videos.	**Moderate** Semi- student centered. There was a balance of roles between the teacher and the students. The students were actively engaged in the discussions.	**Proficient** She intentionally wanted to start from what the students know to design her lesson.	**Moderate**
Knowledge of students	**Moderate** The teacher gave only two misconceptions that the students might have. She	**Moderate** She brainstormed with the students to assess prior knowledge and connected it	**Moderate** She realized the importance of addressing	**Moderate**

	took into consideration the students' prior knowledge while planning for the lesson.	to previous lesson on types of pollution. She mentioned explicitly the misconceptions that students usually have.	misconceptions right away. She identified one misconception developed during the session but could not explain the reason behind its occurrence.	
Knowledge of the curriculum	**Poor** She was knowledgeable about the horizontal and the vertical transition to a certain extent. However, she was not acquainted with the objectives of the national curriculum. She equated the curriculum with the textbook.	**Moderate** She started her lesson by referring to what the students had previously learned about pollution. Made informed decisions to leave some aspects of the topic out of her lesson, however this hindered the students' understanding	**Poor** No reflection was given.	**Poor**
Knowledge of the orientations	**Proficient** The design was aligned with the goals of the lesson. There was a smooth transition between the objectives.	**Moderate** The transition between the objectives was smooth to a certain extent as she struggled with the time. Her ideas were organized and connected. Her questions during class discussion were conducive to reach the	**Proficient** She mentioned incorporating different activities and reshaping the structure of the lesson in a way that is conducive to achieve the goals in	**Proficient**

		lesson goals.	best way possible and to minimize comprehension issues by the students when moving from one objective to the other.	
Knowledge of the assessment	**Moderate** She planned to use one, informal tool (discussion and questions) which was conducive to reaching the goals of her lesson, such as finding the difference between the two videos.	**Moderate** Although a lot of ongoing oral questions were used to assess the students understanding, still the use of one assessment tool is not enough to ensure that all students achieved a deep understanding of the concept.	**Moderate** She realized that the students who didn't participate in the discussion might not have understood the concepts. She said she would implement different type of assessment to ensure that all of the students understood the concepts.	**Moderate**
PCK Category	**Moderate**	**Moderate**	**Moderate**	**Moderate**

Summary of the Findings

As summarized in Table 11 below, teacher profiles seem to fall on a continuum ranging from an overall low PCK profile (Teacher NT1 and ET1) to a moderate profile (Teachers NT2, NT3, ET2, & ET3). None of the teachers approached a proficient PCK profile in the teaching about the greenhouse effect. Overall, experience and the attainment of a teaching diploma play a positive role while planning, teaching and reflecting for all different dimensions of PCK about the greenhouse effect.

Table 11

Overall PCK performance level for the six teachers

	Teacher ET1	Teacher ET2	Teacher ET3	Teacher NT1	Teacher NT2	Teacher NT3
Overall PCK	L	M	M	L	M	M

*L = poor PCK; P = proficient PCK; M = moderate PCK

Table 12 below presents five main patterns among the six teachers that are revealed from the PCK scores. First, all teachers, irrespective of their years of experience and attainment of a TD, seem to have a good PCK scores in two main PCK dimensions: knowledge of orientations and knowledge of content which implies that their conceptions about the greenhouse effect are correct to a certain extent and that they do sequence their lesson in a way to reach its goals. However, all teachers, regardless of years of experience and attainment of a TD, scored low on their knowledge of students, assessment, specific instructional strategies and curriculum. Third, TD holders (NT3 and ET3), regardless of length of teaching experience, scored a higher PCK score than non-TD holders. Fourth, Teachers NT1 and ET1, non-holders of a TD with a big difference in years of experience,

scored an equally low overall PCK score which shows that having an efficient teacher preparation program or a professional learning school environment, regardless of the number of years of experience, is a possible factor for developing a robust PCK. Finally, teachers (NT1 and NT2) who have short teaching experience and are non-holders of a TD, had almost a similar low PCK overall score which implies that experience and a teacher preparation program might be beneficial for the attainment of a robust PCK performance level. Table 13 below shows that the average score of highly experienced teachers is 11.6 while that of those with low experience (novice) is 9.6. Since the score for the highly experienced teachers is relatively higher, then experience could be a factor in development of PCK. In addition, table 13 shows that the average score of TD holders is 12 while that of non-TD holders is 10. Since the score for the TD holders is relatively higher, then the attainment of a teaching diploma could be a factor in the development of PCK.

Table 12

General PCK score dimensions for the six teachers

Teachers	Teaching years	Education	Knowledge of content	Knowledge of specific strategies	Knowledge of students' learning	Knowledge of curriculum	Knowledge of orientations	Knowledge of assessment	*Total PCK score*
NT1	1	B.S./ MS	2	1	1	1	2	2	9
NT2	4	B.S. / MS	1	1	1	2	2	1	8
NT3	6	B.S./TD	2	2	2	1	3	2	12
ET1	8	B.S.	3	1	1	2	1	1	9
ET2	11	B.S.	2	2	2	3	3	2	14
ET3	12	B.S./MS/TD	2	2	2	2	2	2	12
		total score	12	10	9	11	13	10	

1 = poor PCK; 2 = moderate PCK; 3 = proficient PCK

Table 13

Average PCK scores for two groups of teachers

	Highly experienced teachers	Novice teachers	TD holders	Non-TD holders
	9	9	12	9
	14	8	12	8
	12	12	-	9
	-	-	-	14
Average PCK score	11.6	9.6	12	10

Table 14 presents the PCK scores of all six teachers in the three contexts: while planning, teaching and reflecting for all different dimensions of PCK. The following patterns were revealed: First, none of the teachers approached a proficient score (18) in PCK of planning, teaching, and reflecting in the teaching about the greenhouse effect. Second, all teachers got highest scores in planning among the three contexts. Third, the highest PCK scores in the three contexts: planning, acting and reflecting were achieved by ET2 (non-TD holder) followed by ET3 and NT3 (both TD holders) teachers. Fourth, it was evident for NT2, NT1, ET3, and ET1 (more than half the participants) that even if teachers plan their lesson well, it does not mean they will have a robust PCK while action or while reflection. Fifth, all teachers showed the least PCK score (less than 12) in reflection.

Table 14

PCK total scores for all six teachers in the three contexts: while planning, teaching and reflecting

PCK Knowledge Dimension	Teacher ET1			Teacher ET2			Teacher ET3			Teacher NT1			Teacher NT2			Teacher NT3		
	*Plan	*Act	*Ref	Plan	Act	Ref	Plan	Act	Ref	Plan	Act	Ref	Plan	Act	Ref	Plan	Act	Ref
Content	2	3	3	2	2	1	2	2	1	3	3	1	1	2	1	2	3	1
Instructional strategies	2	1	1	2	2	2	3	2	2	2	1	1	2	1	1	2	2	3
Student's learning	1	1	1	1	2	2	2	2	2	1	1	2	2	1	1	2	2	2
Curriculum	2	2	1	3	2	3	3	1	1	1	1	1	3	1	2	1	2	1
Orientations	2	1	1	3	3	3	3	2	2	2	1	2	3	1	2	3	2	3
Assessment	2	1	1	2	1	2	2	2	2	2	2	2	2	1	1	2	2	2
Total score	11	9	8	13	12	13	15	11	10	11	9	9	13	7	8	12	13	12

*Plan = PCK while planning; Act = PCK while teaching; Ref = PCK while reflecting

**1 = poor PCK; 2 = moderate PCK; 3 = proficient PCK

CHAPTER V

DISCUSSION AND CONCLUSION

This study explored the PCK held by teachers who implement environmental education in their classroom to explore their pedagogical content knowledge (PCK) on the topic of pollution. This chapter is organized as follows: first a summary of the findings is presented together with a discussion of the results. Next, possible implications for teacher education and teacher development programs are suggested. Finally, recommendations for future research, teacher preparation programs, and teacher educators are presented.

Discussion of the Findings

The three questions that guided this study were: What is the pedagogical content knowledge of pollution held by experienced and novice secondary level chemistry Lebanese teachers? How does secondary chemistry teachers' PCK of pollution differ between those that hold a teaching diploma degree and those that do not? How does secondary chemistry teachers' PCK of pollution relate to their years of teaching experience? Results revealed that teachers' PCK was found to vary across all domains, at times reflecting moderate PCK (Teachers NT2, NT3, ET2, & ET3), and at others showing poor PCK (Teacher NT1 and ET1). None of the teachers approached a proficient PCK profile while teaching about the greenhouse effect. Abd-El-Khalick and BouJaoude's 1997 study also showed similar results among Lebanese science teachers. In another study in Lebanon, only one out of four Lebanese teachers achieved a proficient PCK level (Rizk, 2009).

Having a teaching diploma, regardless of teaching experience, seemed to have a positive impact on the overall PCK score. Additionally, teaching experience played a positive role in helping the teachers achieve a higher PCK score than novice teachers. Although teaching experience does not guarantee a robust PCK (Friedrichsen, et al., 2009), previous research showed that teaching experience is one of the important sources of PCK development (Grossman, 1990; Shulman, 1987). However, in this study, teaching experience only helped teachers attain a moderate PCK level in teaching the greenhouse effect and global warming. This can be attributed to the schools' professional learning environments which do not offer teachers the opportunity to be involved in meaningful professional development activities, especially in topics in which teachers are not properly prepared. It could also be attributed to the quality of the current teacher preparation programs in which PCK may not be discussed and introduced appropriately (Rizk, 2009). Furthermore, all teachers, irrespective of their years of experience and attainment of a TD, seem to have a good PCK scores in two PCK dimensions: knowledge of orientations and knowledge of content which implies that their conceptions about the greenhouse effect are moderate to a certain extent and that they do sequence their lessons in a way to reach their goals. Conversely, all teachers, regardless of years of experience and attainment of a TD, scored low on their knowledge of students. This might indicate a lack of appreciation of the importance of students' prior knowledge and their propensity to neglect this factor when designing lesson plans, in class actions, and while reflecting on their teaching and student learning. Below I present a detailed discussion of the results.

Knowledge of Content and Knowledge of Orientations

A moderate PCK with respect to related science content is reflective of the quality of teachers' science education in terms of the ways they have been taught science. Most of the teachers did not have a deep understanding of the concepts of the greenhouse effect and global warming as none approached a proficient PCK in this dimension. Moreover, all teachers claimed that they had not taken a course on related environmental issues during their university years and consequently their knowledge about this topic was far from sufficient. Only when engaged in preparing projects relevant to environmental issues for a science fair (Teacher ET1), is a teacher forced to acquire a deeper understanding of a topic such as the greenhouse effect and teach it to her students. The rest of the teachers had confined content knowledge that matches the content of the lesson in the textbook. Teachers never mentioned circulation of CO^2 in nature, especially during photosynthesis and respiration and its relation to the greenhouse effect. They also did not know how to explain how extreme temperatures (climate change) can result from such a phenomenon. Even though none of the teachers had construed a false correlation among global warming, ozone-layer depletion and the greenhouse effect as in the findings of previous research, they did not communicate this correlation when asked by students in class which confused these students and possibly led to students developing new misconceptions. They reasoned that the explanation would take some of the class time. Moreover, most of the teachers stated that they acquired knowledge from television programs and the Internet, while obtaining inadequate information from their courses or current national chemistry textbooks. One teacher, for example, claimed that, "There was some superficial information in some courses but we were given no course directly related to it" (Teacher ET3, Int.1).

Ogan-Bekiroglu's 2009 study highlights the importance of increasing teachers' subject knowledge since it was found that although pre-service teachers had positive views toward alternate forms of assessment, they restricted their implementation of such assessments to subjects of which they had adequate knowledge. Moreover, since good science teaching is associated with "high literacy" (Anderson, 1987, cited in Abdel-El-Kalick &Boujaoude, 1997) and since most teachers use textbooks as the major source of content in their teaching (Chiappetta, Sethna & Fillman, 1993), the current Lebanese textbooks for the secondary level are focused on the "low level of literacy" as conceptualized by Anderson (1987, cited in Abdel-El-Kalick & Boujaoude, 1997) for they only seem to emphasize the knowledge of facts about the world more than the use of scientific knowledge in everyday life experiences (Harbali, 2000). These results are similar to those from other countries in which research results have shown that teacher understanding of the greenhouse effect is inadequate and insufficient to help them teach it to their students (Boyes & Stanisstreet, 1992; Dove, 1996; Fortner, 2001; Hansen, 2003; Papadimitriou, 2004). Even TD holders, who are prepared with a significant amount of science background, did not show a deep understanding of these concepts. This could be due to the fact that TD programs offer numerous courses in general and professional education, leaving little room for specialty areas (BouJaoude, 2000) such as environmental education. It seems plausible to say that TD holders are not given enough opportunity during their TD degree pursuit to challenge their commonly-held misconceptions about various topics in science.

In the knowledge of orientation, experienced and novice teachers used the same teaching sequence: a short questioning period, lecture, discussion, and guided practice. Even though most of the teachers earned the highest scores in this domain, none

approached a proficient level as most held didactic to semi-didactic science teaching orientation focused on transmitting the basic information (Magnusson et al., 1999) to prepare students for the national Brevet examinations. They thought that in this manner the students would receive and understand better the correct information through the reiteration of the main ideas during the session.

Almost all of the teachers began their teaching sessions by asking questions followed by a guided practice designed for students to memorize and practice the lesson's material. Even though the way the lesson was planned to reach the lesson's goals, the teachers were doing most of the talking instead of letting the students themselves build their own meaning. This similarity in the lesson plan structure may be attributed to similar experiences in teacher preparation programs that subscribe to an academic/ technical approach in nature (El Mouhayar & BouJaoude, 2012) or the lack of a professional school learning environment.

Knowledge of Student Learning

Even though most of the teachers asked questions in class to explore the students' prior knowledge, they did not take into account this knowledge while planning or while teaching. Most teachers could not give more than three misconceptions that their students might have held about the greenhouse effect and its consequences even though they had been engaging with the students - sitting with them and observing them, learning about the misconceptions they may have, discovering how they think and reason and about what motivates them and what they care about. This was evident in Rizk's study (2009) in which pre-service teachers had a moderate knowledge of the students' prior knowledge even though they observed how these students reacted to and interacted with their teacher. For example, if teachers end up

memorizing skills and procedures associated with the conceptual change theory and applying some instructional strategies to challenge their students' misconceptions without understanding how differentiated learning about conceptual change differs from the processes of adaptation or assimilation, these teachers would not be able to identify cases where misconceptions are not explicitly articulated by students, nor will they be able to reflect on reasons why their conceptual change techniques might have fallen short on changing students' misconceptions (Rizk, 2009). Moreover, the teachers, drawing on their teaching experiences, anticipated students might experience some difficulties. On the other hand, novice teachers did not anticipate that they would have difficulties with their lessons, and based their understandings of the students on their own K-12 experiences.

Numerous studies have shown that students' preconceptions sometimes act as impediments for scientific understanding (Driver, Guesne, & Tiberghien, 1985). In this regard, reformed science teaching should respect students' prior knowledge when planning for teaching in such a way as to challenge these ideas. It follows that in order to do this, teachers need to understand what students already know about a topic, what those students are likely to have difficulty in while learning the topic, and what concepts need to be challenged to make informed choices about several dimensions of PCK. Such knowledge is a key component of PCK, according to Shulman's conceptualization.

Knowledge of Assessment, Curriculum and Teaching Strategies.

Novice and experienced teachers showed a low PCK score in Assessment, Curriculum and Teaching Strategies. Curricular knowledge affects instructional decisions (Haney & McArthur, 2002). However, this area of research has received little

attention from science education researchers (Abell, 2007). The evaluation of existing curricular materials showed that most materials rarely supported teachers' PCK of scientific inquiry (BouJaoude, 2002; Beyer, Delgado, Davis & Krajcik, 2009) and provided few rationales for instructional decisions (Beyer et. al, 2009). Although the teachers relied heavily on textbooks, they were aware of national curriculum guidelines to a certain extent and insisted on equating the curriculum with the textbook as its instructional objectives were "more clear" than the general objectives mentioned in the national curriculum. However, according to Harbali (2000), the current science national textbooks focus on low literacy and do not emphasize the use of scientific knowledge in everyday life experiences. Moreover, according to BouJaoude (2002), as you move from the level of general objectives of the curriculum to the level of instructional objectives, several aspects of science literacy such as the interaction of science, technology, and society begin to diminish. Additionally, there were very few instructional objectives presented in one aspect of scientific literacy "The knowledge of science" which indicates what content to be covered in each lesson. This means that the textbooks may not be sufficiently helping the teachers to teach so that students could achieve a deeper level of conceptual understanding of the greenhouse effect and global warming.

In the knowledge of instructional strategies, novice teachers relied on individual guided practice, while experienced teachers included small group work as part of guided practice. Experienced teachers believed that struggling students might benefit from the explanations given by their classmates. However, even when group activities were used in class, they were not conducted in an efficient manner and as result, time was wasted. This made teachers feel indecisive about using group activities again in

future lessons. Even though the novice and experienced teachers, including TD holders, viewed their teaching as student-centered, in action they preferred to impart the correct information that would fill any gaps found in their students' knowledge, as they still seem to have a narrow view of how conceptual change takes place in the students' minds. Additionally, they thought that only through re-iteration of the ideas could the students' misconceptions or learning difficulties be overcome. Since there is not enough field work enforced in the curricula of teacher education programs (BouJaoude, 2000), novice teachers seem to worry more about managing the class and maintaining discipline than whether the students attained a deep understanding of the concepts. Apparently, teacher preparation and professional development programs are not helping the teachers to adopt current student-centered teaching strategies in an efficient manner that would make better use of the instructional time.

In the knowledge of assessment, all teachers, including TD holders, seem to view assessment and instruction as separate entities - as the questions addressed in the assessment were not aligned with lesson objectives. The only few questions that were aligned with the lesson objectives did not asses the students' deep understanding of the concepts. They were only used to regurgitate the words of the teacher or the ones found in the national textbook. Neither the novice nor the experienced teachers included assessment in their written lesson plans. When prompted, teachers indicated that they planned to ask questions throughout the lesson as a method of informal assessment, and would grade student worksheets after the lesson in case they thought that the students did not fully comprehend the lesson. Although the experienced and novice teachers differed in the type (informal questioning vs. grading worksheets) and timing (on-going vs. end of the lesson) of assessments, all of them used assessments for the same

purpose: to determine if they needed to repeat parts of their lecture. Both groups had limited views of the purposes of assessment (i.e., informing their instruction), and did not view assessment as a way to help students monitor and assess their own learning. Even when asked during reflection how they would enhance their assessment questions, they preferred to keep them at the same level of Bloom's taxonomy, as the content matches that of the former Brevet test material.

In the interviews, teachers were asked to reflect on their lesson planning process. The experienced teachers' reflections were more elaborate, drawing on multiple knowledge bases as they explained their thinking; this was not the case for the novice teachers to a certain extent. Although the teachers' interview included multiple examples of interactions among PCK components of learners, curriculum, instructional strategies, and assessment, they made few connections to orientations. If students were having difficulty with the material, most of the teachers planned to repeat the explanation instead of re-sequencing the lesson in way that would be conducive to the lesson goals. Some teachers, especially novices, could not use their PCK of assessment to inform their choice of their PCK of teaching orientation. In summary, experienced and TD-holding teachers showed more evidence of interaction among PCK components. However, for all teachers, these interactions were limited in the knowledge of assessment, learners' difficulties, curriculum, and teaching strategies when teaching about the greenhouse effect and its consequences. These interactions did not lead to the use of alternative instructional strategies that are more student-centered and that emphasize guided inquiry techniques. Moreover, teachers still do not consider the use of the students' learning difficulties or prior conceptions to inform their choice about other PCK components (i.e., orientations, assessment, and curriculum).

The Role of Reflection

Planning a science lesson offers many opportunities for teachers to develop their PCK. Importantly, effective lesson planning requires the convergence of content knowledge, which is at the center of any good lesson plan, and pedagogical knowledge, which is essential to engaging students in an effective learning design (Grossman, 1990; Park & Oliver, 2008). Even though all teachers, regardless of experience and completion of a teaching diploma, proved to have a moderate PCK score in planning and in PCK in action, they showed the lowest PCK score in reflection. However, it is not enough to simply plan and enact a lesson. Teachers learn through these personally and professionally relevant activities, supported by their reflection on their own understandings. Some of the teachers did not reflect on their knowledge of the content. They seem to believe that their current conceptions about the greenhouse effect and its consequences should not be questioned. A substantial body of professional development literature has focused on reflective practice (Barnett & Coate, 2005) as a means of enabling the growth or development of teacher knowledge. If reflection supports the development of PCK and helps teachers become more metacognitive about their teaching processes, then reflection should be emphasized in teacher preparation programs as well as in-service professional development. Teachers should be encouraged to reflect - even about reflection - as a crucial professional practice that is the most expeditious means for them to develop pedagogical content knowledge. For example, the current practice of having teachers submit lesson plans in order to document their coverage of content could be greatly enhanced by encouraging them to include a segment of reflection concerning the teachers' understandings about how

students will learn from that lesson, potential formative assessment opportunities, and the teachers' potential role in the enactment.

Recommendations

Recommendations for Teacher Professional Development and Teacher Preparation Programs

Since Shulman and colleagues claimed that the development of teacher knowledge, and in particular PCK, is the primary goal of teacher education, it is recommended that science teacher educators and teacher professional developers use PCK as an explicit framework in their courses. This could lead to the development of shared expectations for teacher knowledge development (Loughran et al., 2006). As can be seen in the following excerpt, the report prepared by UNESCO in preparation for the World Conference on Education for Sustainable Development (DESD) which was held in Japan in November 2014, proposed one action area that would re-orient education towards a pathway that would accelerate the progress on sustainable development:

> Educators are one of the most important levers to foster educational change and to facilitate learning for sustainable development. There is therefore an urgent need to build the capacity of educators, as well as trainers and other change agents, on relevant issues related to sustainable development and appropriate teaching and learning methodologies. (UNESCO, 2013; p.4)

In 2015, one of the UNESCO development workshops to prepare secondary science teachers for delivering lessons on climate change was held in the Seventeenth Annual Science and Mathematics Educators Conference at the American University of Beirut. The workshop strategy was to encourage participants to critically reflect on the connections of climate change themes to their teaching experiences. Even though

current worldwide organizations are offering many teacher professional development workshops to encourage educators to incorporate more topics on sustainability and environmental education into their current school curricula, these workshops are not a one size fits all model that can be adopted in all countries. Secondary Lebanese teachers in the workshop admitted that due to time constraints and condensed high-stake assessment curricula, they prefer to use this limited time to prepare their students for other topics that will see greater coverage in high-stake assessments. Moreover, the workshop focused on only two PCK dimensions: knowledge of the content and knowledge of strategies that are specific to the teaching about climate change. International organizations like UNESCO should coordinate their efforts with teacher preparation programs, the Ministry of Education and Higher Education and private schools to improve the quality of teachers' PCK for pollution which will ultimately lead to improving students' understanding of these topics. Additionally, based on the findings, the following recommendations can be provided to teacher educators, school administrators, and policy makers.

First, teachers learn from each other as well as from environmental experts or education specialist. Consequently, strategies that facilitate professional communication among teachers need to be integrated into teacher professional development. Teachers can reflect on their practices and explore different perspectives through discussion with colleagues about their teaching difficulties. Second, since large classes, heavy teaching loads, daily schedules that include limited non-instructional time, and norms that discourage collegial interaction all combine to separate teachers from their colleagues; schools need to offer enough time to encourage groups of teachers to come together for and/or around professional development. Through work

in groups, teachers share experiences, ideas, or curriculum materials. Melville and Bartley (2010) suggest that in order to ensure efficient and sustained changes to teacher practices, mentoring relationships should exist within inquiry-based communities and PD programs whose learning goals are aligned with needs and schools' readiness to facilitate teacher cooperation and implementation of a new pedagogies (Watson & Manning, 2008).

Despite widespread agreement among parents, educators, and policymakers worldwide that students need skills like critical thinking, problem solving, teamwork, and creativity, these skills are still not being emphasize sufficiently in schools. Therefore, teacher education and teacher development programs that emphasize these skills are indispensable to the success of educational reform in general and specific reform initiatives forced on improving students' understanding of issues related to the environment. The transmission of factual knowledge via lectures and textbooks remains the dominant approach to compulsory education in the Arab world (Dagher & BouJaoude, 2011). Students taught through this method typically do not practice applying knowledge to new contexts, communicating it in complex ways, solving problems, or developing creativity. Therefore, to effectively teach the aforementioned skills to students, efficient teacher preparation programs are needed to prepare graduates who are ready to teach proficiently in a 21st century classroom. Consequently, teacher preparation programs should prepare their teachers to attain a robust PCK while teaching about environmental issues and emphasize the importance of the interaction of topic-specific PCK components.

Recommendations for Future Research

Based on the results of this study, it is clear that there is a need of more research to investigate the PCK of science teachers in a variety of topics. By understanding the development of PCK of novice and experienced teachers, better teacher preparation and development programs may be developed. In addition, there is a need of more research on the structure of PCK and its assessment (Lee et al., 2007). Finally, teachers usually hold strong personal beliefs about issues such as what they view as good teaching, how they think students learn, and which standards they wish to stress in a curriculum (Van Driel, Bulte, & Verloop, 2007). While some prior research (Barnett & Coate, 2005) has explored the role of reflection in teacher learning, there is a need for a more nuanced understanding of how reflection helps teachers develop new understandings.

When is reflection the most helpful? Van Driel and colleagues studied PCK development within teacher education programs. Although they considered teaching experience as the primary source of PCK development, reflection was also a critical component of the teacher education program (De Jong & Van Driel, 2001). Park and Oliver (2008), based on their study of three experienced chemistry teachers, proposed a revised PCK model emphasizing both reflection-in-action and reflection-on-action as critical components of PCK development. The process of reflecting helped the teacher identify critical elements of the lesson, student conceptions, or instructional sequences, and informed their design of improvements to the lesson. Can science teachers develop topic-specific PCK from teaching experience alone, without the benefit of reflective teacher education programs? More research should be done to answer this question where both PCK reflection-in-action and PCK reflection-on-action can be explored. In this respect, it is important to emphasize the use of appropriate data collection tools to

be able to characterize teachers' PCK accurately. Videotaping can be such a tool because it captures the details of teacher practices, student- teacher, and student-student interactions. However, associated with the use of videotaping, there is a need to find valid and reliable methods to analyze data acquired from these videotapes.

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APPENDIX I

ORIENTATIONS, GOALS AND CHARACTERISTICS OF INSTRUCTION

ORIENTATION	GOAL OF TEACHING SCIENCE
Process	Help students develop the "science process skills."(e.g., SAPA)
Academic Rigor (Lantz & Kass, 1987)	Represent a particular body of knowledge (e.g., chemistry).
Didactic	Transmits the facts of science.
Conceptual Charge (Roth, Anderson, & Smith, 1987)	Facilitate the development of scientific knowledge by confronting students with contexts to explain that challenge their naive conceptions.
Activity-driven (Anderson, & Smith, 1987)	Have students be active with materials; "hands-on"experiences.
Discovery (Karplus, 1963)	Provide opportunities for students on their own to discover targeted science concepts
Project-based Science (Ruopp et. al 1993; Marx et al., 1994)	Involve students in investigating solutions to authentic problems.
Inquiry (Tarnir, 1983)	Represent science as inquiry
Guided Inquiry (Magnusson & Palinesar, 1995)	Constitute a community of learners whose members share responsibility for understanding the physical world, particularly with respect to using the tools of science.

Source: Magnusson, S., Krajcik, J., & Borko, H. (1999). *Nature, sources and development of pedagogical content knowledge for science teaching.* In J. Gess-Newsome & N. G. Lederman (Eds.), Examining pedagogical content knowledge. Dordreacht, The Netherlands: Kluwer Academic Publishers.

APPENDIX II

CORE MATRIX

	Enduring idea 1	Enduring idea 2	Enduring idea 3
What do you intend the students to learn about this idea?			
Why is it important for the students to know this?			
What else do you know about this idea that you do not know intend students to know yet?			
What difficulties/limitations are connected with teaching this idea?			
What do you know about student thinking which influences teaching about this idea?			
Are there any other factors that influence your teaching of this idea?			
What teaching procedures would you use, and why, for this idea?			
How would you ascertain student understanding of, or confusion about, this idea?			

Source: Loughran, J., Berry, A. &Mulhall, P. (2006).*Understanding and developing science teachers' pedagogical content knowledge.* Rotterdam: Sense Publishers

APPENDIX III

EXPERT CORE MATRIX OF GREENHOUSE EFFECT

	Big Idea The Greenhouse effect	Big Idea The Greenhouse effect
What do you intend the student to learn about this idea?	When sunlight reaches Earth's surface, it can either be reflected back into space or absorbed by Earth. Once absorbed, the planet releases some of the energy back into the atmosphere as heat (also called infrared radiation). Greenhouse gases (GHGs) like water vapor O_3, CH_3Br and CH_3C, (H2O), carbon dioxide (CO2), chlorofluorocarbons (CFCs), and methane (CH4) absorb energy, slowing or preventing the loss of heat to space. In this way, GHGs act like a blanket, making Earth warmer than it would otherwise be. This process is commonly known as the "greenhouse effect".	The greater greenhouse gas content in the atmosphere cause global warming. Global warming is the main consequence of such an effect which will lead to floods, droughts, intense rain, frequent and severe heat wave, plant and animal extinction and bird migration. Warming and acidification of the oceans, Melting of the ice caps and a rise in the sea levels.
Why is it important for the students to know this?	To be able to understand why it is important to reduce the emission of greenhouse gases, the students need to understand the mechanism behind the greenhouse effect.	Students need to know all the consequences because they are observable and a living proof of this effect. To be aware of the damage done by their daily activities. Need to be aware as future citizens of their role in reducing this effect.
What else you know about this idea that you don't intend the students to know yet	The greenhouse effect refers to circumstances where the short wavelengths of visible light from the sun pass through a transparent medium and are absorbed, but the longer wavelengths of the infrared re-radiation from the heated objects are unable to pass through that medium.	Climate change of solar system Non-human activities that lead to this effect (Cosmic rays)

	The trapping of the long wavelength radiation leads to more heating and a higher resultant temperature.	
Difficulties connected with teaching this idea	The parents' action in community	Students might not understand why some areas would have a lot of rainfall and others suffer from droughts
Knowledge about the students thinking that influences the teaching of this idea	The situation in everyday life. Students may not view earth as heat radiating objects. Students might think that the greenhouse gases are themselves trapped. Students might think that the holes in the ozone layer is behind the greenhouse effect	The parents and students in community are not concerned much the global warming problem Learners' view of the global warming: it affects the whole world and not directly his house. Student might think that these consequences only occur in industrialized countries.
Other factors that influence teaching this idea	The time of the session Prior knowledge of gas s' property The parents' action in community such as burning car wheels, charcoal burning	Traditional, cultural and advancement of technology. Teacher lack subject matter knowledge & approach Prior misconceptions about GW and Ozone dep.
Teaching procedures and particular reasons for using these to engage students with this idea	Student –centered/group activities Using inquiry cycle: 5Es Discussion about the situation and news of global warming in the world and in their country. Using actually situation in everyday life such as sitting in the car, lying down in cloth bag. After that analogy between outside and inside of the car. Building a model of the greenhouses	Use a movie. Synthesize a local news report Lab activity Synthesize an awareness campaign
Specific ways of ascertaining students' understanding or confusion around this idea	Bloom's taxonomy level 2 and above. Formative or summative oral assessment Class discussion and questioning	concept mapping and multiple choice test Writing the short answer, interviews (Q &A session) A Project to build a model of the greenhouse. Research assignment about govt. initiatives regarding this issue in Lebanon