Understanding the Teacher’s Role in a Knowledge Community and Inquiry Curriculum

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Abstract

Knowledge and Community Inquiry (KCI) is an innovative instructional model that integrates a dimension of scaffolded inquiry within a knowledge community approach. While early studies of KCI successfully implemented the model in the form of substantive curricular units, the teacher’s role within those curricula was not clearly explicated, nor is it included formally within current versions of the model. This dissertation seeks to clarify the teacher’s role in the KCI model by examining one KCI curriculum unit in which three high school science teachers coordinated five sections of a ninth grade general science course (n = 106) to collectively study the topic of climate change over a nine-week period. One teacher had been engaged in the development of the curriculum. The study uses open coding and content analysis to examine: (a) the teacher’s role as it was designed or intended in the curriculum design; (b) the three teachers’ prior knowledge and experience, to examine the knowledge disparity among the teachers; (c) the teachers’ enactment of the curriculum, to capture what teachers actually did in their classroom, as contrasted with the designed curriculum; and (d) the teachers’ interaction with students, to identify the interaction patterns and their relationship to the teachers’ prior knowledge and
experience. Curriculum design documents, teacher interviews, and video recordings of classroom teaching provided the data sources.

The curriculum design analysis identified six categories of teacher’s role: (a) content lecturing, (b) evaluating students, (c) introducing learning activities, (d) making connections, (e) explanation or elaboration, and (f) classroom management. The teacher knowledge analysis identified the differences among the teachers in terms of the knowledge and experience of: (a) scientific content on climate change, (b) inquiry and community learning pedagogy, (c) their role as a teacher, (d) technology’s role in teaching, and (e) in the coherence of their knowledge. The enactment analysis revealed that all teachers performed more roles than the research team had anticipated in the designed curriculum. The interaction analysis indicated that while teachers spent a lot of class time dealing with logistical and pedagogical issues, they also spent considerable time guiding students’ learning activity, setting the learning context, and helping students to elaborate their ideas.

The contributions of this study include: (a) a formal description of the teacher’s role in the KCI model, (b) specific guideline for teachers teaching with KCI model, (c) scientific information concerning different forms of teacher knowledge and their correlation with classroom practice, (d) methods of analysing teacher-student interaction and measuring the coherence of teachers’ knowledge.
Acknowledgement

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Chapter 1
Introduction

The 21st century both requires for, and provides the technological capability for dramatic changes in the nature of teaching and learning in K12 schools. The Information Revolution that started in the 1950s has brought us into a “New Economy” characterized by the wide use of information and communication technology (ICT) in every aspect of human life and the globalization of business (Pohjola, 2002). As a result, the demands of the workplace in this century have changed to require workers to have knowledge-intensive and life-long learning skills (De Lisi & Golbeck, 1999; Zuboff, 1988). Schools therefore must now change to prepare students with the capabilities of 21st century citizens. Meanwhile, new information and communication technologies are now widely available in schools (De Lisi & Golbeck, 1999), providing many new tools and opportunities for changes in learning and teaching. Studying how technology is used in schools can help us properly use technology to foster students the desired abilities and skills.

A number of organizations and researchers have made efforts to define and categorize the term, “knowledge-intensive” skills (Warschauer & Matuchniak, 2010). For example, the Partnership for 21st Century Skills (2010a) published a framework of student outcomes, including 23 different knowledge content and skills sets that are grouped into four categories: the core subjects and interdisciplinary themes, learning and innovation skills, information, media and technology skills, and life and career skills. The International Society for Technology in Education (ISTE, 2007) published a standard for students that has six categories of skills, each of which has four performance indicators: (a) creativity and innovation; (b) communication and collaboration; (c) research and information fluency; (d) critical thinking, problem solving, and decision making; (e) digital citizenship, and (f) technology operations and concepts (see Table 1.1). The Assessment and Teaching of 21st century Skills (ATCS, 2010) also published their standard of 10 skills for 21st century learning, organized into four groups: (a) ways of thinking (e.g., creativity and innovation skill, critical thinking, problem solving, and decision making skill, and learning to learn and metacognition skill); (b) ways of working (e.g., communication and collaboration and teamwork; (c) tools for working (e.g., information literacy and ICT
literacy skills); and (d) living in the world (e.g., local and global citizenship skills, life and career skills, and personal and social responsibility skills). Common to these efforts is the notion that students should master not only the conceptual and procedural knowledge traditionally addressed in the school curriculum, but also the skills that will prepare them to be lifelong learners, adaptive problem solvers, critical thinkers and team members. The various frameworks tend to include a strong emphasis on media and technological literacy, critical thinking, creating and elaborating on knowledge, collaborating with peers, sharing in collective responsibility, embracing social and cultural diversity, and adapting to changing contexts (e.g., Bereiter & Scardamalia, 1996; Bransford, A. L. Brown, & Cocking, 2000; A. L. Brown & Compione, 1990, 1996; Partnership for 21st Century Skills, 2010a, 2010b; Scardamalia & Bereiter, 2006).

Table 1.1  
*The National Educational Technology Standards and Performance Indicators for Students*

<table>
<thead>
<tr>
<th>Standard categories</th>
<th>Performance indicators</th>
</tr>
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| Creativity and Innovation | • Apply existing knowledge to generate new ideas, products, or processes.  
• Create original works as a means of personal or group expression.  
• Use models and simulations to explore complex systems and issues.  
• Identify trends and forecast possibilities. |
| Communication and Collaboration | • Interact, collaborate, and publish with peers, experts, or others employing a variety of digital environments and media.  
• Communicate information and ideas effectively to multiple audiences using a variety of media and formats.  
• Develop cultural understanding and global awareness by engaging with learners of other cultures.  
• Contribute to project teams to produce original works or solve problems. |
| Research and Information Fluency | • Plan strategies to guide inquiry.  
• Locate, organize, analyse, evaluate, synthesize, and ethically use information from a variety of sources and media.  
• Evaluate and select information sources and digital tools based on the appropriateness to specific tasks.  
• Process data and report results. |
| Critical Thinking, Problem Solving, and Decision | • Identify and define authentic problems and significant questions for investigation.  
• Plan and manage activities to develop a solution or complete a project. |
| Making                                      | • Collect and analyse data to identify solutions and/or make informed decisions.  
    |                                             | • Use multiple processes and diverse perspectives to explore alternative solutions.  
| Digital Citizenship                        | • Advocate and practice safe, legal, and responsible use of information and technology.  
    |                                             | • Exhibit a positive attitude toward using technology that supports collaboration, learning, and productivity.  
    |                                             | • Demonstrate personal responsibility for lifelong learning.  
    |                                             | • Exhibit leadership for digital citizenship.  
| Technology Operations and Concepts          | • Understand and use technology systems.  
    |                                             | • Select and use applications effectively and productively.  
    |                                             | • Troubleshoot systems and applications.  
    |                                             | • Transfer current knowledge to learning of new technologies.  

An important question is concerned with how schools can help students to develop such 21st century skills. Many scholars argue that the curriculum should be adapted to include these skills within inquiry-oriented learning activities where students collaborate to solve open ended problems, making meaningful use of digital media and critical applications of information (Partnership for 21st Century Skills, 2010b). Thus, a 21st century curriculum should explicitly engage students in 21st century skills during their learning of core academic subjects, demanding that teachers employ innovative and research-proven instructional strategies that integrate modern technologies and real world resources and contexts (Means & Olson, 1995; Partnership for 21st Century Skills, 2010b). However, traditional curriculum, which tends to employ didactic instructional methods (e.g., lecture and problem sets), is quite far removed from this challenging objective (Collins & Halverson, 2009). Therefore, to effectively engage students with 21st century learning skills, schools must begin to change their approaches to teaching and learning.

Another major influence on education is the emergence of information and communication technology (ICT), which has provided new tools and materials to support the integration of 21st century skills into learning and instruction. ICT tools can provide students with opportunities to construct and manipulate their own representations of curricular topics, to progressively revise their products, to access real data and information and engage in more
authentic learning contexts. ICT can also support students as they collaborate with and give and receive feedback from peers and experts in communities that extend beyond their classroom. For example, they could receive support in articulating or explaining their thoughts and deciding what steps to take in their learning. Such deeply connected approaches can help accommodate individual differences, allowing students to explore their individual interests, to develop deeper and more focused interests in the topics they are studying, and to be motivated in their learning (Blumenfeld et al., 1991; Bransford et al., 2000; Scardamalia & Bereiter, 2006). Thus, the integration of ICT in K-12 curriculum could support students’ development of 21st century skills. However, Cuban (1986, 2001) and others have argued that merely providing schools with technology neither improves students’ achievement on standard tests nor enhances their 21st century capabilities. Scholars have argued (e.g., Collins & Halverson, 2009; Slotta & Linn, 2009) that technology simply “added in” will not enhance students’ learning unless accompanied by fundamental changes to the traditional didactic instructional strategies. These scholars emphasize that technology will have positive impacts on teaching and learning only when used in support of carefully designed curriculum and instructional strategies. Their point is that the successful integration of ICT within the K-12 school curriculum will require dramatic changes in how students learn and how teachers teach.

Research on learning and instruction has dramatically advanced our understanding of how people learn. A long history of research into the nature of learning and instruction exists (for a review see Bransford et al., 2000). Since 1990, the learning sciences has emerged as a new multidisciplinary research field, informed by disciplines in psychology, education, computer science, philosophy, sociology, and other scientific disciplines (Bransford et al., 2000; Savery, 2006). With research in learning sciences, we now understand that students cannot learn deeply by simply listening to lecture or reading textbooks because children have a different mind structure and think differently from adults (Savery, 2006). We know the reason that technology had no impact on learning and teaching is that it was used in most school with unchanged traditional curriculum and instructional strategies; technology will have positive impact on teaching and learning only when schools use technology with properly designed innovative curriculum and instructional strategies (Collins & Halverson, 2009). We realize that social interactions has strong influence on student’s learning and that collaboration and collaborative discourse are central elements of classroom-based learning. Learning sciences also inform us that
knowledge (and hence learning) is situated within a context and typically connected to practices that occur in a social or collaborative context (Savery, 2006).

Research in learning sciences has advanced many innovative and effective approaches to learning and instruction. With substantial work by educational researchers in the domains of mathematics (e.g., Kaput & Roschelle, 1999) and science (e.g., Krajcik et al., 1998; Linn & Songer, 1991), many innovative pedagogical models, often with the support of technology, have been proposed and investigated, including cooperative learning (Slavin et al., 1985), project-based learning (Blumenfeld et al., 1991), inquiry-based learning (IL; Krajcik, Slotta, Reiser, & McNeill, 2008; Linn & Songer, 1991), problem-based learning (PBL; Barrows & Tamblyn, 1980), and many others. These approaches have been effective in enhancing student’s learning of both basic content and the 21st century skills (Partnership for 21st Century Skills, 2010b). For example, Hmelo-Silver and her colleagues (Hmelo-Silver, 2004; Hmelo-Silver, Duncan, & Chinn, 2007) reviewed the effectiveness of problem-based learning. These authors concluded that PBL and IL were more effective than traditional approaches to learning when student’s learning outcomes were measured using scores on standardized tests on content learning. PBL and IL were also found effective in fostering students’ deep and meaningful learning. Students learning with PBL and IL methods were more capable of (a) constructing an extensive and flexible knowledge base; (b) developing effective problem-solving and reasoning skills; (c) developing self-directed, lifelong learning skills; and (e) becoming effective collaborators and intrinsically motivated learners.

A promising approach investigated currently by learning scientists is the “knowledge community.” This approach considers the classroom as a community in which students learn through interaction and collaboration with peers, adding ideas and resources to a community knowledge base and maintaining a sense of collective progress (A. L. Brown, 1992; A. L. Brown & Campione, 1990, 1994, 1996; Elbers, 2003; Elbers & Streefland, 2000a; Scardamalia & Bereiter, 1992a, 2003). This “knowledge community” approach aims to advance the collective knowledge and skills of the community as well as to develop students’ individual knowledge (Bielaczyc & Collins, 2006; Lipman, 1991; Scardamalia & Bereiter, 1994, 2006; Slotta & Najafi, 2012). Students work together as a whole classroom (or even multiple classrooms) to gather evidence, debate arguments, and inform one another’s inquiry to make progress on a conceptual
challenge. Ideas are shared and cognitive responsibilities are distributed among the community members. New knowledge is created in the process of reflection and synthesis of individual students’ work, and unique discourse patterns are formed in a progressively scientific fashion (Bielaczyc & Collins, 2006; A. L. Brown & Campione, 1994, 1996; Scardamalia & Bereiter, 1999). The knowledge community approach is consistent with 21st century learning, as students are engaged in authentic learning activities, interacting autonomously with peers in rich social contexts, designing solutions to ill-defined problems with the aid of new media and ICT.

However, the knowledge community approach has not enjoyed much success at the secondary level (Slotta & Peters, 2008; Staples, 2007). Teachers find it quite challenging to adopt such pedagogical approaches, which typically demand substantially change their perspectives about teaching and learning (Cohen, 1994; Elbers & Streefland, 2000b; Fishman, Marx, Best, & Tal, 2003; Fishman, Marx, Blumenfeld, Krajcik, & Soloway, 2004; Shulman & Sherin, 2004; Staples, 2007). The knowledge community approach is a complex form of instruction that requires teachers to incorporate dramatic new forms of student interaction, knowledge building, and autonomous inquiry activities. Yet, current research has not provided enough information about how a teacher should create or adopt a knowledge community approach in the classroom. What should a teacher do to prepare? What kinds of materials, tools or activities should be designed? How should students be introduced to the ideas, and how will they be assessed? This lack of detail has placed such approach even further out of reach of widespread adoption by teachers (Boaler, 2003; Elbers & Streefland, 2000b; Gillies, 2006). Further, Teachers also have little or no opportunity to learn this new approach in the context of any typical professional development (Collins & Halverson, 2009). Hence, no teacher or researcher will likely enjoy immediate success in adopting a knowledge community approach (Slotta & Najafi, 2012). Scardamalia and Bereiter (2006) observed that it could take two years or more to establish such a classroom ecology that is suitable for knowledge building. In addition, teachers in the secondary level have to cover the heavy subject content and to deal with traditional student assessment that required in various curriculum standards (Fishman et al., 2004; Gillies, 2006; Slotta & Peters, 2008; Staples, 2007). All these requirements and concerns, taken together, make the knowledge community approach prohibitive for teachers and researchers, particularly in domains like secondary science where substantial content must be “covered” by teachers (Gillies, 2006; Slotta & Najafi, 2012).
In an attempt to make the knowledge community approaches more accessible to teachers, Slotta and his colleagues (Slotta & Najafi, 2012; Slotta & Peters, 2008) have introduced the Knowledge and Community Inquiry (KCI) model that integrates a new dimension of scaffolded inquiry within a knowledge community approach. In this model, students engage in collaborative knowledge construction activities to explore ideas, add resources and co-edit pages that serve to develop a community knowledge base. Students work individually or collaboratively in scaffolded inquiry activities, drawing resources from the community knowledge base to produce new elements to that knowledge base as well as to a specific outcome (e.g., a design project) that allow assessment of individual understanding (Slotta & Peters, 2008). KCI model is more accessible to teachers compared to other knowledge community approaches to learning.

1.1 Statement of the Problem

To date, there has no research about teacher’s role in KCI model. The KCI model has been implemented several times in previous research studies. Early implementations (e.g., Najafi, 2011; Peters, 2010; Slotta & Peters, 2008) were successful in that students actively participated in the co-authoring of community knowledge resources, developed deeper understanding of subject matters, learned the required curriculum content, and improved their performance over previous years on final examinations (Peters & Slotta, 2010a). These early implementations demonstrated that the KCI model was effective in engaging students as a knowledge community while also structuring inquiry activities that address content expectations (Peters & Slotta, 2009, 2010a; Slotta & Peters, 2008). However, to date there has been no clear explanation of the teacher’s role within KCI model, in terms of the desired forms of teacher-student interactions, use of books and other resources, and identified needs or expectations to be met by the teacher at various points in the curriculum.

In deed, there is a lack of research about teacher’s role in knowledge community approach in general. Current research has not specifically examined the actual teaching process that must occur within such pedagogies in order for teachers to succeed (A. L. Brown & Campione, 1994; Crawford, 2000; Davis & Sumara, 2007; Nir-Gal & Klein, 2004), nor has it articulated what they should ideally be doing. Without such descriptions, it is challenging to design and enact any innovative instructional approach, as the teacher and researchers will lack a
clear agreement on the design and enactment. The knowledge community approach epitomizes this challenge, given the fundamental shift in epistemology that is entailed, the new forms of interactions with students, the complexity of managing groups of students and helping them create and use a knowledge base, and the need to cover extensive content expectations. The activity of a knowledge community approach is very integrated, and needs to be considered holistically, meaning that it should be applied to an entire semester or year-long course, systematically applied to all classroom activities and assessments (Slotta & Najafi, 2012), something that only accentuates the need to articulate the teacher’s role within the model. The limited success of knowledge community approach may be partly a result of lacking understanding about teacher’s role within the approach (Staples, 2007).

1.2 The Importance of Studying the Teacher’s Role

It is important to study the teacher’s role in a knowledge community because teachers play a critical role, both in classroom innovations and, generally, in students’ learning. Implementing a knowledge community approach presents a daunting challenge for teachers whether novices or veterans, and a better understanding of the teacher’s role within a knowledge community approach could inform professional development practices (e.g., teacher training programs).

Teachers play a critical role in the adoption and evolution of any school-based innovations (Borko, 2004; Cochran-Smith & Zeichner, 2006; Cuban, 1993; Hudson, 1997; Margerum-Leys & Marx, 2004; Sherin, Mendez, & Louis, 2004; Spillane, 1999;). Teachers’ intensive involvement is a critical factor for the success of any educational innovation (Nir-Gal & Klein, 2004), including the knowledge community approach (Bielaczyc & Collins, 2006; Slotta & Najafi, 2012). They are the executers of any innovation, and their success will determine whether the desired pedagogical change can be carried out or not (Cuban, 1993; Garet, Porter, Desimone, Birman, & Yoon, 2001). If a teacher does not wish to change, for example, it is not likely that they would do so, no matter what the form of professional development. Teachers’ conceptual understanding of the underlying pedagogical theories will greatly influence whether they can enact the innovation with fidelity to its design (Shulman & Sherin, 2004). However, research has largely ignored the teachers’ role in any educational innovation (Shulman
& Sherin, 2004). Therefore, studying the teacher’s role will help us to better understand how we can support teachers in design and enactment of knowledge community curriculum.

Teachers have substantial influences on students’ learning, including the design of learning sequences and scaffolding of learning processes (Cochran-Smith & Zeichner, 2006; Rowan, Correnti, & Miller, 2002; van Joolingen, de Jong, & Dimitrakopoulou, 2007). Teachers organize students’ learning activities and procedures in classroom (Baines, Blatchford, & Kutnick, 2008; Elbers & Streefland, 2000b). They directly support students’ discussions and interactions with learning materials (Light & Light, 1999; Meloth & Deering, 1999; Mercer & Wegerif, 1999; Rasku-Puttonen, Eteläpelto, Arvaja, & Hääkkinen, 2003; Rasku-Puttonen, Eteläpelto, Lehtonen, Nummila, & Hääkkinen, 2004). According Vygotsky’s (1978) notion of Zone of Proximal Development, students benefit from interactions with peers who are slightly more mature in their understandings, and from materials representing a slightly more sophisticated view or interpretation than their own. Typically, it is the classroom teacher’s role to provide for such interactions (Elbers & Streefland, 2000b). Even though students take more responsibility for their learning in knowledge community, they still need teachers to structure and scaffold their learning process (Baines et al., 2008; King, 2008; O’Donnell, 2006). This includes explicit prompting or guidance in collaborating with peers to attain successful learning (Bennett & Dunne, 1991; A. L. Brown & Campione, 1994; Elbers & Streefland, 2000b; King, 2008; Rogoff, 1994). Hence, studying the teacher’s role in the knowledge community approach can reveal how teachers organize and support students’ learning, thus informing formal descriptions of how the knowledge community approach provides students with learning opportunities and foster their 21st century capabilities (Staples, 2007).

To transform a classroom of students into a knowledge community likely requires a substantial and challenging shift in the teacher’s pedagogical perspective (Fishman et al., 2003; Schoenfeld, 2004; Sherin et al., 2004; Shulman & Sherin, 2004). This is sometimes described as a shift from the role of direct knowledge provider to that of a “coach” or facilitator who functions as a “guide on the side” instead of a didactic “sage on the stage” (Cohen 1994; Cuban, 1993; King, 1993; Nir-Gal & Klein, 2004). However, the notion of facilitator may oversimplify the teacher’s role in the knowledge community approach as being relatively passive or less supportive (Crawford, 2000; Sherin et al., 2004; Staples, 2007). Simply having students take on a
greater responsibility for their own learning does not mean that teachers should step back and just let things happen (Cooper, 2002). Rather, the teachers should gain greater levels of responsibility to actively interact with students, support their collaborative inquiry practices and guide their development of ideas and understanding. The “facilitator” notion is overly vague and does not specify any detailed account of teacher’s role (Staples, 2007). Research on teacher’s role in the knowledge community approach is needed to reflect what really happened in the classroom and to reveal information such as how intrusive should the teacher be? How and when should the teacher intervene, or leave the students to work on their own? How can the teacher evaluate evidences of student achievement, and respond to student ideas? What is the trajectory of student-teacher interaction in a long-term period (Crawford, 2000, Gillies, 2004, Rasku-Puttonen et al., 2003)? Detailed description of the teacher’s role in the knowledge community approach will inform teachers and researchers who want to enact such approach in the classroom.

Professional development is a key to the success of any educational reform (Committee on Science and Mathematics Teacher Preparation, 2001; Supovitz, Mahyer, & Kahle, 2000), which often relies on innovative pedagogy. Teachers in their early stage of technology adoption often need to emulate other’s enactment of new pedagogy (Guo, Wang, & Zhao, 2011). Professional program or pre-service teacher training program needs to provide detailed guidance or scripts to teachers who newly adopt innovative pedagogy. Substantial change or improvement in teacher’s instructional practices results from high-quality professional development programs that can explicitly demonstrate the types of teaching that teachers can emulate (Borko, 2004; Supovitz et al., 2000). Sufficiently detail description of teacher’s role in the knowledge community approach will help to inform professional development program and pre-service teacher training program so that teachers can adopt the approach in schools.

1.3 Research Purpose and Questions

Every pedagogical model is advanced with a particular purpose, features, and principles (Slotta & Najafi, 2012). To achieve the goals of a pedagogical model, teachers should thus perform certain roles and enact in certain patterns. While the model’s principles can be a guideline for teachers, they may fail to say much about the teacher’s specific role (i.e., what the
teacher should do in the classroom, under what conditions). The KCI model is no exception; while one of the principles does state that the teacher should have a clearly defined role, it does not clarify anything about what that role should be. Some implicit aspects that may be inferred do exist. Examples are that the teacher would need to interact with students during inquiry and may need to guide the whole class through discussions. However, the specific roles for teachers are currently not elucidated anywhere. One of this project’s stated goals is to capture such details by examining real teachers’ practices during a KCI implementation.

In order to elucidate the teacher’s role in knowledge community approaches, I analyse the processes of the day-to-day instruction of three teachers teaching a climate change curriculum unit in KCI model. By examining the teachers’ enactment of a designed curriculum and their interactions with students in classroom, I aspire to achieve the following research goals:

- To create a fine-grained description of the teachers’ role as an enactor of the knowledge community and inquiry approach and to characterize the patterns of teacher-students interaction in the classroom.
- To explore the relationships between the teachers’ background knowledge and their patterns of interaction with students.

The specific research questions of my study are:

1. What is the teacher’s role in KCI curriculum? Including:
   a. What roles are designed – implicitly or explicitly – into the curriculum?
   b. What roles are actually enacted by teachers in the implementation of the designed KCI curriculum?
2. What are the patterns of the teacher-students interaction in the KCI climate change curriculum?
3. Do the patterns of the teachers' interaction with students correspond to their knowledge of KCI or other relevant background knowledge?
1.4 About the Researcher

My prior experiences in China led me to an interest in understanding how teachers use technology in their classrooms in productive ways. I obtained my Bachelor’s degree and my first Master’s degree in Educational Technology in the Chinese Normal University system. I also had worked at South China Normal University as a faculty member teaching pre-service students and training in-service teachers about using technology in teaching. I had also been very impressed with the level of interest and effort that Chinese teachers put into improving their practice and how much attention is given to that challenge by scholars.

Coming to Canada expanded my interests to include new ways of structuring instruction. Classrooms in China are usually larger – sometime two or three times larger – than those in most Western countries. The didactic, lecture-based teaching practice is therefore the dominant instructional model in China. Furthermore, few opportunities exist for student-to-teacher or student-to-student interactions in Chinese classrooms. In Canada, I had my first constructivist learning experience during my Masters’ program at the University of Toronto. I found this approach to learning to be more effective than the lecture-based approach and was fascinated by this constructivist approach and its underlying theoretical perspectives. However, I also realized that some constructivist approaches may be so open-ended that they take power and control from the teacher; for example in deciding what students will learn (e.g., in knowledge building or discovery forms of inquiry). In contrast to open-ended constructivist approaches, Chinese teachers take great responsibility in deciding what students should learn and I, therefore, was pleased to find KCI as a theory and practice that takes a middle path.

1.5 About This Thesis

This thesis has five chapters. The present chapter situates the context of my study and presents my research questions. Chapter 2 presents the conceptual framework of this study and reviews related research about the KCI model, teacher’s role within inquiry approaches and knowledge community approaches, and teacher knowledge and teaching practice. Chapter 3 begins by justifying the research methods and use of video data in this study, then describes the details of procedure, research site and participants, and the specific coding schemes and data
analysis techniques. I also discuss the validity and reliability issues involved in the study. In Chapter 4 I present the results of my study in four analyses: curriculum design analysis, teacher enactment analysis, teacher background knowledge analysis, and teacher-students interaction analysis. Finally, Chapter 5 addresses the research questions, discuss the contributions of my study to the learning sciences literature, outline some research limitations, and describe some future research directions.
Chapter 2
Literture Review

In this chapter I first describe the conceptual framework that I adopted to inform my study and literature review. Then, I introduce the Knowledge and Community Inquiry (KCI) model. In the third and fourth sections of this chapter, I review two pedagogical models that underlie the KCI model: inquiry-based learning and the knowledge community approach as well as studies about teacher’s role in these two pedagogical models. In the fifth section, I review theories about teacher knowledge and teaching practice because they influence teacher’s classroom enactment. In the last two sections, I review challenges to adopting new pedagogical approaches to learning and instruction and technology scaffolds for inquiry and the knowledge community approach.

2.1 The Conceptual Framework of My Study

Research framework is the fundamental structure that supports a study (Eisenhart, 1991). It helps define researcher’s perspective and guide the research process for a study. Eisenhart elaborated three types of frameworks that qualitative research can take: theoretical, practical, and conceptual. She defined conceptual framework as “skeletal structure of justification” (p. 209) that argues for the reasons for adopting ideas and concepts. Researchers often build conceptual framework from an array of wide-range of research to facilitate comprehensive investigation of research problems. Eisenhart believed that conceptual framework better suites for educational research.

Figure 2.1 is the conceptual framework that I used in my study. This framework describes the various influences on a teacher’s enactment of a KCI curriculum. The KCI model itself is the core of the conceptual framework of my research. Therefore, three specific theoretical aspects of KCI model, establishing collective epistemology, supporting community of knowledge construction, and scaffolding students inquiry, are included in the framework on the lower level of Figure 2.1. Further, other pragmatic and background features that have strong impact on teacher’s enactment, such as teacher’s knowledge and experience, challenges to teacher’s
adoption of new pedagogical approaches, and technology scaffolds for inquiry and knowledge community approaches, are also included in the framework and shown in the top level of Figure 2.1. In the next few sections I am going to review research literature based on this framework.

Figure 2.1 Conceptual framework of this study

2.2 The Knowledge Community and Inquiry Model

The knowledge community approach has exciting potential for engaging students in 21st century learning, and has earned great respect in the community of learning sciences (Peters & Slotta, 2010a). However, it is quite challenging to implement this approach in any classroom because it requires teachers to substantially change their pedagogical practices to transform their classroom into a community of learners (Blumenfeld et al., 1991; Kling & Courtright, 2003). For this reason, the knowledge community approach has not enjoyed much success at the secondary level (Staples, 2007), partly because of the heavy content expectations teachers must address, the traditional assessments students must perform, and the challenging forms of teaching practice that is required (Slotta & Peters, 2008).
In order to make this method more accessible to teachers as well as to extend the theoretical perspective, Slotta and his colleagues (Slotta, 2007; Slotta, & Peters, 2008; Slotta & Najafi, 2013) have introduced the Knowledge Community and Inquiry (KCI) model, which is a blended model that integrates scaffolded inquiry-based learning with a knowledge community approach. In this pedagogical model (see Figure 2.2), students engage in collective knowledge building activities to explore and examine their own ideas, which are then aggregated into a community knowledge base. Next, the teacher synthesizes students’ ideas and selects driving questions or issues for students to investigate during subsequent scaffolded inquiry activities. Students may be divided into “issue groups,” for example, where each group works on one question or issue that emerged from their earlier knowledge construction activities, adding knowledge resources to a community knowledge base relating to their issues. They would then utilize the knowledge base (i.e., across all issues) as a resource in scaffolded inquiry activities that were carefully designed to engage their learning in the target domain. In order to ensure that the questions connect to students’ personal interests while also addressing the required the curriculum content, KCI gives the teacher a more active role in designing the inquiry activities (i.e., instead of letting students develop their own question). Students work individually or collaboratively in scaffolded inquiry activities, using the knowledge elements or content from the community knowledge base, producing new elements for the knowledge base and achieving specific outcomes that provide measures of individual understanding and the advancement of collective knowledge of the class. Students within a group must decide how they will distribute their learning activities among the members of a group (e.g. with each student working on one or two sections of an issue, or all working together on all sections). Students may also be recomposed using a “jigsaw method” (A. L. Brown & Campione, 1996) where each new group consists of one or two members from each of the previous groups. In the new Jigsaw groups, students combine their expertise built from the earlier groups to create final products that will demonstrate their complete understanding of the entire topic.
The idea behind the KCI model is to ensure a balance between covering the required content and adopting a social, knowledge community approach to learning (Peters & Slotta, 2010b). In a series of published papers, Slotta and his colleague (Peters & Slotta, 2010a, 2010b; Slotta & Najafi, 2013; Slotta & Peters, 2008) articulated the elements and principles of the KCI pedagogical model. The essential elements of the KCI pedagogical model include: (a) a sense of community identity, (b) a community knowledge base that students created throughout the curriculum and improved and used during (c) collaborative knowledge construction activities, and (d) scaffolded inquiry activities, (e) specific learning goals that should be addressed, (f) sustained and distributed interactions, and (f) teacher as player-manager.

Four fundamental principles in the KCI model guide the design of students’ learning activities, the technology enhanced materials and the learning environment (Slotta, 2013; Slotta & Najafi, 2013). First, students work together as a community to produce a knowledge base indexed to the specific content domain. Second, students use the knowledge base as a resource when they engage in a sequence of collaborative inquiry activities. Third, students’ collaborative inquiry activities address the targeted domain learning goals and themes that merge within the community and result in assessable outcomes indexed to the learning goals. Fourth, the teacher’s
role is specified within the inquiry script, in addition to the teacher’s general orchestrational responsibility. These four principles present a foundation for the design of learning activities and the development of technology enhanced materials and learning environments (Slotta, 2013).

2.3 Learning and Instruction through Inquiry and Collaboration

Inquiry-based learning is an instructional approach that inspired by the manner in which scientists approach problems that they would like to investigate through their research (Singer, Marx, Krajcik, & Chambers, 2000). Inquiry has been defined as “the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work” (NRC, 1996, p. 23). Science inquiry process includes the development of theories through a process of successive elaboration and refinement, and the use of scientific models to account for new phenomena in a domain (White, 1993; White & Frederiksen, 1998). Traditional approaches to science teaching have not typically reflected scientist’s practices, as they emphasize the presentation of decontextualized scientific knowledge, facts, models and principles (i.e., the body of knowledge that scientists have already constructed and confirmed). These didactic methods neglect important aspects of scientific practices, such as reasoning skills, the habits of scientific mind, methods of inquiry, applications of science in life world (Dewey, 1910; NRC, 1996, 2000). Researchers in science education have argued that a better approach to teaching science is to “mirror as closely as possible the enterprise of doing real science” (NSF, 2000, p. 2). They have drawn on this notion of inquiry to define this inquiry-based model of learning and instruction.

Inquiry-based learning aims to help students develop conceptual understanding and reasoning skills through investigations of authentic problems (Linn & Eylon, 2006), closely reflecting how scientists conduct real science (NSF, 2000). Many investigators have explored the development of inquiry-oriented instruction for K-12 science, under the argument that by engaging students in such activities, they will develop a deeper conceptual understanding (by constructivist arguments) as well as a better understanding of the nature of science (e.g., Clark, Weinberger, Jucks, Spitulnik, & Wallace, 2003; Hmelo-Silver et al., 2007; Sandoval, 2005; Sandoval & Reiser, 2004; Smith, Maclin, Houghton, & Hennessey, 2000). While the idea of
inquiry-based learning originated in science education, it has been successfully extended to many other disciplines (Allus & Shore, 2008).

One approach to K-12 inquiry in science is that of an “inquiry cycle” that includes five steps which model the scientific inquiry process: defining questions, making prediction, conducting experiments, drawing conclusion, and applying the knowledge learned on new problems (White & Frederiksen, 1998). In the cycle, students first observe scientific phenomena of their interests and pose research questions. Students then generate hypotheses to predict the relations between variables. Next, they design and conduct experiments to investigate the problem by gathering and analyzing data, interpreting evidence, and constructing evidence-based arguments. Then, students draw and justify conclusions, and report their findings in the form of scientific arguments or models. Finally, they apply the acquired knowledge and skills in the inquiry of new learning topics. Ideally, students are engaged in reflecting on each of these steps to examine the limitations of what they have learned and critically examine their own methods. Many scholars have explored science curriculum that emulates this basic cycle, with reported success in terms of conceptual learning and epistemological development (Bell, Urhahne, Schanze, & Ploetzner, 2010; Edelson, Gordin, & Pea, 1999; Krajcik et al., 1998; Sandoval, 2005; Singer et al., 2000; Wheeler, 2000; White & Frederiksen, 1998).

Inquiry-based learning has several characteristics that make this approach suitable for science education (Blumenfeld et al., 1991; Crawford, Krajcik, & Marx, 1999; Edelson et al., 1999; Fisher, 2000; Hmelo-Silver et al., 2007; Krajcik & Blumenfeld, 2006; Krajcik, Blumenfeld, Marx, & Soloway, 1994; Krajcik et al., 1998; Linn, Slotta, & Baumgartner, 2000; Marx, Freeman, Krajcik, & Blumenfeld, 1997). Inquiry learning is student-centered, and adaptable to different learning styles and learning situations. In many implementations, students have the opportunity to select topics of their own interests and plan learning activities for themselves. Students are often motivated by anchoring inquiry learning in authentic, real-world problems that are relevant to students’ personal life or interests and connect abstract concepts to applications in the world beyond the classroom. Students are engaged with a wide range of tools and materials to encourage “high-order thinking” such as constructing and evaluating explanation, discoursing and representing disciplinary knowledge, and thinking critically and logically, rather than by means of memorization. Students collaborate with other students and
teachers in inquiry learning. Students produce tangible artifacts that represent students’ understanding of the problem they have been studying. Technology is often employed to scaffold students to participate in activities that traditional science class cannot provide. Because of these features, students have the opportunities to experience all aspects of scientific inquiry and thus to develop deep science knowledge, inquiry skills and scientific epistemology that science education desires (Edelson et al., 1999; Hmelo-Silver et al., 2007; NRC, 2000; Sandoval & Reiser, 2004).

### 2.3.1 Different forms of inquiry-based learning

Inquiry-based learning can vary in terms of the degree of guidance that the teacher provides as well as the freedom that students are allowed in the course of curriculum activities (P. L. Brown, Abell, Demir, & Schmidt, 2006; NRC, 2000; Zion & Sadeh, 2007). In the most structured form of inquiry learning, the teacher guides every steps of the process, defining the questions and procedures of investigation, providing the materials or tools, and prescribing the methods of data analysis. Students do experiments following the specific steps that are set by the teacher, and draw conclusions from their data. This type of inquiry learning is very specific about the sequence and structure of activities, and is sometimes referred to as a “cookbook” approach. This simple form of inquiry learning can be used to verify or demonstrate conceptual content that the teacher presented to the students before or after the inquiry activities (Kaartinen & Kumplulainen, 2002), and does not engage students very deeply in the learning process (Bell, Smetana, & Binns, 2005; Colburn, 2000; Martin-Hansen, 2002).

In guided or scaffolded inquiry, the teacher defines the question to investigate but students are more involved in determining the methods or procedures of investigation and coming up with conclusions based on their experiences in the activity. The teacher’s role is to provide access to materials, guidance, and learning scaffolds so that students can succeed with the inquiry process (Bell et al. 2005; Colburn, 2000; Martin-Hansen, 2002). In scaffolded inquiry, technology-enhanced learning environments are often employed to “scaffold” students in sense making, managing the activities, solving problems, articulating their ideas and reflecting on their learning (Quintana et al., 2004). Variants of guided or scaffolded inquiry include
problem-based learning (Evenson & Hmelo, 2000), projected-based learning (Blumenfeld et al., 1991), and scaffolded knowledge integration (Linn & Hsi, 2000).

Finally, in full or “open” inquiry models, students are responsible for every step of the inquiry process, including defining the question they will investigate. This approach gives students a lot of freedom in the learning process, and teachers provide materials and supports only when requested by students (Bell et al., 2005; Bell et al., 2010; Colburn, 2000; Fisher, 2000; Martin-Hansen, 2002). Learning processes are not a set of fixed operations, but rather a set of more general knowledge creation activities such as generation, classification, representing, linking, and annotation (Bell et al., 2010). This type of inquiry mirrors scientists’ actual work most closely. Sandoval (2005) believes that, in any inquiry, students are supported with guidance in one or more of the five steps mentioned previously, no matter whether the investigating question is defined by students or the teacher.

Collaborative inquiry adds a social dimension where students engage with peers and the teacher to acquire knowledge (Bell et al., 2010; Staple, 2007). Students work in groups to offer and compare their thoughts, producing shared meaning or understanding through their joint efforts (Linn & Eylun, 2006; Staples, 2007). This allows different perspectives, interpretations and attitudes to be brought into discussion within the learning process, and diverse explanations to emerge (Kaartinen & Kumpulainen, 2002). Collaborative inquiry has been shown to help students solve problems that would otherwise be too difficult for individual students working alone, because the cognitive load is distributed among members of a collaborative group (Pea, 1993; Salomon, 1993). The teacher is also a participant of collaborative inquiry who contributes his or her expertise to students’ learning (Kaartinen & Kumpulainen, 2002). The effects of collaborative learning are influenced by factors such as group composition, students’ developmental level, and features of the task, as well as by interactions amongst these factors (Dillenbourg, Baker, Blaye, & O’Malley, 1996). Collaborative inquiry has its roots in Piaget’s constructivist perspective and Vygotsky’s socio-cultural perspectives (Piaget, 1926; Vygotsky, 1962, 1978).
2.3.2 Teacher’s role in inquiry-based instruction

While a variety of technology supports can be embedded within the inquiry tasks or materials, the most important form of support that students receive will come from guidance provided by the teacher (Lakkala, Muukkonen, & Hakkarainen, 2005). Research about the teacher’s role in guiding inquiry can be categorized into two different levels, according to the grain size of analysis. The “coarse” level of analysis tends to summarize the overall function or role that the teacher provides. Studies in online learning, inquiry learning, and cooperative learning have suggested four general roles: a pedagogical role; a social role; a managerial role; and a technological support role (Berge, 1995; Bonk, Kirkley, Hara, & Dennen, 2001; Maor, 2003). The pedagogical role refers to the set of activities or behaviours that the teacher must enact in order to facilitate or moderate students’ learning, such as asking questions, probing student responses, encouraging and modelling student inquiry or collaboration, providing feedback, assessing or monitoring progress, etc. (Blumenfeld et al., 1991; Bonk et al., 2001; Maor, 2003). The social role serves to create a learning environment that is friendly, with a positive tone that promotes student participation (Berge, 1995; Bonk et al., 2001). In the managerial role, teachers coordinate assignments, manage classroom, and handle overall course structure (Blumenfeld et al., 1991; Bonk et al., 2001). Finally, in the technology support role, teachers assist students to deal with technological issues, diagnose and clarify technological difficulties, and others (Bonk et al., 2001; Maor, 2003; Slotta, 2004).

The more “fine grain” analysis examines the nuanced pedagogical roles that teachers play in helping students participate in the processes of inquiry (Elbers, 2003). The sections below present a summary of all the pedagogical roles that have been ascribed to teachers as they guide inquiry-based learning in their classrooms: encouraging collaboration, making connection, promoting reflection, modelling, guiding student learning, evaluating or monitoring learning, and elaborating student’s thinking. These roles will also serve as a foundation for some of the coding and analysis in this thesis.

Encouraging collaboration refers to that teacher uses various methods to help students become effective collaborators (Hmelo-Silver, 2004). Researchers emphasize the importance of establishing new norms of collaboration (Boaler, 2002; Cohen & Ball, 2001). For example,
teacher should encourage students to develop scientific arguments based on evidence (Minstrell & van Zee, 2000), to take individual responsibilities, and collaborate with peers (Johnson & Johnson, 2008; Lakkala et al., 2005). Teachers should create and maintain a classroom environment of acceptance and mutual respect (Cooper, 2002), encouraging students to share or exchange ideas, and helping them to validate or build on each other’s ideas (Crawford, 2000; Palincsar, 1998; N. M. Webb, 2008). Teachers should also suggest to students how they can engage in collaborative group work, such as how to reach consensus, and how to take turns in talking and listening (Krajcik & Blumenfeld, 2006; Johnson & Johnson, 2008; Palincsar, 1998). Getting the students to discuss the effectiveness of their collaboration and providing feedback on their collaborative behaviours can also be important roles for teachers in an inquiry classroom (Cohen, 1994; Johnson & Johnson, 2008).

Making connections means that the teacher helps students to recall or connect to their prior knowledge, experiences, or personal relevance. Learning involves making connections among ideas. However, students rarely spontaneously generate such connections between their exiting ideas and new ideas in their knowledge web (Linn, Eylon, & Davis, 2004). Therefore, the teacher should help students link their own ideas with the work of other students, as well as with some larger ideas that student will encounter later, and the various other ideas that students have explored during inquiry project (Krajcik & Blumenfeld, 2006; Linn et al., 2004; Staples, 2004, 2007). The teacher should ask students to connect their learning to personally relevant situations. This can include the use of tools that help students represent those connections among ideas or arguments, or links to elements of inquiry process (Linn et al., 2004). N. M. Webb (2008) suggested using questions to motivate students to connect ideas and to link new materials to their existing knowledge. Linn (2006) has argued that instructional strategies that support students in developing strong connections among ideas can provide a foundation for future learning.

Promoting reflection is a role where the teacher should encourage, request, or scaffold students to reflect on their learning activities or the learning process. For instance, Maor (2003) suggested that teachers should promote students’ reflective thinking through debates or role-play. Cohen (1994) emphasized the need for teachers to encourage students to reflect on their group collaboration to promote more collaborative behaviour and less competitive behaviour in classroom learning. Hmelo-Silver and Barrows (2006) suggested a summarizing approach to
help students reflect on the fit between their hypotheses and accumulated evidence in problem-based learning. Johnson and Johnson (2008) recommend having students periodically reflect on the effectiveness of their group work. Reflection can help students identify gaps in their thinking and transfer their problem-solving strategies and knowledge to new context (Hmelo-Silver, 2004).

Modelling is a role in which that teacher uses examples to demonstrate desired learning behaviours in either whole class activities or small group activities (N. M. Webb, Farivar, & Mastergeorge, 2002). Because it is difficult for students to engage in inquiry (Edelson & Reiser, 2006; Krajcik et al., 1998) the teacher should model how to perform investigations (Krajcik & Blumenfeld, 2006), how to guide reasoning with hypotheses, how to think reflectively (Hmelo & Evenson, 2000), how to solve problems (Cooper, 2002), how to explain their thinking, ideas, problem-solving strategies, or what they have learned from their inquiry to peers or the teacher (Oh, 2005; N. M. Webb et al., 2008). The teacher should also illustrate how to make connections, how to work collaboratively with others and build on other’s ideas, and how to deal with priority in inquiry. Showing examples of the attitudes and attributes of scientists is another way that teachers can provide models of inquiry (Crawford, 2000).

Guiding student learning is a role in which the teacher helps students to progress in their learning using various pedagogical strategies. For example, explaining the learning activities or inquiry process that students are going to complete (N. M. Webb et al., 2008) to ensure that students clearly understand the purpose of learning tasks and activities (Moreland, Jones, & Cowie, 2006); suggesting alternatives to the inquiry procedure (Roychoudhury & Roth, 1996); selecting appropriate cases or counter-examples to help students to generate hypotheses, disclose misconceptions, and examine ideas (Hmelo-Silver & Barrows, 2006); directing students’ activity towards the learning objectives (Wood, Bruner, & Ross, 1976); coaching, advising, or guiding students while they carrying out inquiry activities (Collins, J. S. Brown, & Newman, 1989; Krajcik & Blumenfeld, 2006); making the discrepancies between students’ products and the ideal production obvious (Wood et al., 1976) and guiding students to solve the discrepancies (N. M. Webb et al., 2008); providing hints to help students explain their solution of problem (N. M. Webb, 2008); and giving expert’s explanation and advising study practice (Lakkala et al., 2005). Staples (2007) suggested several approaches: requiring students to think
about particular questions or aspects of a problem to help guide their inquiry, providing structure to support students in developing and/or articulating their ideas, and modifying learning tasks to provide ‘food for thought’. Direct intervention, mediation of students’ interaction, and steering students’ discussion toward anticipated directions are also important roles of guiding and scaffolding (Hogan, Nastasi, & Pressley, 2000). Some researchers believed that helping students develop inquiry strategies (Crawford, 2000) and assisting students to become self-dependent for direction and information (Hmelo-Silver & Barrows, 2006) are important roles that can foster students’ general inquiry capability. Taken together, these researchers emphasize that the teacher’s guiding role is important for students to develop new understanding (Oh, 2005).

**Evaluating or monitoring learning** suggests that teacher evaluates, assesses, or monitors students’ learning progress, including their understanding of concepts and their learning outcome, and then provide relevant feedback. Copper (2002) suggested that teachers should ask probing questions to constantly diagnose and look into students’ understanding. Hmelo-Silver and Barrows (2006) recommend asking students to make summaries as a way of checking their understanding, to show students the importance and limitation of their thinking, and to monitor students’ inquiry progress to keep them on track and focused within the inquiry process. Maor (2003) believed that ongoing evaluation of students’ level of engagement is important. Johnson and Johnson (2008) suggest that the teacher should assess and evaluate the quality and quantity of students’ learning outcome as well as monitor students’ completion of learning task and their using of targeted interpersonal and group skills to determine if any intervention is necessary. Staples (2004, 2007) advocated progressively assessing and diagnosing students’ current state of understanding and the underlying difficulties they have. Lakkala et al. (2005) categorized reviewing and evaluating discourse as one type of teacher’s scaffolding in computer-mediated collaborative inquiry. Webb (N. M. Webb et al., 2002; N. M. Webb et al., 2008) advised teachers to actively monitor group work to make sure that every group members are involved collaboratively and that students would provide explanations instead of answers when asked. van Zee and Minstell (1997) and O’Donnell and O’Kelly (1994) also suggested monitoring students’ interaction.

**Elaborating students’ thinking** is where the teacher uses a range of pedagogical strategies to promote or elicit students to think more deeply and elaborate on their ideas. N. M.
Webb et al. (2008) examined the relationship between teachers’ practices of eliciting student thinking and students’ participation in explaining ideas in collaborative learning. These researchers found that how teachers asked students to elaborate their explanations have a strong correspondence with: (a) the nature and frequency of students explaining (of their ideas or understanding) to each other during collaborative conversations, and (b) students’ achievement. However, this relationship is not unidirectional, as teachers’ eliciting practices and students’ participation have mutual influences on each other. Staples (2004, 2007) summarized several methods to elicit students’ ideas and thinking: (a) making space for students’ thinking by seeking students input, thoughts, comments and questions; (b) requesting, pressing, and encouraging students to articulate, further explicate, and share their thoughts and praising them; (c) providing students sufficient time to formulate and articulate their thinking; (d) giving students participation points to contribute to discussion. Inquiry teachers are likely to use questioning techniques to push students’ thinking to deeper levels and to make students’ thinking and depth of understanding more apparent (Hmelo-Silver & Barrows, 2006).

### 2.4 Knowledge Community Approaches to Learning and Instruction

While the inquiry approach may place heavy emphasis on students’ collaboration in learning (Hmelo-Silver et al., 2007), the focus is still on the achievement of individual students, and neglects the social context of learning in a community of peers (Peters & Slotta, 2010b). The knowledge community approach to learning and instruction (Bielaczyc & Collins, 2006; Peters & Slotta, 2010b; Slotta & Najafi, 2010) aims to convert the classroom into a community of learners where students collaborate with peers and teacher (including many of the forms of inquiry reviewed above) to advance the collective knowledge and skills of the community as a whole (Lipman, 1991; Scardamalia & Bereiter, 1994, 2006).

#### 2.4.1 Features of knowledge community approaches

The goal of a knowledge community is to advance the collective knowledge and skills of the community while supporting the growth of individual students’ knowledge (Scardamalia & Bereiter, 1994). Students work collaboratively as members of a community to produce questions
and explanations, formulate hypotheses, interpret data, and develop a collective knowledge base that becomes the valuable “public property” of the whole class to be used as a resource in subsequent inquiry activities (Scardamalia & Bereiter, 1999). The individual student is valued and respected for his or her contributions to the community, and individual learning occurs in the socio-cultural context of activities within the community. That is, students’ personal knowledge grows as a by-product of their contributions to the construction of the collective meaning and insights of the whole community (Elbers & Steefland, 2000a; Rogoff, 1994; Scardamalia & Bereiter, 1999). Emphasis on the advancement of collective knowledge and skills is not incompatible with individual students’ learning (Scardamalia & Bereiter, 1999). Rather, there is a dialectical constitution of individual learning and community knowledge and advancement, which cannot be separated artificially (Stahl, 2000). Personal understanding is articulated and entered into a common knowledge base where it is shared, discussed, negotiated, and continuously revised through the social interaction process with other learners from multiple perspectives. This refined personal understanding then becomes a part of the accepted knowledge of the community, which later shapes individual ways of thinking (Stahl, 2000).

Another distinguishing feature of the knowledge community approach is the distribution of cognitive responsibilities amongst the members of the classroom community (A. L. Brown et al., 1993; Crawford et al., 1999; Slotta & Najafi, 2010). In a knowledge community, each member “makes significant contributions to the emergent understandings of all members, despite having unequal knowledge concerning the topic under study” (Palincsar, A. L. Brown, & Campione, 1993, p. 43). Students take a higher level of responsibility for developing their own questions, sharing and critiquing ideas with peers, reaching joint understanding, and evaluating their own progress (Slotta & Najafi, 2010; Elbers & Steefland, 2000a; Rogoff, 1994). Unlike other approaches that all students in a classroom must develop a base level of understanding on the same topics taught in the class, students in a knowledge community are encouraged to develop distinct forms of expertise in area where they are interested and capable (Bielaczyc & Collins, 1999; A. L. Brown et al., 1993). These different kinds of expertise will be brought together to solve problems and develop new ideas of the whole community. As a result, the community as a whole will be able to deal with problems or issues that are beyond any individual’s capability (Bielaczyc & Collins, 2006). Individual students are not only responsible for developing their own knowledge, but also responsible for the functioning and the
improvement of the collective knowledge and skills of the whole community (Rogoff, 1994). Individual students “rely on the contributions of their peers as a primary resource of learning” (Slotta & Najafi, 2010, p. 193), and community members are crucially dependent on each other (A. L. Brown, 1997). The teacher participates as an expert who can provide various supports and guidance to students instead of as source or expert of knowledge (Rogoff, 1994; Slotta & Najafi, 2010).

The culture of sharing ideas is another important aspect of the knowledge community approach (Bielaczyc & Collins, 2006). Sharing ideas and collaboration have two functions. First, since students are encouraged in developing expertise in an area of their individual interests, and expertise is distributed among the members, sharing knowledge and skills among members of the community is the only way to pull things together and guarantee that students will learn from their peers and develop a comprehensive understanding of the overall learning content (A. L. Brown & Campione, 1996). Second, knowledge sharing leads to knowledge creation (Bielaczyc & Collins, 2006). In a knowledge community, members are excited to share their ideas and feel free to voice their opinions without fear of negative consequences. Individual students’ understanding is displayed publicly to the community with the aim of improving everyone’s understanding (Crawford et al., 1999). Thus, multiple perspectives are presented to students for their consideration, analysis and comparison, allowing them to develop a comprehensive understanding of the entire content domain and add their own new ideas (Bielaczyc & Collins, 2006; A. L. Brown & Campione, 1996). A shared community-knowledge base, where ideas and resources that students contributed to the community are aggregated and developed, provides a mechanism to easily access and share various ideas and resources, informing students’ discussions and arguments (Bielaczyc & Collins, 2006), negotiation of meanings (Crawford et al., 1999), and design and production of artifacts that draw on the collective understanding of a community (Peters & Slotta, 2010a; Slotta & Najafi, 2010).

Reflection and synthesis are a means of creating new knowledge within the community (Bielaczyc & Collins, 2006). In order to create new knowledge or a final product or artifact that represents the collective understanding of a community, students must draw on their individual expertise and disparate ideas, reflecting on their individual works as well as the common endeavor of the community. They need to set up criteria for evaluating their individual works
and common endeavor to determine the quality of their works as well as how they might improve the quality in the feature. They can record their process of carrying out a work and compare it to other similar processes to determine the strengths and weaknesses of their process so that they will be able to make the process better. In this process, the teacher serves as an information broker who communicates and connects students together, and offers resources as needed (Bielaczyc & Collins, 2006).

The discourse patterns of a knowledge community are distinct from the formal language of learning that occurs within traditional classrooms, where the emphasis is on content dissemination. In a classroom community of learners, the discourse pattern emerges through the interaction with various resources and through the construction and negotiation of meanings amongst members. The community will develop its own unique way of articulating the learning process, expressing ideas, or thinking in a progressively scientific fashion. Only the legitimate members of the community can understand such articulation (Bielaczyc & Collins, 2006; A. L. Brown & Campione, 1994).

2.4.2 Specific examples of knowledge community approaches

Knowledge Building (KB) and Fostering a Community of Learners (FCL) are two knowledge community approaches that have been widely recognized and researched in the context of K–12 classrooms (Slotta & Najafi, 2010).

Knowledge building is defined as “the production and continual improvement of ideas of value to a community, through means that increase the likelihood that what the community accomplishes will be greater than the sum of individual contributions and part of broader cultural efforts” (Scardamalia & Bereiter, 2003, p. 1371). In our contemporary “knowledge society” (Stehr, 1994), knowledge creation and innovation are highly valued as the forces of social progress and the sources of health and wealth of a society. Thus, the primary goal of school education should be to help students develop the ability of creating new knowledge so that they will be able to participate as 21st century citizens. Knowledge building is an approach that addresses this goal by engaging learners in the full process of knowledge creation (Scardamalia & Bereiter, 2003, 2006).
The core notion of knowledge building is the advancement of the collective knowledge and skills of the classroom community, rather than individual learning and performance (Scardamalia & Bereiter, 2003, 2006). Knowledge building is constructivist but dramatically disparate from other constructivist approaches in two aspects. First, it addresses the pervasiveness of knowledge creation and innovation in the world. Second, it emphasizes the achievement of a whole community rather than individual students’ achievement. This does not mean that individual achievement is neglected in knowledge building. Individual students’ learning is a recognized by-product of the knowledge building activity for all the members of a community (Scardamalia & Bereiter, 2003).

In knowledge building classrooms, students take collective cognitive responsibilities for the progression of the state of community knowledge (Scardamalia, 2002). Students initiate questions, set the goals, and plan the activities; they work on real and diverse ideas, and creatively and actively improve the quality, coherence, and utility of ideas; they promote the community’s understanding to a higher and more inclusive level; they also monitor the knowledge building process (Scardamalia, 2002; Scardamalia & Bereiter, 1999, 2006). The teacher in a knowledge-building classroom will also share the collective cognitive responsibilities but give students greater autonomy in the process of knowledge building (Scardamalia, 2002). Discourse in knowledge building is more constructive and progressive (Bereiter, Scardamalia, Cassells, & Hewitt, 1997), aiming to advance the state of knowledge, seek shared understanding, and expand the base of accepted concepts (Scardamalia & Bereiter, 2006).

In an attempt to capture the dynamics of knowledge creation in Knowledge Building approach, Scardamalia (2002) proposed 12 Knowledge Building principles: real ideas and authentic problems, improvable ideas, idea diversity, rise above, epistemic agency, collective responsibility for community knowledge, democratizing knowledge, symmetric knowledge advancement, pervasive knowledge building, constructive uses of authoritative sources, knowledge building discourse, and embedded and transformative assessment. These principals provide guidelines to scaffold the knowledge creation in a community with corresponding technology (J. Zhang, Hong, Scardamalia, Teo, Morley, 2011).
A technology environment called the Knowledge Forum has been designed to support knowledge-building activities through functions that support preserving ideas, making ideas available to the whole community for discussion, interconnecting, revising, superseding, and viewing and reconstructing ideas from multiple perspectives and join discourse across communities (Scardamalia & Bereiter, 2003). Knowledge building results in not only a deep understanding of fundamental core content knowledge and the 21st century skills, but also the creation or modification of knowledge. Students in knowledge building classrooms have a different epistemological perspective, focused on knowledge advancement, compared with students in more traditional classrooms (Scardamalia & Bereiter, 2003).

Another prominent approach is that of Fostering a Community of Learners (FCL), where classrooms are conceived as science learning communities in which students engage in research-like activities that embedded in deep disciplinary content to promote critical thinking and reflection (A. L. Brown, 1997; A. L. Brown & Campione, 1994, 1996). FCL is grounded in the day-to-day reality of regular schools, and uses situated learning theory to guide the design, implementation, and evaluation of curricular topics and sequences (A. L. Brown & Campione, 1996).

The core idea of FCL is a three-stage cycle of research, sharing, and a consequential task (A. L. Brown, 1997; A. L. Brown & Campione, 1996). Students first engage in group-research activities to focus on subdomains of an inquiry topic. Each research group takes responsibility for one subdomain, allowing individual students to develop expertise in that area. Students then engage in cross-talk activities to share their expertise with the whole class. After that, they are regrouped in a “Jigsaw design” so that each new group is composed of one member from each of the previous groups. Students thus combine the expertise built in the previous research group activities, and work on a final project to produce a common product that will help them to form a complete understanding of the entire topic. These three stages are embedded in the overall community’s effort to understand the deep disciplinary content, including self-conscious reflection as the “learning community” oversees and coordinates the stages (A. L. Brown, 1997; A. L. Brown & Campione, 1996;). Figure 2.3 is an illustration of the basic system of FCL.
In FCL, students may engage in various meta-cognitive activities and must monitor their own and others’ understanding and reflect on their progress (A. L. Brown, 1997; A. L. Brown & Campione, 1996). Cross-age teaching is another activity of different grades or ages are learning together to develop a better understanding about learning, contribute their expertise to the community, take their own responsibilities, and collaborate with other community members, thereby increasing the knowledge capital of the community (A. L. Brown, 1997). The classroom teacher acts as facilitator and role model, introducing the class to the big ideas and deep principles at the beginning of a unit, leading the students to see higher order relations among concepts.

In FCL, the teacher is supposed to model thinking, self-reflection and reasoning. Typical roles include asking students to justify their opinions and supporting them with evidence, asking groups to summarize what is known and what still need to be discovered, and helping the class establish learning goals (A. L. Brown, 1997). FCL discourse is interpretive, with constructive discussions, questioning, querying, and criticism serving to stimulate active exchange and sharing of ideas (A. L. Brown et al., 1993). FCL has been the topic of more than a decade of research in classroom studies, and proven successful, in terms of students’ learning of domain-specific content, critical thinking and novel use of various principles. Students in FCL
demonstrated improved argumentation and use of advanced analogies and causal explanations (A. L. Brown & Campione, 1996). However, FCL has not been widely replicated, in part because of the substantial challenges of implementation (Slotta & Najafi, 2010; 2013).

2.4.3 The Teacher’s Role within Knowledge Community Approaches

The teacher’s role within any knowledge community approach has not been thoroughly described nor has it been studied. For example, in FCL, some principles are developed for supporting learning (A. L. Brown & Campione, 1996) and for fostering disciplinary engagement (Engle & Conant, 2002). However, there has been no systematic study of the teacher’s role. The following roles were mentioned – but never studied – in several writings without detailed articulation: modelling certain forms of inquiry activities and the behaviours of expert thinking, planning, and reflecting (A. L. Brown, 1997; A. L. Brown & Campione, 1990; A. L. Brown et al., 1993); holding clear instructional goals in mind to make sure that students reach the learning aim (Sherin et al., 2004); leading ‘guided discovery’ and responsively guiding students “discovery processes”; keeping the discussion on track; monitoring students to ensure a reasonable level of understanding (A. L. Brown et al., 1993); diagnosing students’ emerging competences and supporting weaker students to strengthen their emerging competences; pushing students to develop deep understanding (A. L. Brown & Campione, 1990; Palincsar & A. L. Brown, 1984); detecting students’ misconceptions and fallacious reasoning to challenge students thinking (A. L. Brown et al., 1993); allowing students greater autonomy when the students are able to take their own responsibility of learning (Palincsar & A. L. Brown, 1984).

Similarly, research in knowledge building has not fully addressed the teacher’s role, nor offered any detailed description of the specific things the teacher would need to do in the classroom. Even though Scardamalia (2002) proposed twelve abstract, workable principles for implementing Knowledge Building approach, a concrete Knowledge Building pedagogy does not exist. Knowledge Building theory has not provided teachers with any standard and concrete classroom procedures. Rather, teachers in Knowledge Building environment have to develop new views and identify new options for classroom processes themselves to direct their teaching (J. Zhang et al., 2011). In one study that examined teachers’ design sharing practices and their understanding of Knowledge Building principles, J. Zhang et al. (2011) identified some
pedagogical designs and strategies in line with three Knowledge Building principles. Table 2.1 is a replication of the supportive designs and strategies they identified.

Table 2.1

*Designs and Strategies to Support Three Knowledge Building Principles*

<table>
<thead>
<tr>
<th>Principle</th>
<th>Supportive Designs and Strategies</th>
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| Real ideas, authentic problems      | • Contributing theories, problems of understanding, and other forms of epistemic artifacts  
• Identifying “big ideas” in the curriculum and in their own contributions  
• Evolving inquiries by revisiting previous work or discussing current events related to student interests (e.g., hurricanes)  
• Generating questions, formulating thematic goals, sharing initial ideas through whole-class discussions, and working collaboratively to improve ideas  
• Monitoring self- and group progress toward understanding and identifying deeper questions and challenges |
| Collective responsibility for community knowledge | • Creating a safe and supportive community that encourages and works with idea diversity  
• Discussing and highlighting social norms that support Knowledge Building (e.g., respect, careful listening, detailed accounts, building on rather than repeating what others have said)  
• Co-creating mission statements and goals Linking views (workspaces) in Knowledge  
• Forum to convey interrelated knowledge goals and using background pictures to highlight themes and advances  
• Cross-referencing ideas, engaging in incremental building on, connecting current work with ideas and information in the community space (e.g., discussion notes, experimental findings, insights from readings)  
• Using dynamic social structures that integrate whole-class discussions, small-group reading and experiments, and individual work, encouraging students to group and regroup based on evolving needs  
• Reviewing progress as a community, sharing insights, generating excitement, and identifying new problems of understanding |
| Constructive use of authoritative sources | • Highlighting questions and discussing initial ideas before students read material Engaging in small-group cooperative reading of difficult texts  
• Coaching and using strategies of deep reading (e.g., questioning, reviewing, summarizing) |
• Sharing important information from readings in Knowledge Forum and going beyond given information
• Collectively developing an online glossary to help community members understand the related key concepts that are used in the discourse

In an introduction manual for teachers on Computer Supported Intentional Learning Environment (CSILE, an earlier version of Knowledge Forum), Brett and Oliver (1991) concluded with a description of the teacher’s role as (a) introducing concepts or learning content, (b) setting up students’ subsequent investigations, (c) monitoring students and assisting those in difficulty, (d) advising sources of information, (e) giving directions to students who are new to CSILE, (f) encouraging collaborative writing among student groups, (g) keeping track of students’ work and evaluate the work, (h) helping students evaluate their learning, and (i) challenging students to expand their vision. Brett and Oliver thus clarified the kind of role played by teachers in a knowledge building classroom: that they are (a) monitoring students, (b) tracking their work, (c) encouraging collaboration, and (d) interacting closely with students to promote their progress. This is a remarkably clear statement about the kinds of things the teacher should be engaged with, but remains unincorporated in the formal descriptions of KB (e.g., Scardamalia & Bereiter, 2010).

In a study examining the discourse moves that occur in a collective Knowledge Building environment, Hmelo-Silver and Barrows (2008) described how the facilitator provided opportunities for knowledge building discourse by asking open-ended metacognitive questions and catalyzing group process. The researchers identified various questioning tactics the facilitator used: (a) help student monitor their progress and focus on their self-directed learning; (b) elicit knowledge display so that students can find the limits of their understanding and realize what they need to learn more about; (c) to provide model of the kind of causal reasoning that is needed for understanding; (d) problematize students’ ideas by pushing student to explain their thinking; (e) focus students’ discourse in a relevant conceptual space; and, to help students move along. Hmelo-Silver and Barrows’ study emphasized the importance of providing models of questions that promote deep reasoning and metacognition, as well as sharing responsibility with students.
In summary, in the knowledge community approach, researchers have not proposed specific activity structures, procedures, or rules that teachers can follow. They only provided some principles that are often considered as too abstract to be helpful in terms of “how to do it”. The lack of research on teacher’s role has impeded the spread of knowledge community approaches (Scardamalia & Bereiter, 2006). Teacher’s role also remains as an interesting theoretical dimension of knowledge community approaches that deserves greater attention in research. My study engaged with the KCI model to investigate how the teacher’s role was designed and what kinds of interactions emerged during the enactment of a semester-long curriculum. My study explored the intersection of teacher knowledge with classroom practices, and looked for evidence of impacts on student participation and achievement that might derive from specific forms of student-teacher interaction. In its longest view, I designed this study to offer a source of insight to the KCI model itself and, to inform a more formal description of the teacher’s role in a knowledge community approach.

2.5 Teacher Knowledge and Teaching Practices

Verloop, Van Driel and Meijer (2001) suggested that the term “teacher knowledge” refers to “the whole of the knowledge and insights that underlie teacher’s actions in practice” (p. 446). The notion of teacher knowledge is thus an overarching concept that includes the codified or codifiable aggregation of conceptions and knowledge of disciplines, understanding and beliefs of school education and student learning, skills of organization, communication and presentation, and intuitions of context that are all inextricably intertwined in the mind of a teacher (Shulman, 1987; Verloop et al., 2001). Teachers have been said to gain such knowledge from four different sources: knowledge in content disciplines, educational materials and structures, formal educational scholarly literature, and the wisdom of practice (Shulman, 1987). Thus, teacher knowledge can be seen as a combination or amalgam of the knowledge that they acquire from their daily practical teaching experience, the knowledge that they acquired from formal teacher education program or continued professional training, and any specific disciplinary training (Calderhead, 1996, cited in Verloop et al., 2001). Teacher knowledge has the properties of both individuality and conformity: on one hand, teacher knowledge is unique to the individual teacher and confined by the specific content and context. On the other hand, however, teacher knowledge has common, shared or consensual components. In any case, teacher knowledge is
purposed for direct application within teaching practice and encompasses many tacit forms (Verloop et al., 2001). Teachers need such complex forms of knowledge to inform their instructional decisions, both in their planning of lessons prior to and in the enactments of their teaching that may occur “on-the-fly”.

Scholars have suggested different domains of teacher knowledge. Shulman (1987) identified seven categories of teacher knowledge: content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge, knowledge of learners and their characteristics, knowledge of educational contexts, and the knowledge of the philosophical and historical aims of education. Grossman (1990) later delineated four general categories of teacher knowledge: general pedagogical knowledge, subject matter knowledge, pedagogical content knowledge, and knowledge of context. Borko and Putnam (1996) organized their review of research on teacher knowledge and beliefs around three domains: general pedagogical knowledge and beliefs, subject matter knowledge and beliefs, and pedagogical content knowledge and beliefs. With technology increasingly being used in teaching and learning, knowledge of technology (and how to apply it effectively for teaching) has become yet another domain of teacher knowledge. Koehler and Mishra (2005) thus added the concept of Technological Pedagogical Content Knowledge (TPCK) into the teacher knowledge framework. Teacher knowledge is a critical factor that significantly impacts the teacher’s practices and thus their role in any pedagogical model (Roehrig & Kruse, 2005). The sections below review our understandings of the various forms of teacher knowledge.

2.5.1 Content knowledge

Content knowledge is the “knowledge, understanding, skill, and disposition that are to be learned by school children” (Shulman, 1987, p. 9). This form of knowledge includes three levels of understanding: (a) the major facts, concepts, terms, principles, and procedures within a subject area; (b) the structure and organization within that subject; and (c) how scientific works are conducted, evaluated, and accepted in that subject (Carlsen, 1999; Gess-Newsome, 1999b; Schwab, 1964). Teachers acquire content knowledge from their formal college studies, textbook, personal reflection and learning of subject principles, their practical teaching experiences, and related social movement (Gess-Newsome & Lederman, 1995). A teacher’s content knowledge
would likely affect what kinds of activities he or she would undertake or what topics would be addressed within the classroom. For example, in a review of studies about the influences of content knowledge on teaching practice, Gess-Newsome (1999a) concluded that teachers with a lower level of conceptual knowledge of their subject tended to teach isolated and fact-based knowledge rather than promoting students’ conceptual understanding. Further, teachers with sophisticated understanding of the structure and nature of subject matter were more able to connect students’ out-of-school experience to school-based instruction; they were likely to teach students how human knowledge is generated and evaluated as well as the idea that science is a way to understand the world.

Content knowledge also influences the instructional strategies and materials that teachers select in their classroom teaching and their planning of lessons. For example, Carlsen (1991, 1993) examined the effects of biology teachers’ subject-matter knowledge on their classroom discourse and instructional plans. He found that when teaching topics that the teachers self-identified as having low-level knowledge, they tended to lecture more and thus dominate the speaking floor, spend longer time on each speaking turn, spend less class time on group work, allow fewer student questions, and ask students more questions. In laboratories, if the teachers have high-level knowledge on the topic, they were likely to talk more and hold their speaking turn longer; and they spent more time giving students instructions. When asking students questions, the teachers asked relatively more cognitively high-level questions when they were teaching high-level knowledge topics. When planning instruction about topics that they knew well, the teachers planned more whole-class interactions, to teach new materials or review student work. Teachers planned student group activities and lecturing most often when they did not know the teaching topics well, and their plans were not clear in terms of what the students should be doing in their groups. In a qualitative study of five biology teachers’ perceptions of subject matter structure (SMS) and their classroom practice, Gess-Newsome and Lederman (1995) found that teachers’ knowledge of SMS could be translated into their teaching practices at three levels: direct translation, limited translation mediated by the complex interactions of other variables, or no translation. The SMS knowledge was found to influence teachers’ selection of biology textbooks, the sequence in which they presented the content to students, the organization of materials, and the scope of content they would teach. Similar results were found in Sanders, Borko, and Lockard (1993)’s study about the influences of three science teacher’s content
knowledge on their planning of lessons and on their classroom teaching. In addition, Dobey and Schaefer (1984) found that teachers’ science background knowledge affected their ability to implement inquiry-based teaching methods. However, superior content knowledge alone is not sufficient to ensure effective inquiry teaching. Some other domains of teacher knowledge contribute to the successful implementation of inquiry or other innovative approaches.

2.5.2 Pedagogical knowledge

Pedagogical knowledge is the domain of knowledge about classroom management, available instructional strategies, and student learning which is independent of specific subject matter domains (Borko & Putnam, 1996). It is the basis of the conscious activities in which teachers engage in their classroom for the purpose of enhancing students’ learning (Watkins & Mortimore, 1999). Morine-Dershimer & Kent (1999) observed that teachers can acquire pedagogical knowledge from three sources: their personal beliefs and perceptions of teaching and learning based on their experiences as students, the research and scholarly literature that presented to them in teacher preparation programs, and the practical experience working in real classroom during their pre-service student teaching and the early year of professional practice. Other scholars have synthesized pedagogical knowledge into four components of strategies and arrangements for effective teaching: classroom management, instructional strategies, classroom discourse, and understanding and beliefs about learners, learning, and teaching (Borko & Putnam, 1996; Carlsen, 1999; Grossman, 1990; Morine-Dershimer & Kent, 1999).

Knowledge of classroom management enables teachers to establish classroom norms (rules and procedures), manage learning groups, monitor and organize classroom events, and respond to students’ behaviour. Teachers will thus be able to establish and maintain the order of the classroom and keep students highly engaged (Borko & Putnam, 1996). In a study that examined the influences of classroom management knowledge on beginning teachers’ reflection upon classroom practice, Winitzhy (1992) first measured teachers’ knowledge by asking them to group 20 classroom management terms according to their best fit. Then, she measured the teachers’ ability to reflect on the principles of teaching, learning, or classroom management of successful classroom management samples that they had either observed or accomplished themselves. Results showed that teachers “with more organized and complex knowledge
structures were more able to reflect on classroom management events at all levels, from the technical through the moral” (p. 8).

Teachers’ classroom management skills have a critical impact on student achievement (e.g., Emmer & Evertson, 1981; Morine-Dershimer & Kent, 1999). Even though it was difficult to find studies that compare the effects of different levels of classroom management knowledge on teachers’ teaching practice, specific classroom management skills that can result in better students achievement have been identified. For example, Morine-Dershimer and Kent (1999) summarized effective classroom organization and management behaviour, such as: (a) spending more time focusing on content, (b) organizing learning activities that match the students’ level, (c) maintaining momentum in instruction, (d) structuring the materials properly, presenting information clearly, and (e) giving students adequate wait-time to respond. Emmer and Evertson (1981) synthesized effective classroom management strategies as: (a) introducing classroom management system at the beginning of the school year and implementing it consistently throughout the year, (b) letting students work in small group rather than in whole class, and (c) providing more academic feedback and substantive interaction. Both Emmer and Evertson (1981) and Brewer, Dunn, and Olszewski (1988) noticed the effectiveness of extrinsic rewards and incentive system.

_A knowledge of instructional strategies_ provides teachers a repertoire of methods or routines to structure classroom activities, interact with students, ensure students’ participation and engagement, keep lessons running smoothly, promote active cognitive processing of academic content, foster understanding, and assess students’ thinking (Borko & Putnam, 1996). The studies by Joyce and Showers (1988, cited in Morine-Dershimer & Kent, 1999) and Rosenshine (1993, cited in Morine-Dershimer & Kent, 1999) indicate that different instructional models can address different learning goals (developing capabilities of collaboration vs. developing capabilities of self-correction) and learning tasks (well-structured tasks vs. less-structured task). It is reasonable to believe that teachers who have rich knowledge of possible alternative instructional strategies are able to use appropriate teaching methods in accordance with desired learning goals and tasks (Morine-Dershimer & Kent, 1999).

Teachers’ _knowledge of classroom communication patterns_ can also foster positive learning outcomes (Morine-Dershimer & Kent, 1999). Students can achieve better results and
participate more actively when they are able to understand the rules and expectations expressed by the teacher, and when classroom communication matches their home communication patterns. Teachers may misinterpret students’ abilities if they do not know about cultural differences between their students’ communication patterns and their own. For example, both Heath (1982) and Michaels (1984) have noted that minority students sometimes experienced difficulty in schools because the classroom communication patterns differ from the patterns they experience at home.

*Knowledge of learners, learning, and teaching* denotes the “understanding and beliefs about how children think and learn, and about how teachers can foster that learning” (Borko & Putnam, 1996, p. 676). This type of knowledge also includes an understanding of the goals and values of education as well as the understanding of students’ general learning ability at certain stage (age) of schooling. With improved research findings about student learning, our understanding of what teachers should know about student learning also shifts - from considering students as passive receivers of knowledge transmitted by teachers to thinking about them as active problem solvers and knowledge constructors (Borko & Putnam, 1996). Roehrig and Kruse (2005) inspected the relationship between teachers’ beliefs about teaching and learning and their classroom practices and implementation of reform-based curriculum. Twelve chemistry teachers were interviewed to measure their beliefs about students and teaching and how those understandings impacted their curriculum implementation. They were observed first using non-reform-based methods, and then using reform-based curriculum for the purpose of comparing their changes in classroom practice. This study found a strong statistical correlation between teachers’ beliefs about teaching and learning and their classroom practice. In general, teachers who held traditional beliefs about teaching and learning made small changes in their teaching practice when compared between their implementation of non-reform-based curriculum and their implementation of reform-based curriculum. In conclusion of their study, Roehrig and Kruse (2005) believed that content knowledge was also an important factor in classroom practices, which is in resonance with Morine-Dershimer and Kent (1999)’s postulate that general pedagogical knowledge must be adapted to fit the particular content and contexts.

Both content and pedagogical knowledge are essential for teaching. However, merely having deep and rich knowledge in either of these two discrete domains is not enough for
teaching. Teachers also require knowledge in a domain called pedagogical content knowledge (PCK) that enables them to better present content knowledge to their students (Carter, 1990; Shulman, 1986; 1987).

2.5.3 Pedagogical content knowledge

Pedagogical content knowledge is a domain of knowledge that blends “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 represented for instruction” (Shulman, 1987, p. 8). PCK is about how teachers can transform their understanding of subject content into classroom instruction to help students learn the subject content; it is the knowledge about how to use the most appropriate analogies, illustrations, examples, explanations, and demonstrations to reorganize, represent, and formulate the subject content so that student can grasp it. Teachers need PCK to evaluate students’ learning within the specific context. PCK includes both teachers’ understanding and enactment of approaches to helping students learn in specific subject areas; it is teachers’ personal and private knowledge that can be transformed into public knowledge. PCK represents the coherence integration of all aspects of teachers’ knowledge; it is a unique domain of knowledge that has reciprocal and nurturing relationship with content knowledge and pedagogical knowledge; it is more than just the sum of content knowledge and pedagogical knowledge. However, there are no clear-cut borders between knowledge domains because of substantial degree of overlapping of ideas (Cochran-Smith & Lytle, 1999; Gess-Newsome, 1999a; Hashweh, 2005; Magnusson, Krajcik, & Borko, 1999; Park & Oliver, 2008; Shulman, 1986, 1987).

In the effort to conceptualize pedagogical content knowledge, several researchers have tried to identify the components constituting PCK. Based on the work of Tamir (1988), Grossman (1990) and Magnusson et al. (1999) as well as their own multiple case study of three experienced chemistry teachers, Park and Oliver (2008) postulated six components of PCK: orientations to the teaching of subject matter, knowledge of students’ understanding, knowledge of curriculum, knowledge of instructional strategies, knowledge of assessment of students’ learning of subject matter, and teacher efficacy.
Orientations to the teaching of subject matter are teachers’ overarching concepts of the purposes and goals for teaching a subject at different grade level (Grossman, 1990). Teaching orientations influence teachers’ instructional decisions about setting classroom objectives, use of instructional strategies, selection of textbooks and curricular materials, and the evaluation of students (Borko & Putnam, 1996). Teaching orientations play a central role in decision-making when teachers plan, enact, and reflect upon teaching. Teachers with different teaching orientations employ different instructional strategies for different learning purposes (Magnusson et al., 1999). Teachers may hold multiple orientations that are incompatible with the goals for teaching a subject matter (Smith & Neale, 1989).

Knowledge of students’ understanding is teachers’ knowledge about the requirements for learning specific subject concepts, and topics in a subject that are difficult for students to learn. Teachers need to know what prior knowledge is required for the topics they are teaching. Students have different levels of development, ability and skill, and different approaches to learning a subject topic. Teachers need to be aware that a specific content representation may be understood by some students but not by others, because of students’ differences. Every subject has some abstract concepts that contrast to or have no connection to students’ daily experiences. Students often make errors when they do not have problem solving skills in the subject area they are learning. Teachers need to know these abstract concepts, challenging topics, and students’ common errors in order to respond to students effectively (Grossman, 1990; Magnusson et al., 1999; Park & Oliver, 2008).

Knowledge of curriculum refers to three categories of knowledge: the mandated goals and objectives of the specific subject topics that articulated in national- or local-level curriculum documents or guidelines, the horizontal and vertical curricula in a subject area – what students have learned and will learn in the specific subject area of teaching and in related subject area, and the available curriculum programs and teaching materials that are relevant to the specific subject area of teaching (Grossman, 1990; Magnusson et al., 1999; Park & Oliver, 2008).

Knowledge of instructional strategies includes the knowledge of subject-specific strategies and the knowledge of topic-specific strategies. Subject-specific instructional strategies are the general approaches to enacting instruction in a subject area. For example, the Inquiry Cycle model that White and Frederiksen (1998) developed is a specific strategy for science
teaching. Topic-specific instructional strategies are the useful instructional approaches that teachers employ to help students understand specific science concepts. There are two types of topic-specific instructional strategies: representations and activities. The knowledge of topic-specific representational strategies is the knowledge of how to explain specific topic concepts or principles using illustrations, examples, models, or analogies. Teachers should also know the strengths and weaknesses of the illustrations, examples, models, or analogies they may use in their explanation. Teachers’ ability to invent new representations is another element of topic-specific representations. The knowledge of topic-specific activity strategies are teachers’ knowledge of learning activities (and their conceptual power) that can help students learn specific concepts or principles, such as problem-solving activities, demonstrations, simulations, investigations, experiments, field trips, or others (Grossman, 1990; Magnusson et al., 1999; Park & Oliver, 2008).

Knowledge of assessment of students’ learning of subject matter is teachers’ knowledge of what to assess and the methods of assessment in specific subject. Teachers should know what aspects of students’ learning are important and should be assessed in a specific subject. For example, in science learning, conceptual understanding, interdisciplinary themes, nature of science, scientific investigation, and practical reasoning are important aspects to assess. In order to assess different aspects of learning, teachers need to know the specific assessing methods that they can employ as well as the advantages and disadvantages of these methods. The methods of assessment can include the specific instruments or procedures, approaches or activities that fit for the particular unit of study (Magnusson et al., 1999; Park & Oliver, 2008).

Teacher efficacy is an affective component of PCK identified by Park and Oliver (2008) in their study of three experienced high-school chemistry teachers. It is teachers’ beliefs about their ability to carry out effective teaching methods to achieve specific teaching goals. In other words, teacher efficacy is related to their confidence in their own teaching capability. Teacher efficacy plays an important role in their identification of students’ learning difficulties or misconceptions and their selection of teaching strategies. Teacher efficacy may be increased through successful teaching experience; increased teacher efficacy can encourage teachers to apply the PCK they already have or just learned. Teacher efficacy is highly context and domain specific.
The development of PCK is influenced by the interaction of content knowledge and pedagogical knowledge (Hashweh, 2005; Magnusson et al., 1999). Deep knowledge in a content domain is not in itself sufficient for the development of PCK (Hashweh, 2005). Moreover, knowledge in different content domains may influence the development of PCK unequally, according to the nature of the domains or the quality of knowledge in each domain. Therefore, teachers develop PCK via different routes and across multiple pathways (Magnusson et al., 1999).

Teachers’ reflections about their teaching practices can allow for what Shulman (1987) termed ‘wisdom of practice’ providing an important pathway for developing PCK (Hashweh, 2005; Park & Oliver, 2008). Teachers’ reflections include both ‘reflection-in-action’ and ‘reflection-on-action’ (Park & Oliver, 2008). Reflection-in-action is teachers’ real-time reactions to unexpected challenging moment in their enacting of a specific lesson. In this case, teachers develop new PCK dynamically through integrating the knowledge they already have to address the challenge. Reflection-on-action refers to teachers’ re-consideration of their planning and enacting process of a specific lesson after the teaching practice is completed. In this case, teachers develop their PCK through the reorganization, modification, or adding new content to their existing knowledge repertoires (Park & Oliver, 2008).

Interactions with students can also impact the development of PCK (Park & Oliver, 2008), as their challenging questions can push on the boundaries of teachers’ content knowledge and provide enhanced opportunities to develop PCK. Students’ responses to instructional moves, such as their enjoyment, nonverbal reactions, and evidence of learning can also motivate teachers to expand, enrich, and validate their PCK; students’ creative and critical ideas can stimulate teachers developing new instructional ideas; students’ misconceptions can impact teachers’ planning and enacting of lessons as well the content of students assessment, and ultimately improve the teachers’ PCK (Park & Oliver, 2008).

PCK development is closely intertwined with teaching practice, as teachers develop PCK through their teaching practice and their reflections about practice. On the other hand, teachers’ PCK also substantially affects their teaching practice. A large body of research has shown that teachers’ PCK affects how they plan and enact class, how they explain concepts and use demonstrations, and how they assess students (Keys & Bryan, 2001; Magnusson et al., 1999).
For example, Sanders et al. (1993) examined the influence of content knowledge, pedagogical knowledge, and PCK on three secondary science teachers’ planning, interactive teaching, and reflecting. When the teachers were planning classes on topics that they had rich PCK, they were able to present the content in a logical sequence; they had a sense of the amount of content to present; and, they were able to anticipate potential problem, and planned ahead. However, when the teachers were planning on topics where they had less PCK, they were not able to determine the sequence of content, and were not able to predict potential problems that students might have. When engaged classroom instruction, teachers’ rich PCK enabled them to take advantage of unexpected events or questions that came up, and to direct the flow of activities in the classroom. When reflecting on their teaching, teachers’ PCK allowed them to acknowledge the significance of a question that came up, its relevance for future lessons, or its potential as a problem area. Rich PCK also facilitated their reflections on student understanding rather than on their own teaching. In a study that examined the PCK of experienced and novice chemical teachers who teach abstract concepts and have interest in using demonstrations as a science teaching strategy, Clermont, Borko, and Krajcik (1994) found that experienced chemical teachers have richer PCK in terms of the amount of demonstration they posses, the variations in using chemical demonstration, and the cognizant of the complexity of some chemical demonstrations systems in the teaching of abstract concepts. Hashweh (1996) compared the classroom practices of teachers with different epistemological beliefs on science learning and knowledge. He found that teachers holding constructivist beliefs on learning and knowledge were more likely to identify students’ alternative conceptions; used large number of teaching strategies; and frequently utilized potentially more effective strategies. Researchers believe that teachers who employ inquiry approaches to teaching must have rich and deeply developed PCK (Keys & Bryan, 2001).

2.5.4 Technological pedagogical content knowledge

Technological pedagogical content knowledge (TPCK) is the knowledge that teachers need to properly integrate technologies in their facilitating and scaffolding of students’ learning within a particular content domain. It is a unique form of knowledge, extended from (and distinct from) Shulman’s idea of pedagogical content knowledge (Anegli & Valanides, 2009; Niess, 2011). TPCK is the result of the complex interplay of three domains of foundational knowledge
content, pedagogical, and technology knowledge – within a particular context (Harris, Mishra, & Koehler, 2009; Mishra & Koehler, 2006). TPCK provides a conceptual framework for teacher knowledge about effective integration of technology within a content domain (Koehler & Mishra, 2008).

Niess (2005) and Mishra and Koehler (2006) described the following components of TPCK. The first component is teachers’ overarching understanding of the purpose of incorporating technologies in students learning within a particular subject domain. The second component is teachers’ awareness of how technologies can be used to detect students’ prior knowledge, facilitate students’ learning of difficult concepts, scaffold students’ developing of new knowledge, or support students’ strengthening of prior knowledge in a particular subject domain. Teachers’ knowing of technology-enhanced curriculum materials in a particular subject is the third component of TPCK. Teachers’ repositories of instructional strategies of using technology to represent concept and to support students learning in constructive ways is the fourth TPCK component. In addition, I believe that teachers’ knowing of creating new technology-enhanced learning materials or learning environment for a specific subject domain should also be considered as a component of TPCK.

The development of TPCK is often a process that has multiple stages. For example, in a study about mathematics teachers’ learning to integrate spreadsheets within their courses, Niess, Sadri, and Lee (2007, cited in Niess et al., 2009) identified five stages of development: (1) Recognizing – teachers realized the alignment of technology with mathematics content; (2) Accepting – teachers formed a positive attitude toward using technology in mathematics teaching; (3) Adapting – teachers engaged in activities of adopting technology in mathematics teaching; (4) Exploring – teachers actively used technology in their teaching of mathematics; and (5) Advancing – where teachers evaluate the results of their use of technology in mathematics teaching. In a study about the development of rural Chinese teachers’ capabilities in using information and communication technology, Guo, Wang, and Zhao (2010) discussed six stages of development: (a) the Bewilderment stage, in which teachers felt curious, excited, desirous, terrified and resistant to the use of technology in teaching; (b) the Skill Learning stage, in which teachers actively learned basic ICT skills and basic theory of using them in teaching; (c) the Imitation stage, where teachers imitated other teachers’ use of technology after their observation
of other teachers in classroom; (d) the *Accumulation and Development stage*, where teachers realized that merely mastering the technical skills was not enough, and modified other teachers’ use of ICT to fit their own teaching style and context; (e) the *Proficiency stage*, in which teachers acquired clear understanding of the use of ICT in teaching, became sophisticated in using ICT in teaching, and appropriately integrated ICT based on students’ characters and on the learning context; teaching in this stage aimed at fostering students’ abilities to discover, collaborate, and solve problems; and (f) the *Innovative Application stage*, where teachers could create new pedagogical application of ICT based on the authentic teaching context, and were able to support students’ learning using multiple resources without being confined by the curriculum and local learning resources.

Some strategies for TPCK development have been proposed and implemented within teacher professional development research. For example, (Mishra & Koehler, 2006) introduced “learning technology by design” strategy, where teacher education faculty and master students developed their TPCK through their collaborative transformation of a face-to-face course into an online course. Polly, Mims, Shepherd, and Inan (2010) identified three strategies of developing TPCK: (a) mentoring university teacher education faculty, (b) prompting TPCK of both pre-service and in-service teachers through planning and co-teaching technology-rich lessons, and (c) designing technology-rich curricula materials. In general, mentoring, modelling, designing of technology-enhanced lessons, and enacting technology-enhanced lesson are the most often used strategies to develop TPCK (Voogt, Fisser, Pareja Roblin, Tondeur, & van Braak, 2013). In these studies and others, active involvement in authentic design activities and implementation or enactment of technology-enhanced lessons or courses was found to be critical to the development of TPCK (Koehler & Mishra, 2005; Voogt et al., 2013).

TPCK is of central importance for effective teaching with technology. For instance, on reflecting about their experience of bringing successful design experiments to a large-scale urban public school system, Blumenfeld, Fishman, Krajcik, and Marx (2000) believed that the effective integration of technology requires teachers to have sufficient computer skills and understanding of how to use computer as a cognitive tool to enhance students’ learning and thinking. In a reviewing pedagogy related to the use of information and communication technology (ICT), M. Webb and Cox (2004) concluded that technology is a catalyst of teaching practice towards a
more student-centred, collaborative learning model, given that the teachers have the knowledge of the affordances of ICT in students’ learning of particular subject. They also concluded that teachers must have deeper knowledge of technology affordances and pedagogical content knowledge in order to successfully utilize the affordances of technology. However, Hammond and Manfra believed that PCK is more important in affecting teachers’ instructional decisions during lesson preparation and enactment than the choice of technological tools (Hammond & Manfra, 2009; Manfra & Hammond, 2006).

2.6 Challenges to Adopting New Pedagogical Approaches to Learning and Instruction

New approaches to learning and instruction, such as inquiry or knowledge communities, entail considerable changes in classroom practices of students and teachers alike. This section discusses four kinds of challenges that teachers confront: metaconceptual, enactment, domain content, and contextual.

*Metaconceptual challenges* refer to those encountered by the teacher in understanding the principles underlying a new instructional approach, and developing a strong commitment to or belief in that approach. Teachers may doubt whether inquiry really works because it violates the habits they have developed (Bybee, 2000). They need to overcome the career-long habituation of being at the center of the learning process (Scardamalias, 2002). Their beliefs concerning the nature of their role, the goals of schooling, and how students learn may not compatible with the assumptions underlying the innovative approaches to learning and instruction (Anderson, 1989). For example, several researchers have noted the difficulties encountered by teachers in accurately understanding the basic concepts of inquiry learning (Costenson & Lawson, 1986; Trumbull, Bonney, & Grudens-Schuck, 2005). Scardamalia (2002) identified the following barriers to adopting the knowledge building pedagogy: the disbelief that children have the motivation and ability to create, share, and improve knowledge; concern that students will learn something wrong; and belief that creative work can only be done after acquiring enough established knowledge. Still others (J. Zhang, 2010; J. Zhang et al., 2011) have investigated the importance of teachers’ understanding of its underlying principle to their success in a Knowledge Building approach.
Enactment challenges are those that students and teachers may encounter in the progress of learning and instruction. The research literature has identified five enactment challenges relating to students’ inquiry: 1) it is hard to get students to generate high-level questions; 2) students may have difficulties in designing and carrying out various learning activities, such as finding resources, collecting and analyzing data, interpreting the results, and communicating results with others; 3) students may not be able to organize, manage, evaluate, and reflect on learning tasks that are too complex and the students are not able to create appropriate criteria for evaluation; 4) students may not be able to systematically use evidence and science principles under study to formulate arguments, generalize ideas, revise models, and construct theories; 5) collaboration may not be effective because students may not comment on each other’s work, or give superficial rather than constructive feedback to peers (Bybee, 2000; Clark et al., 2003; Costenson & Lawson, 1986; Edelson et al., 1999; Germann & Aram, 1996; Krajcik et al., 1994; Linn, 1992; Palincsar, Anderson, & David, 1993; Scardamalia & Bereiter, 1992b; Schauble, Glaser, Duschl, Schulze, & John, 1995).

Enactment challenges that teachers may confront include: building instruction around authentic problems and linking concepts to diverse activities that motivate students; diagnosing the problems students have during learning activities (e.g., collecting and analyzing of data, or interpreting outcomes of experiments or lab activities); selecting or designing learning materials that promote meaningful science understanding; creating an atmosphere of a learning community, where students can effectively collaborate with peers to share, critique and revise ideas and artifacts; scaffolding students’ meta-cognition and reflection during learning activities; developing strategies or techniques to assess students’ understanding and to track students’ improvement; helping students use technology for investigation, collaboration and artifact development; and using technology themselves to support students’ effective engagement in learning activities (Bybee, 2000; Edelson et al., 1999; Krajcik et al., 1994; Linn & Hsi, 2000; Minstrell & van Zee, 2000; White & Frederiksen, 1998). It is very challenging for teachers to orchestrate all of these simultaneously (Krajcik et al., 1994).

No matter what instructional method they employ, teachers must have sufficient content knowledge in the subject they teach (Blumenfeld et al., 1991; Costenson & Lawson, 1986; Krajcik et al., 1994). To enact the challenging pedagogy entailed by inquiry or knowledge
community approaches, teachers must be flexible and adaptive in their use of content knowledge. Without sufficient understanding of subject matter, they cannot distil the key concepts, identify relations between the central ideas and other concepts, or integrate multiple disciplines (Blumenfeld et al., 1991). Content knowledge intersects with other forms of teaching knowledge, such as pedagogical content knowledge and technological pedagogical content knowledge (Costenson & Lawson, 1986). Teachers who lack such pedagogical related knowledge have difficulty illustrating concepts or theories, or identifying student misconceptions (Shulman, 1986).

Contextual challenges are concerned with the availability of resources, technological and instructional support, class composition and size, problems of managing classroom, scheduling, district curriculum requirement and testing policies, heavy content expectations, dangers that some experiments might pose for students, time and energy required to establish a learning community, and community involvement (Bybee, 2000; Edelson et al., 1999; Krajcik et al., 1994; Scardamalia, 2002; Slotta & Najafi, 2010). These challenges may be less substantive than other challenges from a theoretical perspective, but they nevertheless influence how teachers incorporate innovative approaches to learning and instruction and are very real factors influencing the success of any design (Edelson et al., 1999; Krajcik et al., 1994).

The various challenges discussed above could potentially be remediated by technology scaffolds, with careful consideration and design to support the teacher’s role. The following sections will discuss how technology can support new approaches to learning and instruction, with a focus on the teacher’s role in such approaches.

2.7 Technology scaffolds for inquiry and knowledge community approaches

Computer and network technologies offer new opportunities to support innovative approaches to learning and instruction (Edelson et al., 1999). Building on the perspectives of Roschelle, Pean, Hoadley, Gordin, and Means (2000) and Jonassen, Carr, and Yueh (1998), this thesis distinguishes three ways in which technology can offer support: (a) scaffolding students’
inquiry activities, (b) scaffolding peer collaboration and student-teacher interactions, and (c) scaffolding the teacher’s activities.

Technology can scaffold students’ inquiry by sustaining their motivation, providing supports or tools in the inquiry steps, and reducing cognitive load (Bell et al., 2010; Blumenfeld et al., 1991; Clark et al., 2003; Hmelo-Silver et al., 2007; Jermann, Soller, & Lesgold, 2004; van Joolingen et al., 2007). To sustain students’ motivation, teachers can use technology scaffolds for helping students control and access real data, design and produce artifacts, perform experiments that might otherwise be impossible or take a very long time, adapt tasks to individual students’ knowledge or proficiency, and help students express their personal understanding or ideas (Bell et al., 2010; Blumenfeld et al., 1991; Clark et al., 2003). During the inquiry process, technology can scaffold students in formulating research questions, designing and planning investigations, collecting and analyzing data, building and testing conceptual models or formulas, supporting hypotheses, displaying information, producing and manipulating artifacts, and developing deep explanations (Linn & Eylon, 2006; Slotta & Linn, 2009). Scaffolds for argumentation have been devised to help students achieve deeper reflections and more comprehensive arguments (Bell, 2004; Jermann et al., 2004; Kollar, Fischer, & Slotta, 2007). Technology can help to reduce students’ cognitive load in two ways: First, with the capability of storing, retrieving, and sorting large amount of data, automatically generating data, and performing labour-intensive computations, technology can automate routine processes and thus decrease the overall burden of details and activities required of students. Technology can also be used to constrain the options available to students, providing increased structure to the learning tasks and thereby reduce students’ cognitive loads (Bell et al., 2010; Hmelo-Siver et al., 2007; Jermann et al., 2004; Suthers, 2006).

To scaffold students’ interactions with peers and teachers, a variety of technology systems and approaches have been advanced. Communication and information transmission technologies, such as structured or unstructured discussion forum, chat tools and conferencing tools, can help students share and exchange ideas, receive feedback, clarify, critique and explicate ideas, develop mutual understanding, and learn from their peers and teachers (Hoadley & Pea, 2002; Jermann et al., 2004; Laffey, Tupper, Musser, & Wedman, 1998; Scardamalia, 2002; Stahl, 2000). Representation tools, like concept mapping tools, can provide a shared
context for students to discuss issue have been shown to help students to engage in peer interaction, reflect deeply, externalize ideas, and solve problems collaboratively (Baker, Vries, Lund, & Quignard, 2001; Baker & Lund, 1997; Jermann et al., 2004; Robertson, Good & Pain, 1998; Soller, Goodman, Linton, & Gaimari, 1998). Socially oriented knowledge building technologies have been used to support students in developing a sense of online community (Bielaczyc, 2006; Hoadley & Pea, 2002; Scardamalia, 2002; Scardamalia & Bereiter, 1996). Asynchronous communication technologies can help to prevent biases, foster equitable engagement, allow students the time required to compose comprehensive response to their peers, and support collaboration across time zones and culture (Bell et al., 2010; Gobert & Tinker, 2004; Slotta & Jorde, 2010). Wiki technologies have been used to provide students with a shared workspace where they can produce a shared product for further refinement and exploration of ideas (Bell et al., 2010; Suthers, 2006; Peters & Slotta, 2010b). Technology has also been employed to support “collaboration scripts” (Dillenbourg, 2002) where students are prompted to interact according to predefined steps and sequences, reducing the cognitive load for the teacher, and enhancing the quality and effectiveness of collaborative reflection (Jermann et al., 2004; Weinberger, Fischer, & Mandl, 2001 cited in Clark et al., 2003).

To scaffold teachers during inquiry, technology can help by guiding and supporting students, and providing information about student learning. Technology can also supplement teacher’s managerial roles, relieving them from complex or labour-intensive tasks (Blumenfeld et al., 1991). Logging tools that record the history of learners’ actions can provide a visual display of students’ learning progress and their interaction patterns (Jermann et al., 2004). Diagnosing tools can compare a student’s activity pattern with a desired pattern, providing teachers with information about the student’s learning progress. Social network analysis tools can reveal the properties of a group’s interactions or the contributions of a particular student within a collaborative activity (Jermann et al., 2004). Teachers can use these tools to evaluate whether students’ learning is on the right track, whether the interactions among students are effective, and to inform their revision of the learning activities and assessments. Artificial intelligence can be used to provide teachers with suggestions on what type of feedback, coaching and guidance should be provided to students, or how to model problem solving (Jermann et al., 2004; Soller & Lesgold, 2007; Slotta, 2010). However, such technology environments that can
provide “real-time” information to teachers about students’ ideas and the property of their interactions are still in their infancy.

Without technology support, it would be quite difficult for teachers to conduct such complex forms of teaching (Blumenfeld et al., 1991). The design of such technology environments must balance the practical constraints of the curriculum with the constraints of available technologies (Hoadley & Pea, 2002). Quintana et al. (2004) suggested seven guidelines for technology materials and environments to scaffold learners in inquiry learning: use representations and language that bridge learners’ understanding; organize tools and artifacts around the semantics of the discipline; use flexible representations that learners can inspect in different ways; provide structure for complex tasks and functionality; embed expert guidance about scientific practices; automate non-salient, routine tasks; and facilitate student reflection during the investigation. It is also important to consider the social structure of classrooms when designing technology-based learning environments.

Bielaczyc (2006) delineated a framework of four dimensions for designing social infrastructure. The first dimension is cultural beliefs, referring to the beliefs that teachers and students held in a learning setting. Social infrastructure designers need to consider how teachers and students conceptualize learning and knowledge, how they understand their social identity, and how they view the purpose of the technological tool. The second is practices, referring to the standard and participation structures of any learning activities. Designers need to think about the activities that students will be engaged and the related participant structures of students and teachers. They also need to think about the coordination of learning activities that carried out with technology and those that carried out without technology. The third is socio-techno-spatial relations, referring to the arrangement of physical- and cyber-space to scaffold student interactions using technological tool. Designers need to think about the configurations among student, teacher, technological tool, and physical- or cyber-space as well as the relationship between cyber-space and physical-space. The last, interaction with the ‘outside world,’ refers to how students interact with people outside of their immediate classroom. Designers need to think of ways, using or without using technology, to help students introduce knowledge from outside of their immediate classroom (students as receivers), to spread student work beyond their
immediate classroom (students as producers), and to interact with others (students as both receivers and producers).
Chapter 3
Research Methodology

This dissertation study was embedded in a larger-scale study whose overarching goal was to develop the KCI model to support a knowledge community approach in secondary science classrooms (Slotta & Najafi, 2012). The broader research program employed a design-based research methodology in which distinct investigations, including several dissertation studies, were embedded each within its own curriculum context. The design research paradigm entailed an evaluation of the curriculum enactment, a redesign of the curriculum according to the evaluation, and then a re-enactment of the revised curriculum, which as then evaluated to begin another cycle. For each curriculum design, this large research program employed the co-design process in which a team of researchers, science teachers and technology developers created an innovative grade-nine curriculum unit on global climate change. During curriculum enactment, students collaboratively developed a knowledge base and engaged in a variety of science inquiry activities to develop a deep personal understanding of the associated science topics.

My own study was embedded within two iterations of design and implementation of the Global Climate Change curriculum. In the first iteration, the team designed and implemented the curriculum with the support of a wiki-based technology environment over an eight-week time period (20 lessons) in the 2008-2009 academic year. However, the implementation was found to be lacking in its adherence to some of the KCI principles (Slotta & Najafi, 2012). One important limitation or shortcoming was that the knowledge base developed by students about climate change was not fully utilized as a resource during subsequent inquiry activities. In part, this was due to limitations in the technology environment, which did not provide effective supports in terms of indexing the content, making it difficult for students to find meaningful connections to their inquiry activities. In response to the limitations found in iteration one (Slotta & Najafi, 2012), the team revised the curriculum design during the summer of 2009, and redesigned the technology environment as well. The second iteration of the curriculum was run in the 2009-2010 academic year over the same time period (nine weeks, with 21 lessons). The second iteration was an improvement in terms of having the students use the contents in the knowledge
base to connect to their science inquiry activities and also in terms of the role played by the technology environment.

Section 3.1 in this chapter situates my study within the context of the on-going, whole-school research partnership by providing a background from literature related to the co-design process and design-based research. Section 3.2 turns to the specific methods I employed in the main study investigating three teachers’ enactments of the global climate change curriculum. My dissertation followed both iterations of the project’s design and implementation efforts and reports the pilot work as Section 3.3 and the main study as Chapter 4. In this chapter, Section 3.4 elaborates features of the research site and participants, while Section 3.5 describes the curriculum and technology environment. Section 3.6 describes details of the four major analyses I employed in the main study, including the data sources, data collection approaches, and data analysis techniques for each. Finally, Section 3.7 provides a discussion of the resolution of validity and reliability concerns related to the methodological approaches employed in the study.

3.1 Design Based Research and Curriculum Co-design Process

Design-based research (A. L. Brown, 1992; Collins, 1992) is a methodological approach to conducting learning research in the naturalistic and complex context of real-life settings through systematic design and study of instructional strategies and tools (Barab, 2006; The Design-Based Research Collective, 2003). The cognitive revolution in psychology in the 1970s led to a progression of research methods, from studying individual students’ learning using psychological experiments in laboratory settings to examining students’ interaction and the knowledge advancement of a community of learners in real classroom settings (A. L. Brown, 1992). Design-based research emerged as a reaction to the observation that traditional learning research had ignored the social context where real-life learning and teaching happen (A. L. Brown, 1992; Collins, 1992). Design-based research was advanced as a means of studying learning that occurs in complex, naturalist contexts; it involves multiple iterations of testing and refinement of researcher’s design of learning environment, including technological tools and curricular interventions. In design-based research, scholars ground their design on learning theories derived from prior research to identify and examine how multiple, interactive variables of learning environments can influence students’ learning, cooperation, and motivation. The
goals of design-based research are: (a) to advance the learning theories; (b) to develop new artifacts that can be used to improve teaching and learning; (c) to inform the practices in teaching and learning; and (d) to generalize these theories, artifacts, and practices to other broader context (Barab, 2006; A. L. Brown, 1992; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; Collins, 1992; Collins, Joseph, & Bielaczyc, 2004).

Teachers often form individualized conceptions of innovative approaches to teaching and learning, and thus adapt researcher-designed curriculum to fit in their concrete learning context in ways that may not match the intentions of the researchers (Keys & Bryan, 2001). Therefore, the successful implementation of research-based curriculum (for purposes of research as well as student learning) depends upon the teachers’ understanding of the underlying theoretical perspective (e.g., KCI) and their faithful enactment of the designed curriculum (Peters & Slotta, 2009).

One way to ensure teachers’ commitment to or ownership of the designed curriculum is to actively engage them in the process of curriculum design. This method will ensure that the teachers’ voices will not be neglected and will help the teachers come to understand the researchers’ perspective (Ben-Chaim, Joffe, & Zoller, 1994; Hiller, 2009; Keys & Bryan, 2001). Curriculum co-design is one such process, where researchers, teachers, and technology developers work in close collaboration in the design and implementation of curriculum and research materials to address an educational research need, such that the voices of the teachers are deeply included (Penuel, Roschelle, & Shechtman, 2007; Roschelle, Penuel, & Shechtman, 2006; Shrader, Williams, Lachance-Whitcomb, Finn, & Gomez, 2001). Teachers play active roles in co-design by contributing to the design process according their particular expertise regarding the learning context and content; they provide inputs to refine the curriculum, suggest technology designs, and contribute to important features like user interface design (Penuel et al., 2007; Roschelle et al., 2006). During the implementation of the design, teachers can provide ongoing context information, modifying the design to accommodate ideas or elements that were missing. By participating in the curriculum co-design process, teachers may feel stronger ownership of the resulting design; they may have more chances to reflect on their practice as well as develop and refine their own ideas about teaching and how students learning (Penuel et al., 2007; Roschelle et al., 2006). Curriculum co-design will help researchers to produce
curricula that are both theoretically and practically compelling and are tightly integrated with teaching practice and technology. This method can also serve to broaden our knowledge of how teachers envision and carry out innovative pedagogical approaches (Keys & Bryan, 2001; Penuel et al., 2007). Curriculum co-design is highly compatible with design-based research, in that it emphasizes a methodology where research questions are situated or embedded within a design for purposes of examining questions that are deeply contextualized in classroom learning and instruction (Peters & Slotta, 2010b).

3.2 Research Methods (Main Study)

My study consisted of four analyses, named as follows: curriculum design, teacher knowledge, teacher enactment, and classroom interactions (i.e., between teacher and students). The purpose of the curriculum design analysis was to identify the teacher’s roles as they were explicitly and implicitly designed into the curriculum. The aim of the teacher knowledge analysis was to capture the different forms and levels of knowledge of the teacher participants of this research. The teacher enactment analysis examined the practical (i.e., observed) roles played by the teachers during curriculum enactment. Finally, the classroom interactions analysis aimed to examine the pattern of teacher-student interaction when students were engaged in KCI group activities. Finally, as well as to identify correlations between teachers’ knowledge and their interaction pattern. I applied two specific techniques in these four analyses: (a) an open coding procedure, based on the grounded theory research method (Strauss & Corbin, 1998) and (b) a content analysis on text and video data (Chi, 1997; Krippendorff, 2004).

The grounded theory method is a creative process to generate or discover a theory by grounding ideas or codes in data that are systematically gathered and analysed (Strauss & Corbin, 1998). In grounded theory design, researchers start exploring a phenomenon without any pre-conceived theory in mind (Creswell, 2007; Morrow & Smith, 1995). Theoretical sampling is the sampling technique that grounded theory researchers often use to choose research participants (Creswell, 2005, 2007; Strauss & Corbin, 1998). In grounded theory studies, researchers collect and analyse data through a “zigzag” process (Creswell, 2007), where they first collect some data, then analyse the data, and again collect and analyse new data based on the preliminary results from previous data collection and analysis process. A serial steps of open,
axial, and selective coding are often used by grounded theory researchers as the date analysis method to identify conceptual categories and sub-categories, relate the categories and sub-categories, and integrate and refine theory (Strauss & Corbin, 1998). Grounded theory researchers constantly compare data with emerging categories until all data are saturated (Strauss & Corbin, 1998); they write memos “throughout the research process to elaborate on ideas about the data and the coded categories” (Creswell, 2005, p. 411); they select a core category to pull all other categories together to form the theory (Strauss & Corbin, 1998); they produce a visual coding paradigm or a series of propositions or a narrative story to present their theory (Creswell, 2005, 2007; Creswell & M. L. Brown, 1992). The ultimate aim of grounded theory research is to generate a theory that can explain the process, the action, or the interaction shaped by the views of the participants of the phenomenon that studied (Creswell, 2005, 2007; Creswell & M. L. Brown, 1992; Morrow & Smith, 1995; Strauss & Corbin, 1998).

A potential problem of applying grounded theory method is that researchers’ prior knowledge and perspective about the research topic can influence the results they will recover from the data (Kelle, 2005; Suddaby, 2006). Some researchers thus believe that one should start any grounded theory approach with a completely blank slate, even deferring the survey of literature until data has been collected (Suddaby, 2006). However, it is usually impossible for a researcher to conduct a reasonable study without clear research questions derived from theory and informed by the literature (Suddaby, 2006). Moreover, it is impossible to conduct any empirical observation without the influences of one’s prior knowledge (Kelle, 2005; Strauss & Corbin, 1998). Suddaby (2006) summarized two ways to avoid being influenced by prior knowledge when conducting grounded theory research. One approach was to conduct cross-disciplinary research, as one’s primary discipline would not as likely influence the grounded coding when in a new, unfamiliar discipline. The other way was to constantly remind oneself of the potential of being influenced by prior knowledge. Strauss and Corbin (1998) suggested that the researcher could ask a reflective question: “Am I seeing these concepts in the data because I am so familiar with them?” (p. 49).

In one analysis within this study, I identified the roles that the research team designed for teachers, often implicitly prescribed within the design documents, meetings and emails. The goal was to evaluate the accuracy of those projections, and if so, to make the designed roles more
explicit. Thus, my prior knowledge about teachers’ role in their classroom (gained from literature and my own experiences) did not prevent me from identifying categories of the designed roles. Instead, my prior knowledge did help me categorize the designed roles in a meaningful way, providing “a source for making comparisons to data” (Strauss & Corbin, 1998, p. 49) and enhancing my “sensitivity to subtle nuances in data” (Suddaby, 2006, p. 635).

Instead of adopting the grounded theory method in its entirety, many researchers only use some of the procedures from grounded theory rather than the entire analytic process, when the purposes of their studies is not to develop an integrated theory, but rather to simply describe a phenomenon, discover categories or themes, or organize concepts (Glaser, 1992; Strauss & Corbin, 1998). Open coding is one of the procedures in grounded theory design that researchers often use to identify concepts and discover their properties and dimensions from data by constantly comparing data (Strauss & Corbin, 1998). The open coding process consists of sequential steps of conceptualizing and discovering of categories. Researchers first read the text line by line to break raw data down into discrete parts that each represents a single and the smallest idea or incident. They then label the discrete parts with names to identify and classify concepts. Later, the researchers grouped the concepts into categories – the more abstract and higher order concepts – that have the potential to explain and predict. During this process, researchers constantly add and compare new data with the concepts and categories that emerged until the categories are saturated (Creswell, 2005; Strauss & Corbin, 1998).

I chose open coding as a suitable data analysis method for describing the teacher’s role in a KCI curriculum. As no prior studies had inclusively described the teacher’s role in community-based approaches to teaching and learning, a description of the teacher’s role in the form of role categories could support the classification, interpretation, and understanding of the teacher’s role within the KCI model. Further, the research team previously had not explicitly described the roles that teachers should play in design stage, even though the team had scripted the learning activities in detail. I used open coding in analysing the curriculum design documents and the video recordings of the practical enactment of the designed curriculum with the intent of making the teacher’s role categories emerge from data.

Content analysis “is a research method that provides a systematic and objective means to make valid inferences from verbal, visual, or written data in order to describe and quantify
specific phenomena” (Downe-Wamboldt, 1992, p. 314). Content analysis is a data analysis technique that researchers can use not only to discover the manifest content that resides inside the data, but also to examine the latent content that subjects to the researcher’s interpretation of data in context (Krippendorff, 2004; Potter & Levine-Donnerstein, 1999). Researchers often use content analysis when they want to obtain a much richer, more detailed, and more accurate representation of the phenomena under study with the attempt to remove subjectivity and yet maintain the richness of context (Chi, 1997). When applying content analysis, researchers need to first decide the unit of analysis, then segment the data, define categories and develop a coding scheme and coding rules. They must then pre-test the coding scheme with a sample of segmented data, assess reliability and validity, and revise the categories, coding scheme and rules when necessary. Finally, they code all data, interpret results and draw conclusions from the data (Chi, 1997; Downe-Wamboldt, 1992; Krippendorff, 2004; Y. Zhang & Wildemuth, 2009).

Content analysis may be used for the purposes of describing patterns or trends in the content analysed, testing hypotheses, comparing the content with the real world, assessing the representation of particular groups in society, and drawing inferences (Gunter, 2000; Krippendorff, 2004; Wimmer & Dominick, 2011). The goal of content analysis is to discover the inside and obtain rich knowledge and understanding of particular phenomenon, and thus to inform practical actions (Downe-Wamboldt, 1992; Krippendorff, 2004). Researchers use content analysis method either as a quantitative approach or a qualitative approach to studying a phenomenon (Gunter, 2000; Hijmans, 1996; Hsieh & Shannon, 2005; Krippendorff, 2004). When used as a quantitative approach, the outcome is often a quantification of categories and their relations that describe the phenomenon under study (Chi, 1997; Downe-Wamboldt, 1992).

I employed content analysis as a means of capturing teachers’ knowledge, measuring and comparing teachers in terms of their levels of content knowledge, pedagogical knowledge, and technological knowledge. I also used content analysis to capture teacher-student interaction in order to portray the pattern of their interaction with students in the enactment of the KCI curriculum. I reasoned that content analysis was a good match for analysing classroom enactment data to (a) describe and compare the behavioural patterns of the three teachers and (b) interpret why these patterns occurred (Chi, 1997; Morgan, 1993).
My examination of the interaction of people with peers and with objects in their environment helped me to identify regularities in their practices (Jordan & Henderson, 1995) and thus understand more about the general role of teachers in the KCI approach. I used video recording as an important data source from which to analyse teachers’ interactions with their students and their enactment of the designed curriculum because it has some advantages that other types of data cannot provide. First, video recording provides a naturalistic record of social interactions accomplished through talk, gestures/bodily language, and others actions (Heath, 2004). Second, video recording affords the ability to replay any recorded sequence of interactions, allowing researchers to deeply analyze many aspects of event. Third, the richness and permanence of the video record can reveal patterns or phenomena that other forms of data cannot (Goldman-Segall, 1993). Fourth, video recording provides a detail record of complex activities in practice and the context in which they occur that even a trained observer cannot keep track of (Chi, 1997; Jordan & Henderson, 1995). Finally, video recording may remove some of the dependency on the researcher’s selectivity, and thus make the analysis relatively strong (Chi, 1997).

3.3 Two Iterations within the Larger Research Program

The larger research project in which this dissertation study was embedded was a design-based research project, which included two iterations. While the dissertation is mainly about the second iteration, this chapter describes the first iteration, which served as a pilot or guide for the dissertation study. It is important to discuss this first iteration, because it served to guide the design of the second iteration (i.e., with respect to the “fit” to KCI) and also informed revisions to the technology environment.

3.3.1 Description of the first iteration

This effort involved one teacher, Mary, and her students (n=42) in two class sessions. The curriculum implementation included 20 lessons lasting for eight weeks. The climate change science content that was covered in this iteration was the same as in the main study, which included Climate Changes in Canada, Earth’s Atmosphere, Greenhouse Effect, Energy Saving and Greenhouse Gas Impacts, Thermal Energy and Oceanic Circulation, Carbon Sinks and
Sources, Paleo-climatology, Extreme Weather Patterns, and Climate Change Remediation. The curriculum had three phases: establishing the KCI epistemology and setting the learning context, collaborative knowledge construction, and scaffolded inquiry. However, the overall activity design was based on the seven regions in Canada: Nunavut, Western Arctic, British Columbia, Prairies, Ontario, Quebec, and Atlantic provinces. It is important to note that the specific learning activities in each stage and grouping strategies were different between the first and second iterations.

The first phase included two types of activity that interwaved each other: establishing the KCI epistemology and setting the learning context and brainstorming. To establish the KCI epistemology, a researcher led an in-class discussion on the philosophy of collaborative learning. He explained the concepts of knowledge community and collaboration and the importance of this concepts and its practice in scientific research in the 21st century. The purpose of establishing KCI epistemology was to set students a mindset of proper learning approach in a knowledge community of collaborative inquiry. Students thus were informed that they would work with students from another class sessions to collectively contribute to a community knowledge base and that they would be evaluated as a whole in groups. In addition, the teacher also introduced the resource annotation activity, which asked each student to contribute at least two climate change resources to the knowledge base. The researcher then talked about the “tagging” function, and explained the importance of tagging in learning community.

In the activities to set the learning context and brainstorming, students in each class session worked separately. They first watched the Sila Alangotok video, a 15-minutes video about the influences of climate change on the aboriginal people in the Sax Harbour in Northern Canada. Then, students engaged in a jigsaw activity. They were divided into seven groups according to the seven regions in Canada. Each group included three students representing members from three entities of occupations: natural resources related entity (e.g., miner, farmer, fisherman, hunter, etc.), industrial or manufacturing entity (e.g., engineer, food processing, etc.), and service industry entity (e.g., teacher, doctor, government employee, environmentalist, etc.). Each regional group was then given one corresponding poster about the climate change issues in the group’s representing region. Each student was asked to collect information from the poster about how climate change affects the life/occupation that he/she represented. After they collected
the information, students then re-grouped according to the three occupational entities, so that each occupational entity group had at least seven students, each representing one of the seven regions in Canada. Each student presented the information he/she had found to his/her occupational entity group and discussed with others in the group about the information they collected.

In the second phase, students collaboratively constructed and refined the knowledge base while they studied the climate change science content. Students from the two class sessions worked together scaffolded with a wiki-based technology platform. Students worked in seven groups, each represented one of the seven regions in Canada. In each regional group, six students from both class sessions collaboratively built a wiki page for their regional group. On the regional wiki page, students first wrote about the overview description of the region with information about the major industries, cultural and political issues, and other economic sources and activities of the region. Then, they wrote about the climate change science that is related to their region, which include greenhouse gases, ocean currents, air currents or weather patterns, carbon sinks and carbon sources, and thermal energy. They also wrote about the climate change issues that six stakeholder groups (primary industry, tourism industry, energy industry, other industry, environmentalist, and Minister of Environment) might want to address in their region. Finally, they added related information that they collected when they studied climate change models.

In the third phase, the students engaged in scaffolded inquiry where they applied the climate change science they learned to address various issues in the seven Canadian regions from the above-mentioned six stakeholders' perspectives. Students in the two class sessions were re-grouped and worked with members from both class sessions together again to compose wiki pages in six stakeholder groups: primary industry, tourism industry, energy industry, other industry, environmentalist, and Minister of Environment. Students in each stakeholder group wrote an overview of key concerns of climate changes in Canada from their perspective; they predicted the kind of climate changes that are important for their stakeholder group using climate change science models (e.g., more ice melting is important to fishing industry); they authored paragraphs about the climate change impacts on each of the seven regions in Canada that are important to their stakeholder group as well as the remediations to the impacts.
The enactment of this first iteration followed its original design. However, the research team was not satisfied with the enactment in terms of its fitting of KCI principle. The next section provides my review of the enactment from the KCI principle perspective.

3.3.2 Evaluation of the first iteration

The research about the first iteration has been reported in detail in another Ph.D. dissertation (Najafi, 2011) and is summarized here because it provides important context. Once the curriculum enactment was completed, the research team and the teacher who co-designed the curriculum unit sat together to review and discuss the issues or problems experienced during the enactment, and identified the following:

1. In the second phase, when students collaboratively constructed and refined the knowledge base, students were asked to contribute from the perspectives of the stakeholders they represented. However, what the students should contribute to the regional inquiry was not clear. One possible reason was that the students were unable to adopt the perspectives of the stakeholders they represented, as they did not have any experiences related to the specific stakeholders.

2. The relevance of the knowledge base to the scaffolded inquiry projects was not clearly stated and emphasized in the pilot study. Therefore, the knowledge base was not fully used by students during their scaffolded inquiry learning.

3. The science content was not clearly indexed when students collaboratively construct the knowledge base. Hence, it was difficulty for students to connect the climate science to the impacts of climate change and the remediation of impact from the six stakeholders perspectives.

4. Near the end of the unit, we were running out of time and behind schedule. The teacher had to run a few make-up lessons in order to cover all the required science contents in the curriculum standard. The teacher’s role thus became focused on time management and classroom management.

5. From the co-design perspective, the curriculum did not include any technological development. We used a wiki-based system in which the functionality was not customizable. Thus, we could only use the available function to support teaching and
learning. Management was difficult in this wiki system in terms of assuring group permissions to facilitate the grouping and re-grouping of students.

3.3.3 Modifications in the second iteration

The co-design team began meeting about the second iteration not long after completing the first. The team sought to address these issues in a new design of curriculum and technology, which provides the context for analysis in the next chapter of my dissertation. I summarize some of the key design changes that emerged after the first iteration here. The details of the second iteration design will be described in Section 3.5, below.

First, the research team made some changes to the learning activities. In the brainstorm and setting context activities, students still worked in groups. However, the brainstorm was not limited to any specific Canadian regions. Students examined climate change issues in general using the posters of the seven Canadian regions as a hit to stimulate their thinking. The collaborative knowledge construction and the scaffolded inquiry activities were evolved around climate change issues that the students were interested in investigation, without considering the specific regions of Canada and the stakeholders groups.

Second, we changed the grouping methods in different phases. In the first phase, students did not work in a jigsaw activity. They worked in groups without re-grouping in another group configuration. In the collaborative knowledge construction activity phase, instead of being grouped in seven Canadian regions, students were grouped according to their interests in climate change issues. Students in each climate issue group were composed of members from two class sessions. In the scaffolded inquiry activity, students were grouped according to the climate remediation plans they were interested in. In addition, students worked only with members from their own class sessions instead of working with members from other class sessions.

Third, we changed the technology platform in the main study. I designed the technology platform with Drupal content management system. Drupal offered a distinct advantage, and a dramatic improvement over previous technologies in terms of the rapid development of a Web site, materials, functional collaborations, permissions, dynamic display of content, and the secure handling of student data. The advantages of this practice were: (a) we were able to address any
technical issues during the enactment of the curriculum; (b) from the co-design perspective, technology developer was involved in the design and was able to offer insight in the design and enacting of the curriculum.

3.4 Research Site and Participants

The research site was a mainstreamed and academically heterogeneous secondary school (grades 7 – 12) in the city of Toronto. Three science teachers and their students from five class sessions at grade nine participated in this study. Students of all five sections (n = 106) of the ninth grade taught by these three teachers participated in the second iteration of the curriculum enactment studies.

The first teacher, Mary, had over 15 years of experience in science teaching and taught two of the five class sessions. She was an expert teacher in terms of KCI model, because she had collaboratively worked with our research group twice before in other research projects that implemented the KCI curriculum. She had the most relevant experiences and the best understanding of the KCI model among the three teachers. Indeed, Mary co-designed the climate change curriculum unit with the research team, joining the co-design team at the end of her summer break and contributing one hour every week until the beginning of the climate change unit. Mary suggested various teaching materials and learning activities and contributed to some of the design elements, such as the interface for showing and filtering references as well as the teacher evaluation tools (see section 3.4.2 for detail). She had an acceptable level of technology skills, with fluent use of standard MS office suite, email, and web browsers fluently. She was able to trouble shooting simple technological problems, and had many rich experiences of using technology in teaching. Because she was clearly the most knowledgeable and experienced of the teachers with regard to collective inquiry (and indeed, to climate change science as well), Mary’s enactment of the curriculum was used as a model in this study for the purpose of comparing teachers and suggesting best KCI practices.

The second teacher, Steven, also had over 15 years of science teaching experiences. He also has an acceptable level of computer skills. He also had used iClicker in teaching. Steven once worked with one of my colleagues in the use of video technology to teach physics. He was
not involved in the curriculum co-design process and received the curriculum design documents to interpret for himself. He only taught one of the five class sections.

The third teacher, Jonathan, was a new science teacher who just started his career as a supplemental teacher when he participated in the study. Like Steven, he was not involved in the curriculum co-design activity and received the design documents for reference. He left the research project in the middle of the enactment because his contract with the school had ended. He taught two of the five class sessions. When Jonathan left the program after the winter break, a fourth teacher took over his two class sessions. Students in these two class sessions continued to participate in the study. Both Steven and Jonathan attended teacher-researcher meetings a couple of times to learn about the designed curriculum.

3.5 The Curriculum and Technology Environment

The curriculum design process was an on-going and iterative process. The research team designed the overall framework of the curriculum as well as the specific learning activities and science content of the first 11 lessons before the formal start of the climate change unit. The research team continued to add and modify content as a result of events occurring in the classroom during the enactment of the curriculum. In addition, the climate change curriculum was improved considerably through further co-design meetings with the original teacher, in terms of its student activities, materials, and technology infrastructure. In the second iteration of this study, the research team modified and improved the curriculum based on our evaluation of the enactment of the first iteration of the curriculum.

3.5.1 The curriculum and its implementation

This section refers only to the second iteration of the curriculum. The first iteration had a different design, and is reviewed in Section 3.3, above. At the time of the second iteration, the ninth grade science curriculum in Ontario included four major units: Climate Change, Chemistry, Biology, and Optics. The Climate Change unit contained 21 lessons, including two unit tests and one final presentation. The unit covered topics including: Climate Changes in Canada, Earth’s Atmosphere, Greenhouse Effect, Energy Saving and Greenhouse Gas Impacts, Thermal Energy
and Oceanic Circulation, Carbon Sinks and Sources, Paleo-climatology, Extreme Weather Patterns, and Climate Change Remediation.

Based on the KCI model (see Figure 2.1), the design included three phases of activities: (a) KCI epistemic orientation and issue brainstorm, (b) working on issue pages, and (c) working of remediation pages. These three phases of activities were designed in accordance with the design principles outlined by the KCI model (detailed in Chapter 2), beginning with the establishment of a collaborative culture (i.e., epistemological framing), then proceeding to collective exploration and knowledge construction, interwoven with scaffolded inquiry (Slotta & Najafi, 2013). Figure 3.1 shows the three phases of the designed learning activities along a timeline of the 21 class periods in the design, together with three corresponding elements of the general KCI model and the technology scaffolds. The following sections describe the details of the designs of these learning activities, as revealed by the design documents.

Figure 3.1 The Three Phases of the Learning Activities and Corresponding KCI Elements and Technology Scaffolds

**Epistemic Orientation and Issue Brainstorm.** The purpose of establishing KCI epistemology was to orient students toward adopting a mind set of how to effectively learn in a knowledge community of collaborative inquiry. That is, students needed to collectively contribute to the community knowledge base, collaboratively inquire about science topics, and be evaluated as a
group. A KCI approach should affect students’ learning behaviour and their understanding of learning, including students’ construction and refinement of community knowledge, their scaffolded inquiry activities, and their production of learning outcomes.

To establish the KCI epistemology, our design was that one of the researchers would lead a discussion with students about the main ideas of knowledge community and peer collaboration, explaining their importance as a reflection of the nature of real life in this society. The discussion would include references to “science 2.0” (e.g., the Human Genome project), and “Web 2.0” (e.g., Wikipedia), and connections to the collective aspects of the Climate Change unit, including the design of special tools to support groups as they collaborate. Next, the classroom teachers would emphasize that collaboration is valued in the school and describe how this unit will provide the students with a new and challenging learning opportunity. Teachers were also asked to mention that the students’ contribution to the learning community would be evaluated. We also introduced, in the first epistemology lesson the notion of “tagging”, including an explanation of why tagging is important within a learning community. Lastly, the school librarian would teach the students how to evaluate the content of resources, especially online ones.

The goal of establishing a KCI epistemology was designed to be reinforced several times throughout the unit, by asking students to reflect on their understanding of collaborative inquiry and community learning at various points in time. By establishing the epistemic context in this way, the design team sought to help students build a sense of community identity.

Class periods 1 to 3 (see Figure 3.1) were designed to orient students to the content domain of climate change, and how the curriculum unit would be enacted. In addition to completing a pre-test of student knowledge about climate change, students engaged in a set of activities designed to orient them to the content domain, including (a) searching for relevant references; (b) watching a video about climate change in Canada and discussing its content; (c) a collaborative crossword puzzle activity; (d) writing a letter to a new paper editor about the climate change issue that they think hurt Canada most; (e) reading materials, including handout prepared by the teacher about “traditional ecological knowledge” and selected materials from a project called Green Learning; and (f) a culminating e-card activity where students studied current energy topic, created an electronic card with graphics and message about climate change
issues they thought important, and sent it by email to others (e.g., friends, parents, etc.) (Greenlearning, n.d.a).

The 15-minute video about climate change in Canada was named Sila Alangotok, was concerned with the effects of climate change on the life of aboriginal people in the Sax Harbour in Northern Canada. Before playing the video, we designed three questions that the teacher would give students to reflect on during a debriefing conversation: (a) What were some of the observations about Climate Change made by the community members of Sachs Harbour? (b) How can the observations of the Inuit elders be important in the study of Climate Change? (c) What issues around Climate Change were raised as a result of this video?

In the brainstorm activity, the five class sections would cooperate as follows: In Lesson 1, students in each of the five class sessions worked in groups of three or four to brainstorm various climate change issues that they could think of, writing each issue on a post-it note which was then stuck to a large piece of chart paper. Students needed to speak about any issue they added, with one student speaking at a time, and an instruction that they should try to build on others’ ideas. Students would be required to generate as many ideas as possible, without making judgment about others’ ideas. Students would also be given a set of posters that were prepared by the Canadian government (Natural Resources Canada, n.d.) about climate change in seven different regions in Canada (Nunavut, Western Arctic, BC, Prairies, Ontario, Quebec, Atlantic provinces) as clues of brainstorm.

In period 2 and 3, students from Class section 1 would be divided into five groups to sort the post-it notes (from all sections) on chart papers into categories of similar issues, and to try to name those categories. Students from Class section 2 would then continue from where students in Section 1 had left off, working in five groups to sort out the post-it notes from all 5 class sections. The design team expected that they might need to create new categories (i.e., for new climate change issues) as they were sorting the post-it notes. In class sections 3, students continued with the aim of completing the sorting of all post-it notes. This could include proofing the work from previous class sections, by re-arranging post-it notes or changing category names, or creating new categories. Students in Session 4 and 5 would be charged with creating “Issue Brainstorm pages” on the Drupal technological platform that was designed for this unit. They would need to create one Issue Brainstorm Page for each category that the previous class
sessions had generated. On each Issue Brainstormed Page, they were asked to add the content (in point-form notes) of all the post-it notes under the corresponding category. In this way, five class sections of students were able to brainstorm a wealth of climate change issues, then synthesized those into a set of course-wide Issue Pages that would serve as a framework for all subsequent activities.

The issues that students brainstormed would serve as the framework for the community knowledge base in this issue. In subsequent activities, students would be charged with collaboratively investigating these issues as they study the science of climate change. Thus, the Issue brainstorm served to initialize the community knowledge base, preparing for the co-construction and refinement of community knowledge. Within this learning activity, students’ primary ideas would be captured and stored in the community knowledge base as advance organizers for future use.

**Working on Issue Pages.** According to the KCI model, students should collaboratively construct and refine the content of the community knowledge base, which was initialized in the earlier brainstorm activity (i.e., the climate change issues were articulated). Students worked in small groups, based on their selection of one of the Drupal Issue Pages, which their group was responsible to populate, over the next six weeks, with connections to relevant science topics, principles and real world examples. Each Issue group had eight students from two of the five different class sessions (four from each) that participated in this study.

We designed an Issue Page template that has following sections and sub-sections: (a) description of the issue; (b) related sciences, including sub-sections that connect to the topics of greenhouse effect, thermal energy and circulation, carbon sinks and sources; (c) evidence that documents the issue; (d) scientific models and scenarios; (e) legislation and remediation efforts; and (f) references that are used for that page. The purpose of using such a template was to scaffold students’ learning to ensure that they examine certain specific climate change science topics that should be addressed according to the curriculum expectations. We also asked students to tag the content they input in each of the sections mentioned above. Figure 3.2 shows the template that we pre-formatted.
We also designed a peer-reviewing activity where students reviewed Issue Pages from other groups. The purpose of this activity is for students to learn about other issues and to evaluate the science content of other groups. Students could then make changes to their own group’s Issue Page based on other students’ comments. Students were asked to review two issues pages of other groups in the curriculum design.

The collaborative Issue Page editing activity is a process of refining the brainstormed issues that are already put in the community knowledge base in the second learning activity. Such collaborative knowledge co-construction yielded completed Issue Pages stored as elements of community knowledge base, which were one form of learning outcome that was accessible to the wide community and used by students in subsequent learning activities. In this process, community voices and emergent themes will be captured and aggregated in the knowledge base.

In the designed curriculum, the climate science concepts and principles the students will study includes carbon dioxide and greenhouse gas effects, the influences of atmospheric layers and solar radiation on climate, albedo, carbon sinks and carbon sources, El Nino and La Nina effect, energy saving, extreme weather patterns, heat transfer, CFC (Chlorofluorocarbon) and human impact on Ozone, paleoclimatology, ocean circulation and thermal energy convection, water cycles, and others. Students study the science concepts and principles in various formats, including lecture-discussions about climate science content led by the teacher, science laboratories, working on Web-based inquiry activities such as the WISE Climate Change lesson, reflecting on learned content, and doing various homework activities.

The Issue Page editing started in Lesson 4 and ended in Lesson 17. Students were given about 15 minutes (time permitting) of each class period to work on their Issue Pages, with the task of adding the science content that they learned into the relevant sub-section of their Issue Page. For example, after studying the science of carbon dioxide and greenhouse gases, students working on the Alberta Tar Sand Issue Page should add information about how greenhouse gas effects are related to this issue. This activity supported students in making connections between the science content they learned and the climate change issues they were investigating.

**Working on Remediation Pages.** This third major learning activity was designed to scaffold student inquiry that employed the Issue Pages as a primary resource, in the form of an
activity where they developed a remediation plan for climate change issues. Students again worked in small groups, this time within their class section, and focused on issues other than the one they had specialized in the Issue Pages portion of the unit (for which they had already considered previous or existing remediations). Now they were asked to consider new issues, to think about what should really be done, and to justify their position using the science of climate change (including predictions of climate models in the future). In this learning activity, teachers re-grouped the students into jigsaw groups consisting of students from different Issue Page groups but in the same class section. Teachers were asked to remind the students to review the contents in the knowledge base (i.e., the references and the remediation section of the Issue Pages the students created during previous learning activities) and to use that content as a resource in their creation of the Remediation Pages. To scaffold this activity, we designed pre-formatted empty “Remediation Pages” (see Figure 3.3). This activity lasted from Lesson 18 to Lesson 20.

The curriculum was implemented over a nine-week period during the 2009-2010 academic year. The first 12 lessons of the designed curriculum were enacted before the Winter break. After the Winter break, the reset of the designed curriculum was enacted. During the implementation of the curriculum, the researchers engaged in continuous communication with the three teachers about the enactment of the designed learning activities and various issues raised during the implementation. Nothing special happened (e.g., teacher strikes or schedule changes) that prevented or interfered with any teacher’s implementation of the curriculum.

3.5.2 The technology environment

A technology environment was used in this study for the purposes of constructing a community knowledge base, supporting students’ collaboration and inquiry, designing and delivering instruction and research materials, and collecting all student work. Drupal, an open-source content management framework, was used to build the technology environment.

Unlike typical content management system, Drupal is a configurable, customizable, flexible and scalable web development framework that allows for a broad range of interactive web applications, such as community web portals, discussion forums, personal blogs, and social networking websites (Fitzgerald, 2008). The Drupal framework includes two parts: Drupal core
and contributed modules. Drupal core is the standard installation of Drupal, consisting of essential modules and themes that provide fundamental features for user management, menu management, page layout customization, system administration, searching, blogging, discussion forums, file upload etc. The contributed modules are plugins that extend, build or enhance Drupal core functionality. They provide enhanced image functions, custom content types and content listing, community building, WYSIWYG editors, third-party application integration interfaces and others. There are over 4000 free modules developed and contributed by members of Drupal community (Fitzgerald, 2008; Tomlinson, 2010).

From research team’s experience, we found that Drupal offered a distinct advantage and a dramatic improvement over other technologies in terms of the rapid development of the required collaborative environment, adding substantive functionality for coordinating groups, granting access permissions, tracking comments, semantic tagging, dynamic displaying of content, secure handling of student data, and more. Drupal was also quite flexible during the runtime of the curriculum. For example, enabling menu items as needed for students and teachers was easy during the actual running of the project. The dynamic access and adaptations of the curriculum during runtime, without compromising the stability of the system or the security of student data, were another major contribution of Drupal.

The technology environment supported students’ collaboration and inquiry in three ways. The first was to scaffold the creation of knowledge base in the brainstorm stage. The second was to scaffold students’ collaborative editing of climate change issue pages during the science content acquisition and inquiry stage. The third was to scaffold students’ collaborative editing of remediation pages in their final inquiry learning activities.

To scaffold the creation of knowledge base, we created a “Brainstorm” template for students to briefly write about the climate issues they were interested in and a “Reference” template for the students to create references that are related to climate change. The “Brainstorm” template was very simple, including two fields: title and description. Students needed to give a title of the issue and write a brief description of the issue. Students were prompted to use bulleted points to list their brief ideas about the climate change issue in which they were interested. The “Reference” template included five fields: title, annotation, citation, tags and additional tags. When creating a reference, students needed to write a brief introduction
of what the reference is about in the annotation field, the MLA citation format of the reference in
citation field. The students also needed to check at least one tag that the reference is related to in
the tags field. The tags were pre-set in the template. The first teacher who participated in the
curriculum co-design provided the tags. Students could add additional tags to the reference in the
additional tags field. In order to index the brainstormed issues and references, “Brainstorm” and
a “Reference” links were created in the navigation section on the website, where students could
browse all brainstormed issues and references. These two links were always available to students
no matter where they are on the website. Students could filter the display of references by
selecting pre-set tags.

To scaffold students’ collaborative editing of issue wiki pages, the research team pre-
formatted the wiki pages for each climate change issue with a template shown in Figure 3.2. The
issue page template had the following sub-sections: (a) Description (of the issue); (b) The
sciences (including sub-sections for: greenhouse effect, thermal energy and circulation, carbon
sinks and sources); (c) Evidence; (d) Models and scenarios; (e) Legislation; (f) Remediation; and
(g) references. Each of these fields, except the issue title, had a “tag” field so that students could
tag the content with keywords. These issue pages were designed to enable multi-user editing.
Because students in each group came from different class sessions, they needed to coordinate
their communication and collaboration, distribute their work among group members, discuss
content they needed to address, or make suggestions and comments to peers. Students could use
a “To Do” Web page that the research team designed to support the communication and
coordination within each Issue group.
To scaffold students’ remediation activity, the research team created a pre-formatted “Remediation” page template, shown in Figure 3.3. The template has seven sections: description, issue impacted, effectiveness, overall effectiveness, improvements/extensions/new alternatives to the remediation, prediction of future effectiveness of modified remediation, and references. Once again, these remediation pages were designed to enable simultaneous editing on different sections.
To support the delivery of research materials, the researchers used the technology environment to collect students’ reflections on their role in collaborative knowledge construction and to record students’ editing history of the issue pages and the remediation pages (Najafi, 2011). To support the complex process of evaluation, we provided the teacher two different ways to retrieve students’ editing history on issue pages and remediation pages. The first way was to use the “Revisions” function from Drupal, which (similar to a wiki) highlights what changes were made in each version of the page. The second was using the “View” function” in Drupal to provide a list of editing history of a page of any given student. However, the teachers were not satisfied with this function for two reasons. First, Drupal did not provide a sophisticated function in terms of showing the differences between versions of editing history, making any assessment difficult.
of student’s individual contributions to the page quite challenging. Second, the teachers had to do a lot of work to identify students’ intellectual contribution (e.g., making the idea growth) rather than logistical contribution (e.g., correcting grammar and spelling, formatting a page). There is no computer program could help the teacher identify students’ intellectual contributions automatically.

3.6 Analyses

The study includes four major analyses. This section describes the data sources, data collection approaches, and data analysis techniques for each.

3.6.1 Curriculum design analysis

The data sources and data collection. At the time of designing this climate change curriculum unit, the research team was not sure about the kind of roles the teachers should play in the KCI model. Therefore, the design was mainly focused on students’ learning activities. The purpose of my curriculum design analysis was to identify the roles that the researchers defined (i.e., the “designed roles”) for the teachers – both explicitly and implicitly – based on the curriculum documents, email record, meeting minutes, and so on. Data sources included: two curriculum design documents, six lesson plans, and 14 emails between the researchers and the teachers. The curriculum design documents included two wiki pages. The first curriculum design document was the curriculum outline of the 21 lessons constructed as a wiki page. The page contained brief information about the 21 lessons in the climate change unit: titles of the lesson or activity, the teaching date, the name of the available resources, the outcomes that each lesson addresses in accordance with the Ontario curriculum requirement, and the homework for students. The second curriculum design document was the full curriculum that describes the 21 lessons in detail, also constructed as a wiki page. This document included information such as the steps of each learning activity, time allocation for each activity, the locations (e.g., the URLs) of resource materials, the science content topics that the teachers need to lecture, students grouping and re-grouping methods, and others. These two documents resided on a wiki-based system with access limited to authorized persons. The lesson plans included six lesson plans prepared by the teacher participating in the curriculum design. She prepared the lesson plans for
the other two teachers and included: (a) descriptions of each lesson, (b) curriculum expectations of each lesson specified by the Ontario curriculum standards, (c) the detailed description of the teaching and learning activity, (d) time allocation for each activity, and (e) materials and resources for each activity. Finally, fourteen emails were included in the analysis of the designed teacher’s role. These emails were about the activities in which students would be engaged, the specific climate change contents that would be covered, and the specific steps of teaching/learning activities.

**Data analysis techniques.** Open coding was used in the curriculum design analysis. The attention of this analysis was to develop a category that could explain what roles the researchers had designed for the teachers in the KCI curriculum. This analysing process included two steps. The first step was conceptualizing. I started this step by first examined the curriculum outline wiki page. I opened up the curriculum outline and divided the text into smallest segments—one or two bulletin points in each segment. Each text segment specified only one single thing that the teacher should do. I then labelled the text segment as a concept using imperative sentences. I compared new text segment with existing concepts and generated a new concept if it was necessary. At the end, I generated 40 concepts from the curriculum outline. Then, I examined the full curriculum document with the same text chunking, comparing, and labelling procedures I used with the curriculum outline document. However, if none of the existing 40 concepts could be used to label a segment of text, I generated a new concept. Another 12 new concepts were generated after examining the full curriculum. Then, I brought in the six lesson plans and the fourteen emails and analysed them using the same procedure. Finally, in this conceptualizing step, I generated a total of 95 concepts that explicitly and implicitly specified the things that teacher should do in this climate change curriculum.

The next step of curriculum design analysis was discovering categories. In this step, I identified the concepts that had the ability to explain similar things that teacher should do and grouped them into a higher level of categories. When naming the categories, I referred previous studies on teachers’ role to stimulate my thinking (Strauss & Corbin, 1998). In this round of categorizing, all 95 concepts were grouped into 12 categories. However, some of these 12 categories had very close meaning and function in describing what the teachers should do. Therefore, I tried to refine these 12 categories into a more abstract level. This resulted in a
construct of nine categories that described the types of roles that the researchers designed for the teachers in the curriculum design documents. Nvivo (Version 8; QSR International, 2008) was used in this process to help me label concepts and refine the categories.

3.6.2 Teacher knowledge analysis

Data sources and data collection. The purpose of teacher knowledge analysis was to measure teachers’ knowledge levels from five categories: climate change science content, knowledge of inquiry-based learning, knowledge of community learning, knowledge of the general role of teacher, and knowledge of the role of technology. The data for teachers knowledge analysis were the transcripts of one-on-one interviews of the three teacher participants. One day before the designed curriculum was implemented, I interviewed the three teacher participants. The interview protocol (see Appendix A) included 12 open-ended questions asking the teachers to articulate their own understandings of the above-mentioned five types of knowledge. My supervisor designed the interview questions. The interviews were tape-recorded and then transcribed verbatim by myself. Each interview was about 20 minutes in length. The transcripts of all the interviews were 12-page long.

I did not find an appropriate instrument for measuring teacher’s knowledge. My purpose was to assess (a) the complexity of what should be accounted for as necessary knowledge and (b) the complexity of the interactions among content knowledge, pedagogical knowledge, and technological knowledge. I found that some of the existing instruments were problematic in that they were unable measure the teacher’s knowledge level. For example, asking respondents to rank their agreement on a statement like “I have sufficient knowledge about mathematics” (Schmidt et al., 2009) did not really measure the level of respondents’ content knowledge on math. Therefore, I used interviews as a way of measuring teacher’s knowledge. The advantage of interview as a data collection method is that it enables teachers to voice their own experiences without constraints and thus enables the researcher to elicit what a teacher knows in a way that cannot be captured through observation or other methods of data collection (Creswell, 2005; Patton, 2001). In addition, interviews can overcome the problem associated with written self-report responses, which often reflect what the teachers think they should do rather than what they have actually done in practice (Fang, 1996).
**Data analysis techniques.** I used content analysis technique to quantify teachers’ interview transcripts, allowing for measurement and comparison of the three teachers’ knowledge levels. Table 3.1 shows the coding scheme that I used. Teachers’ knowledge was measured from five categories. For any interview comment that reflects a given knowledge category, depth of understanding was scored on a scale of 1 (*low*) to 3 (*high*). I developed this coding scheme based on review of related literature and on my supervisor’s advice. The coding scheme was developed before I transcribed the interview and I did not change any of the codes during the segmenting of the transcripts. The unit of analysis was idea. Therefore, I segmented the interview transcripts into text chunks that each contained one single idea. And, each text segment included one or more sentences. For example, the following excerpt from a teacher’s interview transcript exemplifies the coding of multiple sentences as one segment (Chi, 1997) as this teacher was really just trying to talk about his understanding inquiry learning:

*Any particular type of learning where, uh, the learning goal is fairly open-ended. Uh, it is the students responsibility or, you know, their TASK to find out, what is the problem they want to solve instead of us giving it to them. And, try to discover a solution for that and there is no necessary right or wrong answer sometimes.*

- Jonathan, 9th grade science teacher

Table 3.1

*Coding Scheme for Teachers’ Knowledge Analysis*

<table>
<thead>
<tr>
<th>Knowledge categories</th>
<th>Levels</th>
<th>Definitions of knowledge levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate change content</td>
<td>Content_3</td>
<td>Deep discussion of content. Teacher is able to mention any specific content knowledge or PCK, the complexity or connections among sub-topics; be able to connect 3 or more concepts together; talk about the social influences on students’ learning.</td>
</tr>
<tr>
<td></td>
<td>Content_2</td>
<td>Some mention of specific content and learning goal; be aware of that this is a multi-discipline topic; mention that the topic is relevant to real world.</td>
</tr>
<tr>
<td></td>
<td>Content_1</td>
<td>Vague or general treatment of content or statement of personal doubt or concern.</td>
</tr>
<tr>
<td>Inquiry based learning</td>
<td>Inquiry_3</td>
<td>Students collaborate and communicate with each other; students come to the conclusion or find out the results themselves; students collect and analyse data.</td>
</tr>
<tr>
<td></td>
<td>Inquiry_2</td>
<td>Student create their own ideas, student generate questions.</td>
</tr>
<tr>
<td>Code</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>Inquiry_1</td>
<td>Projected based learning, problem solving, doing (superficial) inquiry project.</td>
<td></td>
</tr>
<tr>
<td>Community learning</td>
<td>Community_3: Students progress as a whole group or class, build on peers’ ideas, use elements in knowledge base, contribute to the understanding of the whole class, identify “big ideas” in learning. Community_2: Students from different class sessions work in same group, scripting, dialogue, jigsaw, use wiki in learning, sharing their questions and sharing their problem-solving process. Community_1: Students work in groups with workloads divided, talk about the value or importance of collaboration, essential 21st century skills.</td>
<td></td>
</tr>
<tr>
<td>General role of teacher</td>
<td>Role_3: Create a safe and supportive learning environment, link students’ learning to personal or previous relevance, cross-referencing ideas, provide feedback or help to students when needed, modeling collaborative work, guide or lead students to the direction they should go, foster students’ problem solving skills. Role_2: Coordinate group work, Monitoring students’ progress (“make sure it all going well”, “students on same page”), set the learning goal. Role_1: Knowledge transmission, delivery content, lecturing, classroom management, make up missing content, help to solve technical problems.</td>
<td></td>
</tr>
<tr>
<td>Role of technology</td>
<td>Technology_3: Student-centered use of technology, support students’ communication and collaboration; connect students to real-world contexts, technology as knowledge construction tools, conversation and collaboration tools; as data collection and manipulation tool. Technology_2: Technology is a tool for learning. Use technology for simulation, visualization, storing information; use technology as semantic organization, dynamic modeling, or information interpretation tools. Technology_1: Use technology to support teaching; students need technology skills; students are attracted by or become excited with technology in class; use technology to motivate students; use technology as much as possible.</td>
<td></td>
</tr>
</tbody>
</table>

Each text segment was then coded with one or two codes depending on whether the idea in the segment can denote two different categories of knowledge. For example, the next excerpt was coded with both Technology_2 and Inquiry_3 because the teacher was suggesting that technology could be used as a modelling tool and that students could thus to test hypothesis and to find out the results themselves. I acknowledge here that a teacher uttered a statement that was
coded as a “2” (i.e., and not a 3) this does not mean that the teacher only possessed this level of knowledge. Indeed, teachers typically made statements that I coded in several categories of knowledge.

*And even with some of the physics stuff, we can get really good data by manipulating [software]. You can do it so much fast online. So, once you get the idea of it, then you can try whole bunch of different things and try, you know, test whole bunch of hypothesis and come back with something.*

- Mary, 9th grade science teacher

I used HyperRESEARCH (version 2.8; ReserchWare, 2009) in this process to code the interview transcripts. Then, I exported the coding results into Excel to calculate the scores of teachers’ knowledge. Each of the three knowledge levels was given a numerical value: 1 for basic level, 2 for intermediate level, and 3 for the advanced level. The resulting calculations comprised five scores, each of which served as a measure of one of the five categories of a teachers’ knowledge.

In order to get a more comprehensive measurement of teachers’ knowledge, I employed Epistemic Network Analysis (ENA) to examine the connections amongst the five categories of knowledge. ENA (Shaffer et al., 2009; Shaffer & Graesser, 2010) is a statistical method developed from the epistemic frame theory for the purpose of finding and quantifying the patterns of connection among discourse elements, instead of individual ideas within the discourse (Orrill & Shaffer, 2012). Derived from this idea, I was able to understand and model teachers’ knowledge as a network of connections among its frame elements: climate change science content, pedagogy of inquiry-based learning, pedagogy of community learning, general role of teacher, and role of technology. Thus, ENA provided a new means for measuring the interconnectedness of teachers’ knowledge. To apply ENA, I first coded teachers’ interview transcripts and formatted them to create an ENA set. Based on the coding results produced in the above steps, an ENA set was created using the three teachers as the analytic units, the interview questions as the stanzas, and the knowledge level scores on the five measuring elements (content, inquiry, community, teacher role, and technology) as weighted density. The ENA data set was then uploaded to the ENA website to plot three maps that each represents the connectedness of
the five measured elements of each teacher’s knowledge. The plotted maps were then interpreted qualitatively.

3.6.3 Teacher Enactment Analysis

Data sources and data collection. The purpose of the teacher enactment analysis was to identify the practical roles the teachers adopted (i.e., the enacted, as opposed to the designed roles) during the implementation of the curriculum. The data for teacher enactment analysis were 58 hours of video recording of the three teachers’ classroom teaching. The videos were recorded using a high quality digital camcorder. A Bluetooth microphone set, including a receiver and a transmitter, was used to capture the teachers’ voices when they talked to a small group of students or individual student. The receiver was mounted on the camcorder and the transmitter was hanging on a lanyard around the teacher’s neck. The camcorder was placed at the back of the classrooms for the purpose of getting a full scene of the classroom, and occasionally panned to capture the teacher when s/he walked outside the framed scene. Most, but not all class sessions were recorded, with some sessions missed due to scheduling or logistical constraints (e.g., time conflicts, illness, etc.). Any missed class sessions were random in nature, and are considered as lost data. In total, fifty-one class sessions were recorded, not including the final two lessons for remediation presentation. All the recorded videos have been used in this analysis.

Data analysis techniques. In this round of enactment analysis, the video data were coded at a relatively coarse grain size level. For each recoded class session, the video was played, and paused at any point that demarcated a change of teacher activity. Then, the content of the preceding video clip was compared against the nine categories of teacher’s roles that emerged from the curriculum design analysis (these categories are themselves one of the Results of the dissertation, emerging from the open coding and presented in section 4.1 of Chapter 4). If the video clip matched one of the categories, it was coded as such (i.e., as being an example of that particular role). If it did not fit in any of the nine roles identified in curriculum design analysis, it was added as a new role that a teacher performed in his/her enactment of the designed curriculum, and given a name based on the review of previous research. This process led to the identification and construction of categories that capture the types of enacted roles that the three teachers actually played during the implementation of the designed curriculum. The enacted
roles and the designed roles (identified in the curriculum design analysis) were compared to recognize any differences (see Chapter 4).

### 3.6.4 Classroom Interaction Analysis

**Data sources and data collection.** The teacher enactment analysis served to describe the practical roles the teachers played during in the enactment of our KCI curriculum. However, this description was at a coarse grain size, not sufficient to address the question of when certain roles were played (i.e., in what context), nor how the teacher interacted with students when they were working in various KCI group activities. To address such questions, I examined the patterns of teacher-student interactions when students were engaged in KCI activities at a fine grain size level. The patterns were investigated in terms of time allocation on each type of interaction during each KCI activity. The interactions were defined in terms of the fine roles the teachers played, which were identified in the enactment analysis.

For this classroom interaction analysis, I selected video recordings of 25 representative class sessions from the 58 hours of recorded video. The purpose of this analysis was to capture the representative features of the teacher-student interaction that are specific to KCI pedagogical model, as they occurred during various phases, and specific activities within the curriculum. The 25 selected class sessions represented three distinct KCI learning activities: (a) establishing KCI epistemology and setting context activity, (b) collaborative knowledge construction (i.e., when students were editing their Issue pages), and (c) scaffolded inquiry activity (i.e., when students were editing their Remediation pages). For each class session video, I excluded any parts when students were watching videos in the classroom or when the teacher went out of classroom (e.g., to get handouts for students). I did this for two reasons: (a) there were no teacher-student interaction during these parts; (b) they cannot provide any meaningful information about the classroom interaction patterns. In the end, a total of 29 hours and 46 minutes of videos that included 25 class sessions and covered 6 lessons were used in this analysis. Table 3.2 shows the information of the videos I selected for this classroom interaction analysis.

**Table 3.2**  
*Information of the Videos of the 25 Class Sessions Selected*
**Data analysis techniques.** I used content analysis to code and tabulate the interactions to precisely and objectively describe the pattern of teacher-student interactions. The first step was to segment the video data. The unit of segmentation (or unit of analysis) was the conversational or activity turn (Chi, 1997). A new turn was considered to start when the teacher begins an activity or begins to talk to a particular group of students, or to the whole class (i.e., when s/he switches the object of discourse). A turn was considered to end when the flow of an activity changed, or the teacher turns to another group of students, or when the topic (content) of the conversation changed. In the case where a student has started talking to the teacher, but the teacher’s attention has not turned to this student, the “turn” point should not be set at the time the student started talking, but the time that the teacher has turned his/her attention to this student.

After segmentation, I used one of the codes from the first-level teacher-student interaction coding scheme (Table 3.3) to code the video segment. This first level of coding scheme was developed based on the objective of the research purpose to examining whether and

<table>
<thead>
<tr>
<th>Class sessions</th>
<th>KCI activity</th>
<th>Teacher</th>
<th>Lesson</th>
<th>Length of time coded</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009_11_16_s03</td>
<td>Setting context</td>
<td>Jonathan</td>
<td>1</td>
<td>00:37:26.508</td>
</tr>
<tr>
<td>2009_11_16_s05</td>
<td>Setting context</td>
<td>Jonathan</td>
<td>1</td>
<td>00:28:00.612</td>
</tr>
<tr>
<td>2009_11_16_s01</td>
<td>Setting context</td>
<td>Mary</td>
<td>1</td>
<td>00:28:47.834</td>
</tr>
<tr>
<td>2009_11_17_s02</td>
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<td>Mary</td>
<td>1</td>
<td>00:31:58.056</td>
</tr>
<tr>
<td>2009_11_17_s04</td>
<td>Setting context</td>
<td>Steven</td>
<td>1</td>
<td>00:26:39.406</td>
</tr>
<tr>
<td>2009_11_19_s03</td>
<td>Setting context</td>
<td>Jonathan</td>
<td>3</td>
<td>01:07:27.863</td>
</tr>
<tr>
<td>2009_11_19_s05</td>
<td>Setting context</td>
<td>Jonathan</td>
<td>3</td>
<td>01:10:55.546</td>
</tr>
<tr>
<td>2009_11_19_s01</td>
<td>Setting context</td>
<td>Mary</td>
<td>3</td>
<td>01:12:56.777</td>
</tr>
<tr>
<td>2009_11_24_s02</td>
<td>Setting context</td>
<td>Mary</td>
<td>3</td>
<td>01:13:42.356</td>
</tr>
<tr>
<td>2009_11_24_s04</td>
<td>Setting context</td>
<td>Steven</td>
<td>3</td>
<td>01:11:53.367</td>
</tr>
<tr>
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<td>Issue page editing</td>
<td>Jonathan</td>
<td>4</td>
<td>01:08:59.967</td>
</tr>
<tr>
<td>2009_11_26_s05</td>
<td>Issue page editing</td>
<td>Jonathan</td>
<td>4</td>
<td>01:01:02.185</td>
</tr>
<tr>
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<td>01:11:42.496</td>
</tr>
<tr>
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<td>01:10:21.766</td>
</tr>
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<td>01:09:17.519</td>
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<td>00:56:59.003</td>
</tr>
<tr>
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<td>11</td>
<td>01:03:54.523</td>
</tr>
<tr>
<td>2010_01_20_s02</td>
<td>Remediation page editing</td>
<td>Mary</td>
<td>19</td>
<td>00:57:49.015</td>
</tr>
<tr>
<td>2010_01_20_s04</td>
<td>Remediation page editing</td>
<td>Steven</td>
<td>19</td>
<td>01:02:36.704</td>
</tr>
<tr>
<td>2010_01_21_s01</td>
<td>Remediation page editing</td>
<td>Mary</td>
<td>19</td>
<td>00:52:06.004</td>
</tr>
<tr>
<td>2010_01_22_s02</td>
<td>Remediation page editing</td>
<td>Mary</td>
<td>20</td>
<td>00:52:09.139</td>
</tr>
<tr>
<td>2010_01_25_s01</td>
<td>Remediation page editing</td>
<td>Mary</td>
<td>20</td>
<td>01:01:41.090</td>
</tr>
</tbody>
</table>
how often the teachers interacted with students as a “whole class” or with students working in small groups.

Table 3.3

First Level Coding Scheme for Teacher-Student Interaction

<table>
<thead>
<tr>
<th>Codes</th>
<th>Full name of each code</th>
<th>Definition of codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>WCI-L</td>
<td>Whole class interaction – logistical or procedural</td>
<td>The teacher provides procedural or logistical information to the whole class or to students a small group. For example, teacher describes the organization of a future test or quiz; teacher describes the grading policy; teacher passes out a hand-out or worksheet; teacher manages students’ classroom behaviour; teacher helps students solve technical difficulties; teacher gives instructions on how to use software; teacher gives the URL of a website; teacher mentions things students need to do for homework; etc..</td>
</tr>
<tr>
<td>SGI-L</td>
<td>Small group interaction – logistical or procedural</td>
<td></td>
</tr>
<tr>
<td>WCI-C</td>
<td>Whole class interaction – conceptual</td>
<td>The teacher explains, teaches, or lectures science concepts or principals to students in the whole class or in a small group.</td>
</tr>
<tr>
<td>SGI-C</td>
<td>Small group interaction – conceptual</td>
<td></td>
</tr>
<tr>
<td>WCI-P</td>
<td>Whole class interaction – pedagogical</td>
<td>The teacher performs activities or behaviours in order to facilitate or moderate students’ learning rather than direct lecturing in the whole class or in a small group. For example, teacher gives direct instructions on what to do; suggests ways of thinking or collaboration; evaluates students’ learning outcome; connects learning content to students’ real life; helps students to reflect on what they’ve learned; encouraging or modelling collaboration or reflective thinking.</td>
</tr>
<tr>
<td>SGI-P</td>
<td>Small group interaction – pedagogical</td>
<td></td>
</tr>
<tr>
<td>WCI-O</td>
<td>Whole class interaction – off topic</td>
<td>The teacher talks to students about things that are not related to the climate change content. In these interactions, teacher does not offer opportunities for students to learning climate change science. For example, the teacher talks about a basketball game the school team attended.</td>
</tr>
<tr>
<td>SGI-O</td>
<td>Small group interaction – off topic</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>No Interaction</td>
<td>The teacher is not interacting with students. For example, the teacher is working on his/her own computer; he/she is dealing with technology difficulties of his/her own (not for students); he/she is preparing technology for lecturing; he/she is getting help from researcher; he/she is drinking water, etc.</td>
</tr>
</tbody>
</table>
To further refine the coding of interactions, a smaller grain size description of the teacher-student interaction was then employed. Among the nine codes in Table 3.3, the pedagogical interactions (i.e., WCI-P and SGI-P) were the most interesting from the standpoint of the research questions, warranting a more detailed analysis of the content of teacher-student interactions: not just whether the teacher was interacting with a small group, but *what* was the nature and role of that interaction. Therefore, a second level of coding scheme (Table 3.4) was developed according to the function played by that teacher’s activity, behaviour, or discourse. The original coding scheme was informed by the results of the enactment analysis as well as a review of relevant research literatures (see chapter 2 for detail). The coding scheme was then “fine-tuned” (Morgan, 1993; Chi, 1997) by adjusting or refining the definition of existing codes or adding new codes in order to capture the specifics of the data. For example, WCI-Context and SGI-Context, which were not identified in literature review, were two codes I added to the coding scheme during the coding process.

Table 3.4

*Second Level Coding Scheme for Teacher-Student Interaction*

<table>
<thead>
<tr>
<th>Code</th>
<th>Full Name of Code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>WCI-Collaboration</td>
<td>Whole Class Interaction-Collaboration</td>
<td>Teachers help students become effective collaborators. Including: encourages, helps, or coordinates students to collaborate with each other, exchange ideas, and build on each other’s ideas; suggests students how to collaborate.</td>
</tr>
<tr>
<td>SGI-Collaboration</td>
<td>Small Group Interaction-Collaboration</td>
<td></td>
</tr>
<tr>
<td>WCI-Reflection</td>
<td>Whole Class Interaction-Reflection</td>
<td>Teacher encourages or requests students to comment on their learning activities or processes; asks students to report back what they just learned.</td>
</tr>
<tr>
<td>SGI-Reflection</td>
<td>Small Group Interaction-Reflection</td>
<td></td>
</tr>
<tr>
<td>WCI-Connection</td>
<td>Whole Class Interaction-Connection</td>
<td>Teacher helps students to recall or connect to their prior knowledge, experience, or personal relevance.</td>
</tr>
<tr>
<td>SGI-Connection</td>
<td>Small Group Interaction-Connection</td>
<td></td>
</tr>
<tr>
<td>WCI-Context</td>
<td>Whole Class Interaction-Context</td>
<td>Teacher helps students understand the broader context and purpose of the activity. This may include talking about the agenda of a class, generally describing a learning activity (not the specific steps) to let the students get an overall idea about the activity, talking about the purpose and the rationales of an activity. It is more like about “sharing the story with the students, which is a sort of meta-knowledge”. The key here is to provide meta-knowledge to students.</td>
</tr>
<tr>
<td>SGI-Context</td>
<td>Small Group Interaction-Context</td>
<td></td>
</tr>
</tbody>
</table>

| WCI-Modeling | Whole Class Interaction-Modeling | Teacher uses examples to illustrate how to think reflectively, how to connect knowledge to their real life, how to work collaboratively and build on other’s ideas, how to deal with learning priority, etc. Specific examples or learning topics must be used in this. |
| SGI-Modeling | Small Group Interaction-Modeling |

| WCI-Guidance | Whole Class Interaction-Strategy | Teacher helps students understand the expectations of inquiry activities; engages students in evolving chains of inquiry; suggests how and what to do next in order to continue (go to next step of) their learning process as well as how to find resources to help themselves in learning; explains the detail steps of a learning activity. |
| SGI-Guidance | Small Group Interaction-Strategy |

| WCI-Evaluation | Whole Class Interaction-Evaluation | Teacher evaluates, assesses, or monitors students’ learning progress, their understanding of concepts, their learning outcome, and praise them. |
| SGI-Evaluation | Small Group Interaction-Evaluation |

| WCI-Elaboration | Whole Class Interaction-Elaboration | Teacher promotes or elicits students’ deep thinking. Teacher asks students to explain more about their own thinking or idea clearly, to explain their learning products, or to think beyond what they are learning. |
| SGI-Elaboration | Small Group Interaction-Elaboration |

Segmenting and coding video at such a fine grain size was challenging. For each class session, there were inevitably “dilemma situations” where I needed to make decisions on how to segment and code the data. I used the following rules were used to guide the coding.

1. Segment and code a shift of interaction only if the current interaction lasts for more than 10 seconds.
2. Any segment that is shorter than 10” will be coded as part of the segment before or after – which ever is most relevant. For example, if a “WGI_L” segment is 5” long and its preceding is a 15” SGI_L, then these two segments will be coded together as one 20” long SGI_L.

3. A “None” turn is considered to start when a regular turn is ended. A “None” turn is considered to end when a regular turn is started. None and off-topic (SGI-O or WCI-O) segments must last at least 15” in order to be coded as such. If shorter than 15”, code it as part of the segment before it, unless it is more meaningful to code it as part of the segment after.

4. In the case that the flow of a long continuing turn/interaction is interrupted by another short period turn/interaction:
   a. Code the interrupting short period interaction as a separated code only when the short interaction lasts 10” or longer; and code the long continuing interaction as two separate interactions.
   b. However, if the long continuing interaction is a None or off topic (SGI-O or WCI-O) one, code the interrupting short period interaction (it must be a L, C, or P) as a separated code even if it is shorter than 10”; but, it must be longer than 5”. Code the long continuing interaction as two separate interactions of None or off topic (SGI-O or WCI-O).
   c. However, if the interrupting interaction is a None or off topic (SGI-O or WCI-O) one, code the long continuing interaction as two separated codes only when the None or off topic (SGI-O or WCI-O) interrupting interaction is longer than 20”.

5. In the case that two or more segments that are shorter than 10” are following continuously:
   a. If they are the same code (i.e., SGI-L), then code them as one with the same code.
   b. If they are having the same types of interaction (e.g., one of L, C, or P), then code them with the audience code that has longer time. For example, if 4 segments are SGI-L, WCI-L, SGI-L, WCI-L; if the sum of the time of SGI segments is bigger than the sum of the time of WCI segments, then code these 4 as one segment using SGI-L.
   c. If they are having the same of type of audiences but different type of interactions, then code these segments using the code of the interaction type that has longer sum of time.
   d. If none of the above situations apply, code these short interactions as one interaction using the code of which is the longest among them, or code them as one code based on my objective judgement considering the context.
6. In the case that two events are interwove, code these two as one segment. If the two events have the same code, then code this segment using the code; if the two events have different codes, code this segment using the code of the one that is longer.
7. If a None or off topic (SGI-O or WCI-O) segment happens at the very beginning or end of a class, this None or off topic (SGI-O or WCI-O) segment will be removed out and not be considered as part of the classroom interaction (LessonLab, 2003).
8. For those that cannot be coded for any reasons (i.e., the audio is not clear), if it happens in the middle of a meaningful segment and its length is shorter than 10”, it will be coded as part of the meaningful segment.
9. The above codes are defined clearly. However, there are situations that more than one code can be applied to one segment of video. In this case, I used the most promised code depending on my personal judgement of the context to resolve the ambiguous of interpretation (Chi, 1997). Therefore, each segment was only coded once with one single code.

I used HyperRESEARCH (ResearchWare, 2009) in segmenting and coding the videos. The coding results were exported as a text file, which contains 2048 records. Later on, I used Excel and Visual Basic Application (VBA) to clean and reorganize the data in a format that is conducive to further statistical analysis. The result of this analysis is an Excel spread sheet that contains 25 records. Each record represents a class session that is being analysed. Each record has a number of fields that represented the average time a teacher spent on each type of interactions and information about the teacher and the class sessions.

3.6.5 Statistical Analysis of Quantified Interaction Data

I applied statistical analyses to the quantified teachers’ knowledge data and classroom interaction data. There were two reasons to apply such analyses to the qualitative data (interviews transcripts and video recordings). First, quantitative analysis could serve to strengthen, justify, and enhance the qualitative findings (Chi, 1997; Shaffer & Serlin, 2004). Second, quantitative methods are a convenient, powerful, and visually straightforward means of illustrating and communicating results, conclusions, or claims. I used simple descriptive analyses, including total scores, mean values, and percentages, to examine teacher knowledge
and teacher-student interaction patterns. I used Kendall’s rank (Kendall’s tau) and biserial correlation tests to examine the strengths of the relationships between teachers’ knowledge and the observed interactions with students.

I emphasize here that the purpose of using statistical analysis in this study was not to generalize the results to a larger population of teachers. Instead, I desired to reveal the features of the three teacher participants’ enactment patterns in the KCI curriculum, and thus to gain new insights and understanding about the teacher’s role within the KCI model (Leinhardt & Leinhardt, 1980). In general, the goal of using parametric statistics is to estimate the parameters of a large population by calculating the parameters of a sample of the large population (Tukey, 1977) because it is usually impossible or impractical to get the data of every individuals of a population. In educational research, statistics are often used for the purpose of determining “whether the effects seen in the sample are likely to reflect ‘true effects’ for ‘students in general’” (Shaffer & Serlin, 2004, p. 15). In contrast, educational qualitative research is often ill-structured and does not meet the general requirements of statistical analysis. Frist, the variables examined in qualitative research are often brought into account based on investigators’ perspectives without well-verified, substantive theory. Second, data are typically collected via purposive sampling, rather than scientifically designed random sampling (Leinhardt & Leinhardt, 1980). Therefore, an inappropriate purpose of using statistics in qualitative research is to “generalize” the results as traditional quantitative research does. The appropriate purpose is to explore and search for ideas or patterns of relevance to the researcher’s interests (Leinhardt & Leinhardt, 1980; Shaffer & Serlin, 2004).

The use of Kendall’s rank and biserial correlation tests could at first seem problematic, in the sense of traditional quantitative research. Use of only three teacher participants as the unit of analysis obviously violates the requirement of minimum number of units in any statistical analysis. My solution was to use lesson session as the unit of analysis instead of teachers. Shaffer and Serlin (2004) introduced the concept of intra-sample statistical analysis (ISSA) – a “technique that combines methods and assumptions of qualitative and quantitative research within a single analytical process” (p. 14). Using a hypothetical study that qualitatively examined the patterns in the relationships between 12 students and their three mentors in a mathematical design activity, Shaffer and Serlin demonstrated that using students as unit of analysis would
change the nature of research from a thick description of the activity pattern of the twelve students within design episodes to a general claim about students’ behaviour during the design activity. They suggested considering the large pool of “possible observations” of what the students did as the “population” and all “recorded observation” as the “samples”. Looking at the data this way, the recorded observation could then be considered as repeated measures of the same 12 individual students. As a consequence, it was possible to use any appropriate statistical techniques in the analysis of the quantified observational data. The ISSA concept supports the use of coded qualitative observations as the unit of statistical analysis, rather than treating individual participants as the unit of analysis. Given that my purpose was to describe the teacher-student interaction patterns, rather than to generalize the interaction pattern to a wider population of teachers, it was reasonable to consider all the lesson sessions (the “observations” in my study) from the three teachers as being a limited “population” and the 25 lesson sessions that I recorded and analysed as being the “sample”. Therefore, I used the lesson sessions as the unit of analysis instead of individual teachers. Consequently, I reasoned that it was appropriate to use correlational statistics to explore the relationship between teachers’ knowledge and their patterns of interactions with students. Considering that fact that 25 cases was still a small sample size and that the teachers’ knowledge would be treated as a categorical variable, I decided to use Kendall’s tau and biserial correlation coefficients in this analysis.

3.7 Validity and Reliability Issues

Validity refers to the accuracy or credibility of research findings (Creswell, 2005, 2007), while reliability is the stability or consistency of research findings (Altheide & Johnson, 1994 cited in Whittemore, Chase, & Mandle, 2001). Research literatures in qualitative research methods suggest that researchers should clearly discuss validity and reliability threats of a study as well as the criteria and specific techniques employed to overcome the threats (Whittemore et al., 2001). They also have suggested various ways to deal with validity and reliability issues. In this section, I deliberate the various validity and reliability threats to my study.

Because distinct validation approaches do not exist for the most frequently used approaches to qualitative research, Creswell and colleagues (Creswell, 2007; Creswell & Miller, 2000) suggested eight strategies of warranting the validity of qualitative research in general: (a)
prolonged engagement and persistent observation in the field, (b) triangulation, (c) peer review or debriefing, (d) negative case analysis, (e) clarifying researcher bias, (f) member checking, (g) rich, thick description, and (h) external audits. These authors also suggested qualitative researchers included at least two of these strategies to enhance the validity of research.

I employed three strategies that Creswell and Miller suggested to enhance the overall validity of my study. First, I persistently engaged in the field to closely observe the teachers over a long time, attending 56 of the 95 class sessions during the nine weeks that the climate change curriculum unit was implemented. While I was in the class, I video-record class sessions and wrote observation notes to record salient moments. Additionally, I watched all the recorded videos at least twice and spent 8-10 hours to code each hour of videotape. Furthermore, in the larger research project, the research team had also a history of prolonged engagement in the research environments. Members of the team had set up very good relationships with the three teachers who participated in the study and with other teachers and staff in the school. The team had collaboratively worked with the teacher who participated in the curriculum design for a long time. Also, the research team also had provided various technical hardware facilities to the school to boost its wireless system and the accessibility of laptops in the science department. The second validation strategy I used was “peer review or debriefing”. I held meetings every week with my academic advisor to discuss my data analysis, the findings, and the writing of this dissertation. We worked together to develop the coding schemes and coded all the interviews and some videos. The third strategy that I employed was the “rich, thick description” of the research. In section 3.3 of this chapter, I described the research participants and the research site in detail. I portrayed the three teacher participants in terms of their teaching experiences, technological skills that I observed during my study, and their experiences working with researchers. In section 3.4, I described the pilot work of the larger research project in which my dissertation work was embedded. In section 3.5 I depicted the curriculum and the steps of how the curriculum was implemented as well as the technological environment used in the research project. In section 3.6, I also explained in detail on how I handled the data. These thorough descriptions will give readers full information about my research so that they can determine the quality of data analysis and whether the findings are trustworthy.
Some concrete validity threats to my study include: (a) researcher’s preconceptions about the meaning of a particular experience, (b) observational bias, (c) observee reactivity, and (d) poorly defined behaviour categories and inappropriate selection of code (Charmaz, 2006; Merrell, 2008). To overcome the influences of my preconceptions about teacher’s roles, I embedded myself in the classroom for an extraordinary amount of time initially to become familiar with the things that characterized teachers’ activities in the class so that I could then acquire in-depth knowledge of the teachers’ behaviours in the classroom (Charmaz, 2006).

Observational bias happens when the observer consistently considers observed behaviours in a particular way so that the observation accuracy may be distorted (Merrell, 1999 cited in Volpe, DiPerna, Hintze, & Shapiro, 2005). Observational bias was minimized in my study in three ways: (a) giving myself adequate training through publishing the results of preliminary analysis in various conferences, (b) coding the data with my academic advisor together to ensure the reliability of coding, and (c) eliminating some of the dependency on my objective selectivity by video-taping the class sessions (Chi, 1997; Volpe et al., 2005). Further, in the analysis of teachers’ knowledge, I mixed the transcription text of all teachers together and removed their names. Therefore, when my advisor and I analysed the transcripts, we did not know which transcript belonged to which teacher. This method to a certain degree prevented us from deliberately assigning higher-level codes to our favourite teacher—the teacher who participated in the curriculum design. This method was effective as evidenced by the fact that we wrongly matched teachers with paragraphs of transcript text several times.

Observee reactivity refers the fact that the target teacher participants might alter their behaviors as they knew they were observed and thus lead to inaccurate estimates of real target behaviors (Volpe et al., 2005). The specific methods that I used in my study to overcome the reactivity issue were that I: (a) had prolonged contact and collaboration with the teachers to build trust; (b) explained the purpose of research to teachers and students; (c) emphasized that the main reason for using the camera was to record what the teachers did and said, rather than what the students did and said; (d) pledged that the video data would not be available to others; and (e) signed research consent forms with the teachers and the students.

Any coding scheme may systematically distort the coding of interaction and thus produce artifactual data (Poole & Folger, 1981) if the behaviour categories were not well-defined and
inappropriate codes were attached to video or text segments. To enhance the validity of coding scheme, I read large amount of research papers when developing the coding scheme to make sure that the categories in the scheme were inclusive. I consulted my academic advisor in terms of the codes and the definition of codes. I also pilot tested the scheme in a few conference presentations. A coding rule (coding book) was developed to ensure the consistency of data segmentation and labelling of video and text segments. Furthermore, I also applied statistical tests on the quantified qualitative codings to examine any significant results as a method of validation (Chi, 1997).

Silverman (2000) defined reliability as “the degree of consistency with which instances are assigned to the same category by different observers or by the same observer on different occasions” (p. 188). Therefore, reliability in qualitative research often refers to “intercoder agreement” (Creswell, 2007). Intercoder agreement was calculated for the analysis of teachers’ knowledge and teacher-student interaction. For the teachers’ knowledge analysis, I first segmented and coded some of the interview transcripts; then my advisor and I reviewed my coding together. This process continued until all interview transcripts were analysed. One hundred and two (102) segments were generated and coded. Among them, my advisor and I agreed on 56 of them. Using the calculating method proposed by Potter and Levine-Donnerstein (1999), and considering that there were 15 codes in the coding scheme, the Kappa coefficient (Cohen, 1960) of this analysis is 0.52, which is at moderate level (Gelfand & Hartmann, 1975; Landis & Koch, 1977) of intercode agreement.

Analysis of all of the video data with my advisor was not practical in the analysis of teacher-student interactions because of the large amount of data available. Therefore, my advisor only reviewed instances in which I was less confident with my coding. My advisor and I together analysed videos covering a total class time of 24 hours 30 minutes and 16 seconds, which is 42.31 per cent of the total videos. I analysed the rest of the video data by myself without my advisor’s review of my coding. My advisor and I reviewed 196 codings together. Among them, we agreed on 82 codings. Using the calculating method proposed by Potter and Levine-Donnerstein (1999), with 23 codes in the coding scheme, the Kappa coefficient of the teacher-student interaction approximated 0.39, which is fair according to Gelfand and Harmann (1975)
and Landis and Koch (1977). However, it is important to emphasize that this is not the overall Kappa coefficient of the teacher-interactions analysis.

### 3.8 Summary

In this chapter, I first contextualized my research by briefly explaining how my research was embedded in a larger research project about the KCI model and by describing the research sites and participants. Then, I described the first iteration of the larger research project as the pilot work of my study, which severed the purpose of refining the curriculum and technology design. After, I described in very detail the curriculum and technology design of the main study. Finally, I explained the data collection and data analytic techniques of the four analyses of my study, including coding schemes. Table 3.5 summarizes the data analytic techniques and data sources of the four analyses I conducted mapping with corresponding research questions. Next chapter will report the finds of the four analyses of my research.

Table 3.5

**Summary of Data Analytic Techniques and Data Sources**

<table>
<thead>
<tr>
<th>Type of analysis</th>
<th>Data source(s)</th>
<th>Analysis technique(s)</th>
<th>Research question and sub-questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curriculum design</td>
<td>• 2 curriculum design documents</td>
<td>Open coding through constant comparative method</td>
<td>1-a) What roles are designed – implicitly or explicitly – into the curriculum design?</td>
</tr>
<tr>
<td></td>
<td>• 6 lesson plans</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 15 emails between the researchers and the teachers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher knowledge</td>
<td>• Teacher interviews</td>
<td>• Content analysis using teacher knowledge coding scheme</td>
<td>(No specific question addressed. Results were used together with the results of class interaction analysis to answer question 3.)</td>
</tr>
<tr>
<td></td>
<td>• 30 minutes each</td>
<td>• Divided transcripts into segments and coded</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Epistemic Network Analysis</td>
<td></td>
</tr>
<tr>
<td>Curriculum enactment</td>
<td>• 51 class sessions</td>
<td>Compared what was enacted vs. what was designed</td>
<td>1-b) What roles are actually enacted by the teachers?</td>
</tr>
<tr>
<td></td>
<td>• 57:55 of videos</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Classroom interaction

- 29 hours of video
- Selected from 25 class sessions
- Represented 3 phases of KCI activity

- Content analysis with a two-level coding scheme
- Segmented video into fine-grain clips and coded
- Kendall’s rank and biserial test (together with the results from teacher knowledge analysis)

2) What patterns of teacher-student interaction occurred within the KCI classroom?

3) Do patterns of classroom interaction relate to teachers’ prior knowledge?
Chapter 4

Results

As described in Chapter 3, the dissertation study draws upon four analyses. The first is an analysis of the design itself (i.e., before any enactment), to capture what the co-design team envisioned, at the outset, as being the teacher’s role in a KCI curriculum. The second is an analysis of the three participating teachers’ knowledge and prior experience at the time they began the enactment. Next is an enactment analysis, to capture what actually occurred in the classroom (i.e., the teacher’s actual role). Finally, I present an analysis of teacher-student interactions in the classroom, to add detail to our understanding of the teacher’s role in KCI. Four major sections below address each of these analyses in turn.

4.1 Curriculum Design Analysis

This analysis was designed to answer the first sub question of my first research question: What roles are designed for the teacher – implicitly or explicitly – into the curriculum? The climate change curriculum was designed based on the principles that Slotta and his colleague developed during early stages of the KCI model development (Peters & Slotta, 2010b; Slotta & Najafi, 2013; Slotta & Peters, 2008). We designed three major learning activities that constituted a nine-week climate change curriculum. However, the details of the teacher’s role were not well specified in this design, for two reasons. First, the design team was paying most attention to the learning activities for students and the related science content and social issues to be covered. The teacher’s role was not an aspect explicitly considered in the design process, and hence was not detailed in any design documents, even though there were some clear ideas about what kinds of roles and student interactions should be ascribed to the teacher. Second, no prior research existed in which KCI had specified the teacher’s role within the model, nor had any other knowledge community approach made clear assertions about the role of teacher. Hence, this analysis was required in order to reveal what was actually designed about the teacher’s role, drawing inferences from any available source (e.g., design documents, emails, and lesson plans). The next section provides the results of using open coding to identify and categorize aspects of
the teacher’s role that the researchers implicitly or explicitly described in their various curriculum design documents.

4.1.1 The teacher’s role in the designed curriculum

KCI is a model that blends scaffolded inquiry learning with the knowledge community approaches. Thus, teachers need to play a role that both scaffolds students’ inquiry learning and helps students advance knowledge as community. Building on the “constant comparison” methods of coding described by Glaser (1965) and Strauss and Corbin (1998), a number of categories defining the teacher’s role were identified from the literature review and finalized through systematically coding the various design resources (wiki design documents, emails, and lesson plans). These categories included: (a) content teaching, (b) co-ordinating, (c) establishing an epistemological perspective of KCI, (d) evaluating students, (e) guiding learning activities, (f) organizing learning activities, (g) making connections, (h) setting the learning context, and (i) providing technical support.

Content teaching is the role of lecturing and discussing (i.e., through question-and-answer) specific climate change science content and phenomenon. In the curriculum design, the teachers would need to address various science concepts and principles that are related to climate change, including certain science phenomenon, such as the Albedo effects. Content teaching was designed to occur mostly during the collaborative knowledge construction (i.e., Issue Pages editing) activity. The science topics that should be covered in this climate change unit include things such as atmosphere layers, solar radiation and greenhouse effect, atmospheric circulation of thermal energy, carbon sinks and carbon sources, climate change legislation, climate change models, energy saving and greenhouse gases impacts, extreme weather patterns, ocean circulation, paleoclimatology, tree cores and climate, and many others. There were 16 specific duties identified from design document that fell within this category.

Co-ordinating refers to the role that teachers play in helping activities run smoothly and successfully. Teachers’ behaviour or actions that fall into this category are: asking students to add climate change modelling information to their Issue Pages; asking students to use their To-Do List to co-ordinate their group issue editing work; assigning students into remediation groups carefully with the consideration of different students ability to make the group working
coherently; checking Issue Pages to see if remediations are directly related to issues that have been investigated in this climate change unit; co-ordinating the selection of climate change issues; grouping students into brainstorm groups, issue groups, and remediation groups; keeping record of students’ selection of issues; and re-grouping students to share mini lab data. Ten concepts fell into this category.

**Establishing KCI epistemology** is the role in which teachers orient students to the idea of working with their peers collaboratively as a learning community. The purpose of this role is to help students achieve a social orientation and understanding collaborative learning community. Two specific activities were designed for the teachers to in this category: talking to students about the importance of collaboration; asking students to reflect on their understanding and practices of collaboration. We also designed to have the school librarian help students think about how to analyse the quality and credit of resources they would find from the large Internet community.

**Evaluating students** includes everything that teachers should do for the purpose of evaluating students’ learning. Nine specific duties were identified as part of this category: arranging the date and time for post-test; asking students to study for a test; organizing pre-test and several quests; explaining the issue group work assessment rubric, modifying assessment plan; piloting the evaluation materials with students; going through the marking scheme, and leading the review of content the students learned.

**Guiding learning activities** is when teachers give students detailed instructions on how to work on certain learning activities, such as the Canada jigsaw activity, the Issue Pages editing, group brainstorm activity, and creating issue brainstorm pages. Because the learning activities we designed for this curriculum unit are typically unfamiliar to students, the teacher must explain in detail how each learning activities will be enacted. This category included four related concepts.

**Organizing learning activities** refers to how teachers arrange or ask students to work on various learning activities, including the references assignment, brainstorm activity, crossword puzzles activity, e-card activity, climate change in Canada jigsaw activity, Issue Page editing activity, reflection activity (reflections both on climate change content and understanding of KCI
epistemology), ecological footprint calculation activity, TELS activity, ice core lab activity, the Atlas modelling activity, tree core lab activity, past climate graphic analysing activity, human impact on greenhouse gases activity, issue peer review activity, energy saving cards activity, remediation activity, and remediation presentation activity. This role also refers to giving students homework, assigning reference topics to each student, and preparing for e-cards activity. While this category is straightforward to understand, it is quite important, and was most referenced role in our design, with twenty-eight concepts grouped under this category.

Making connections refers to the support role where teachers try to help students connect the concepts they’ve learned, or to connect science content to real life situations. One important kind of connection that KCI asks teachers to perform is in helping students make use of content from their community knowledge base during inquiry activities. For example, the teachers might ask students to search through the remediation tags in the references they created, to check Issue Pages that were not their own, or to skim the remediation section of all Issue Pages when they are working on remediations. Other activities that the teacher could perform to help students make connections include: letting students work on the activity to examine the fuel efficiency of their home vehicles; letting students work on the personal home energy audit activity; or highlighting students’ choice of individual actions. In our design, this connection role should happen very often during the collaborative community knowledge construct stage when students are learning climate change science content (i.e., and mapping it to their Issue Pages), and during the scaffolded inquiry stage when students are working on climate change remediation plans. Ten concepts were categorized under this designed role.

Setting learning context is when the teacher sets the context for instruction or activities. Specific activities that we designed for the teachers in this category include: introducing the climate change unit to students; playing videos about climate change; debriefing the videos, introducing various learning activities; letting the students read a Web page about climate change on e-Cards website (Greenlearning, n.d.b) and preparing the hand-out concerning Traditional Ecological Knowledge. There were three videos that the teachers wanted to play: the Sila Alangotok video, a rap about climate change, and a video about the causes of climate change. The purpose of setting the context for a learning activity is to generally motivate or describe it, more than just giving the specific steps of an activity. In our design, introducing learning activity
includes the following specifics: introducing and explaining the references assignment, explaining the purpose of brainstorming activity, introducing the e-card activity, showing students a list of issues generated from brainstorming that lead to issue activity, introducing the issue activity, and introducing the remediation activity. Fourteen concepts were categorized under this designed role.

**Providing technological support** refers to how teachers help students to deal with various issues related to the use of technology during the climate change unit. This role includes: demonstrating how to complete the references assignment technology; helping students join, and then start working in the online portal; introducing the technology used for brainstorming climate change issues, Issue Page editing, and reflection. One other activity categorized in this role is when teachers make themselves familiar with the technology used. Six concepts are grouped into this category.

Appendix B lists all the concepts under each role category. The numbers that follow each concept is the number of times this concept was referenced in the design documents.

### 4.1.2 Summary

When we designed the curriculum for this climate change unit, we did not set out to specify the teacher’s role, explicitly. My analysis of design documents led to the identification of nine role categories implicitly designed for the teachers during the curriculum design process. Among the nine roles, some are basic roles that almost every teacher plays in any pedagogical model, such as content teaching, evaluation, guiding learning activities, organizing learning activities, and technical role; others are more specific to KCI or inquiry-oriented pedagogy, such as co-ordinating, establishing the collective epistemology, and making connections. I believe it is important to note that very little emphasis was placed on the nature of teacher-student interactions (e.g., while students working in small groups), even though it was possible to identify important aspects of the teacher’s role within the design documents. The importance of such interactions can be inferred from the emphasis that the writers of the documents placed on the need to help students make connections, re-use the knowledge base, and making integrated Issue Pages. Still, I found no explicit comments or descriptions regarding teachers’ engagement
with students as they were working in small groups. This will be the content of teacher-students interaction analysis in Section 4.3.

4.2 Teacher Knowledge Analysis

As discussed in Chapter 2, teachers’ knowledge and beliefs have been shown to affect their practices in the classroom (e.g., Ireland, Watters, Brownlee, & Lupton, 2012; Keys & Bryan, 2001; Roehrig & Kruse, 2005; Zohar, 2006). I chose to first investigate the knowledge of the three participating teachers (in this section) before examining how teacher knowledge relates to patterns of interaction with students (see Section 4.4.5).

4.2.1 Descriptive analysis

Using a content analysis of teacher interviews, I measured the three teachers’ knowledge in five categories: climate change science content, pedagogy of inquiry-based learning, pedagogy of community learning, general role of teacher, and role of technology. The coding schemes for this analysis are detailed in section 3.6.2, where I applied a 1 (weak) to 3 (strong) rubric to any comment that pertained to a given knowledge category. Table 4.1 shows the number of text segments in each teacher’s interview transcript that I coded for each of the five knowledge categories, broken into the three different levels for each category.

Table 4.1

*The Number of Text Segments Coded at Each Level of the Five Knowledge Categories*

<table>
<thead>
<tr>
<th>Knowledge aspects &amp; level</th>
<th>Jonathan</th>
<th>Mary</th>
<th>Steven</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community_1</td>
<td>1</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Community_2</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Community_3</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Content_1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Content_2</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Content_3</td>
<td>0</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Inquiry_1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Inquiry_2</td>
<td>0</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Inquiry_3</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Role_1</td>
<td>1</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Role_2</td>
<td>1</td>
<td>10</td>
<td>4</td>
</tr>
</tbody>
</table>
Figure 4.1 shows one way of viewing these statements, according to the total (i.e., summed) level of knowledge revealed by teachers during the interview. Several other ways were examined, including average and length-adjusted. In the end, the total sum measure was chosen as it reflected the content of interviews and captured some distinctions between teachers. While this measure can only be considered as being a cursory reflection of teacher knowledge, there is some validity, as the teacher interview directly addressed issues of pedagogy and practice (see Chapter 3, section 3.5.2 and Appendix A). In the remainder of the thesis, these measures will be employed as reflections of teacher knowledge in the 5 categories, with the recognition that a more comprehensive assessment would need to be performed in order to make any strong claims about the specific content of the teacher’s knowledge in these categories. To support the measures provided in Table 4.1, examples from teachers’ interview statements are provided to illustrate their knowledge in each of the categories.

<table>
<thead>
<tr>
<th>Category</th>
<th>Role _3</th>
<th>Technology_1</th>
<th>Technology_2</th>
<th>Technology_3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inquiry</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Role</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technology</td>
<td></td>
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</tr>
</tbody>
</table>

Figure 4.1 Three teachers’ knowledge level

*Category one: Community learning*
Mary was the teacher who co-designed the curriculum unit with the researchers. She had worked with one of the researchers before in a primary study about KCI model. Mary scored eight points in the knowledge category of Community learning. She thought that community learning could provide high quality learning and that students needed to have skills to work in a team. For example,

*To me, it provides high quality of learning. And, that’s the academic aspect of it. There’s also social job aspect. The world today, very few people are working in solo. So, they have to have the skills to be able to get along, and problem-solve, and work in a team.*

- Mary, teacher interview response

Mary also believed that community learning would give students the opportunity to refine their thinking, exchange ideas with peers, and get feedback from peers.

*I definitely like when they have to do some verbal dialoguing verses just writing, because they have to say things out aloud, which means they have to test what they are saying. A lot of time, saying in their head isn’t good enough; they have to say it aloud. And then, they can pick up some mistakes they have, their peers can give feedback. So that is a lot of formative assessment that happens to clarify understanding.*

- Mary, teacher interview response

However, Mary’s knowledge of community learning did not reach the highest knowledge level (the third-level) (see Table 4.1). As mentioned above, this could simply be an artifact of the interview, where such understandings were not evoked in her responses, because one would expect that Mary would have a substantial knowledge of KCI and community-oriented learning, given her background as a research collaborator and designer.

Steven did not engage in the curriculum co-design process. He had a score of six points in the knowledge category of community learning. His comments reflected a limited understanding of community learning as students working collaboratively and sharing ideas. Following is an excerpt from his interview transcripts.

*If we can get the kids to do that [students explain concepts to each other] in some sense where they are collaborating with each other; sharing their questions;
sharing their problem-solving together. There is that aspect of, OK, Hey I just got this. Here, let me explain it to you. And, like, Oh, I get that.

- Steven, teacher interview response

Like Mary, Steven’s understanding of community learning did not reach the third-level of knowledge, with three text segments being coded as second-level knowledge (see Table 4.1). His score on knowledge of community learning was the lowest among the three teachers.

Jonathan got the highest score, 10 points, on knowledge of community learning, with one comment reflecting an understanding of students imitating the real-world scientific community in addition to building on each other’s ideas. He expressed the value of collaboration in several statements coded as level 2, and also stressed the importance of emphasizing the value of sharing knowledge within a community.

Politicians for example are discussing this issue, they are doing it in a way that we are going to do it, where they do some research; they talk with each other about it. You know, everybody is reviewing each other’s ideas, you know just like a scientific community would. It is a peer collaboration.

I think collaborative learning, uh, is, uh, you know, can be much more beneficial, depending on the context, than the individual learning. Right? I mean this kind of the old adage, you know, two heads are better than one. Right? so by sharing knowledge, by bouncing ideas of each other, you really get a dialogue going, right, you can really explore other people’s ideas where they are coming from, so I think it can be very good, very beneficial for the students.

- Jonathan, teacher interview response

Category two: Climate change science content

Mary had taught a similar climate change unit in the pilot work of this research (Section 3.4), and had several years’ experience teaching this topic, in general. Hence, she had the strongest knowledge of climate change science content, with 16 total points in this category. Mary was able to recognize the interconnectedness of the science topics involved, with four interview statements coded as level 3. Not only could she mention several specific science concepts, Mary could connect three or more science topics together when asked to elaborate
challenging concepts for students. In the following excerpt, Mary connects the topics of thermal energy, greenhouse gases, air currency, and water currency.

Ah, the concept that is all about thermal energy, which a lot of people seem to miss. But, we teach Heat in grade seven. And, it all comes back to that game. Like thermal energy from the sun; the fact it trapped by greenhouse gases; the fact it moves around the earth by the air currency and water currency. And, what the extra thermal energy is doing? Which is what we are calling climate change. [Students need] To be able to pick that up and figure out where it is coming from.

- Mary, teacher interview response

While Steven was an experienced physics teacher, this was his first time teaching the topic of climate change. His total score was six points in this category of content knowledge – the lowest among the three teachers. He only mentioned two specific climate change science concepts, but could not connect them, as illustrated by the following interview excerpt.

Possibly because they were created by the media fighting for the other side ... fighting for non-science, both those guys, might make the job a little, ... at least .. , maybe not. I think that would be very interesting if some of that leaks into the classroom. ... Then, maybe we will get a chance to talk about the larger role of science in general.

- Steven, teacher interview response

Jonathan got a score of ten points, even though this was his first time teaching the climate change topic, and he acknowledged that he did not have a sophisticated knowledge of the content. However, he was able to recognize that the climate change content was relevant to students’ real life; it was multi-disciplinary; and it needed students’ systematic thinking. He only mentioned one specific climate change science topic where students might have difficulty: climate modeling.

You know, I would say, the basic things, like you know, climate modeling. I thinking it is difficult to understand because it is very uncertain, it is based on statistics and probability, right? So, you know, how do currents in the atmosphere affect temperature. How do ocean currents affect climate? These are difficult things to get for 14 or 15 year old, because they’re very dynamic, they’re always changing.

- Jonathan, teacher interview response
Jonathan had no text segment from his interview transcript being coded as first-level knowledge or third-level knowledge. He had five text segments being coded as second-level knowledge (see Table 4.1).

**Category three: Inquiry learning**

Mary got the highest score, 23 points, on the knowledge of inquiry learning. She considered inquiry learning as directed problem solving where students explore on their own under the teacher’s direction. For example, when asked to define inquiry based learning, she responded:

*Problem solving. I would call it more directed problem solving, like the kids, in ideal situation, the kids could feel like they are moving along on their own. So they do not waste time and get lost in myth of learning.*

- Mary, teacher interview response

She also believed that inquiry learning would give students the opportunity to grasp the idea that inquiry is a processing, to create their own ideas, and to build their own knowledge:

*If they are thinking a processing and hopefully they will pick up that. ... They can make their own ideas and statements to say that kind of stuff, as they are building application knowledge at the same point. So they gonna to take the stuff they are learning in theory and look for where it fits in the real world.*

- Mary, teacher interview response

Mary acknowledged that inquiry learning involved students collecting data, manipulating and analyzing data, and making their own conclusion:

*The other one is a stream study that I do, where simulate cause I cannot take them up twice. But they collect data and they have to analyze it in context of the environment they make prediction based on it.*

- Mary, teacher interview response

Steven got 16 points on knowledge of inquiry learning, considering inquiry as lab-oriented activities where students can figure out the results. He believed that in inquiry learning,
students could use materials provided by the teacher to sort out the outcome, without knowing their destination beforehand; students might have the opportunity to use knowledge from multiple discipline; and, students would have certain degree of ownership and responsibility.

[I] made up a little lab activity with kids, pertaining to the center of gravity, and water bottles and then tipping over, and sort of … having the kids do a little activity with water and ramps and meter sticks and water bottles, where they sort of figure out what the center of gravity has to do with an object tipping over, in general. ... The student is not told what the final destination is. They are just provided with the means to sort it out for themselves. .... I am not sure, like I was just thinking of physics examples in my head. Like Centripetal Acceleration, the kids can figure out for themselves. ... Maybe one subject area puts a certain type of information together and another subject area, maybe geography, puts their kind of information together, and then they can do sort of a larger project using this knowledge base that they have together sort of created. ... I kind of described it that way where the kids have sort of a certain degree of ownership, and responsibility, for gathering the bits and pieces, the kernels, the breadcrumbs that they are gonna use later on to do something larger.

- Steven, teacher interview response

Jonathan also got 16 points in the measure of knowledge about inquiry learning. He articulated that inquiry learning has the following characteristics: open-ended learning goal, students taking responsibility, exploratory, students’ independent work, peer collaboration, peer teaching, students working on specific task, students discovering solution instead of teacher giving facts, and others. The following excerpt is an example from his interview transcript.

Any particular type of learning where, uh, the learning goal is fairly open-ended. Uh, and so, it is the students responsibility or, your know, their TASK to uh find out, what is the problem they want to solve instead of us giving it to them. And, try to discover a solution for that and there is no necessary right or wrong answer sometimes

- Jonathan, teacher interview response

Jonathan did not have any text segment from his interview transcript being coded as second-level knowledge. He had one text segment being coded as first-level knowledge and five text segments being coded as third-level knowledge (see Table 5.1). When asked to give an example of inquiry teaching he had used before, Jonathan was not able to give any specific example.
Category four: Role of the teacher in an inquiry classroom

Mary received 34 points on the knowledge and understanding of the teacher’s role in an inquiry classroom. The roles that Mary articulated in the interview include: check what the students are doing; repeat the content that students did not get; manage students behaviour; solve technical problems; make sure that students complete every activity or assignment they are assigned; facilitate, coordinate, and scaffold students’ learning; give students feedback; set the overall learning goals; group the students properly to complement each other’s strength; facilitate students’ reflection to promote problem solving skills. The following three excerpts illustrate some of her understanding of teacher’s role.

*Once they get working I can be checking on them, facilitate it and give them feedback, checking the social skills, checking who is doing stuff. So they are actually do the work at this point. But I have to have the big picture set up so that they can keep doing it.*

*Put the kids in the right groupings so that they complement each other’s strength. And, they do not magnify the weaknesses. If I got somebody does not pay attention, I cannot have more than one person like that in a group. Ah, I cannot put people that do not get along together. And again, hopefully balancing groups of another classes. So part of its under my control, part of its not. So we all in sense of have to balance the groups so that even if one person does not do the job, the big thing gets done.*

*Push them enough so that they are doing stuff and I am not holding their hand too much, but holding their hand when they need it. And again, trying to facilitate in a way that, from their perspective, they are carving their own path, but I am kind of putting invisible barriers that keep them going a direction where they are going to get something. And also to facilitate reflection, so that, the skills they are going to learn from doing this, not only they’re gonna learn about climate change and applying it, but the skills of problem solving. If they reflect on some of these things, they should be able to replicate.*

- Mary, teacher interview response

There were five text segments from Mary’s interview transcript coded as first-level knowledge, ten text segments coded as second-level knowledge, and three text segments coded as third-level knowledge (see Table 4.1). Her score on knowledge and understanding of the teacher’s role is much higher than Steven’s and Jonathan’s.
Steven got 11 point on the knowledge and understanding of teacher’s role. He said his role was only “to survive,” as this was his first time teaching climate change content. He thought that there was less pressure on him because of the nature of the unit. For example:

My role is to survive, really. I am not looking to be particularly glossy polish teacher in this environment. I am just looking to, say again, this is my first time teaching climate change. ... Plus, it is nice that the kids are doing a lot of the work, and guiding things to a certain extend. So I guess there might be less pressure on me due to the nature of this unit.

- Steven, teacher interview response

Roles that Steven articulated in the interview includes: guiding, trouble shooting, helping students sort out what is going on, wondering around to see what the students are doing, and helping students to grasp the “big picture” of the climate change unit. Following are example excerpts from Steven’s interview transcript.

I guess except surviving, yeah, my role will be helping the students to sort out what is going on.

So, you know, being nervous about how this is all going to work, I will sort of be wandering around a little bit, listening to what is going on, and butting in every now and then, with what ever kind of advice, seems to be wanted at the time. Uh, ... something I see I find interesting, I might ask them questions about it. Just sort of let my natural curiosity lead me as I wander around, to see what they are doing. Uh, ... Yeah, uh, that and I will probably be trouble-shooting as well. Sir, the computer’s not booting, I cannot log in, that sort of stuff.

I do not feel too bad with playing with the student outcomes. I just think big picture. I know they will get something out of this. ... I am not overly concerned about some of the smaller details, or curriculum point that might be missed or overlooked. It’s a little bit liberating in a sense. ... Let’s not sweat over the little details, big picture, seeing big picture.

- Steven, teacher interview response

Jonathan’s score on knowledge and understanding of teacher’ role was 18. He believed that he should be an authoritative resource of related scientific concepts. Roles that Jonathan articulated in the interviews include: making sure the students stay on tasks, facilitating students’ learning, directing students, constantly evaluating students, clarifying their understanding of
certain concepts, and thus to help them get most out of their learning experience. Following are some of his words from the interview.

_I think there will be opportunities for the teacher to teach, didactically sometimes, right? We have to each certain concepts. But I think for the most part, it is gonna be more on a facilitation. Where we are just a kind of guiding the students and advising them as to how they can get the most of this particular learning opportunity._

_I think based on my professional judgment, and my experience and knowledge, you know, direct them into ... focusing their research, for example, which is something that students have problems with, especially in this type of inquiry based learning, it can be very overwhelming, because they do not know where to start. So, I think I can help them definitely that way._

_I would say that I would foresee myself circulating continually, listening very closely to their conversations, and questioning them a lot. You know, based on what their conversations are._

- Jonathan, teacher interview response

Jonathan did mention that he should help students to collaborate. It is interesting that he is the only teacher who said that he should emphasize the value of knowledge building for students.

_You know I think I have to be affective, you know, and helping them understand what is needed; how to best go about learning their issue, collaborating together. And, I think of course that will be, you know, a dual role for both of us in helping them understand what the main objective is? What the process is? What their product should be? I think process is very obviously, I think, more important in this, right? in terms of, you know, what is the value of a knowledge building community, right? So, emphasizing that [the value of knowledge building community] continually, I think. So that the kids can get most out of this learning experience._

- Jonathan, teacher interview response

_Category five: Role of technology_

Mary was comfortable with technology. Throughout the interview, she repeatedly described interesting applications of technology in her own instruction. She also frequently gave important input related to technology during the curriculum design meeting.
Mary scored 16 points on knowledge of role of technology – the highest among the three teachers. She believed that Blogs were a good tool for reflection and that technology can give students the opportunity to manipulate data and try different solutions. She also thought about the role technology could play in helping students communicate with each other.

*I think it allows them to manipulate stuff. And that is big thing. They have to, to learn deeply you have to make mistakes. Ah, and, you can do superficial survey of things. So, you got to pick something that is real important and get into it; in a scenario that they can make mistakes, because that is where a lot of the learning happens.*

*And even with some of the physics stuff, we can get really good data by manipulating. You can do it so much fast online. So, once you get the idea of it, then you can try whole bunch of different things and try, you know, test whole bunch of hypothesis and come back with something.*

*The wiki is a technology that allows the kids to develop and write, and bring things around in electronic world they are really comfortable with. I’ve been reading some stuff about cell phones which is not really in that line, but facebook with it they can actually use some of those to communicate results. Some day I will try the phone stuff.*

- Mary, teacher interview response

In Mary’s interview transcript, four text segments were coded as third-level knowledge, and two text segments were coded as second-level knowledge. There was no text segment coded as first-level knowledge (see Table 4.1).

Steven scored 14 points on knowledge of the role of technology. He believed that technology could engage students a little bit more even though technology might distract students from learning. He recognized that technology could facilitate the communication among students and teachers and make team collaboration effective. He mentioned that he could use technology to check what the students were doing. He thought that technology could help in building a learning community. Here are some excerpts from his interview transcript.

*Well, it’s a little bit engaging. Ah, I mean the technology itself hold a bit of interest I think for the students. ... I do not mean to sound fatalistic, like this is a bad result. I do not think it’s a bad result. But, it’s already happening. And, I think it’s inevitable. And, ... like all things it probably has potential to be either useful or distracting.*
Education is really all about communication from teacher to students, students to teacher, students to students, etc. May be even teacher to teacher. And, of course, with home and the media in general out there. Ah, technology certainly facilitates all of that. Right? That is why we’re having learning remotely, long distance courses available in college and else where, and all sorts of options. So, if it’s a facilitator of communication, and I guess storage, then, all those things can be used … to, to help out.

It would probably happen without teacher’s input. Kids are already talking to each other to solve questions. I mean we can see that on First Class at our school. You know, I poke in every now and then, and look at what they are doing, and I can see that they are there communicating with each other, and … asking each other questions. And, they are pretty good about not bugging me unless they are unsatisfied with what is going there. So, uh, they are already using it even if I am not using it as part of the class officially.

- Steven, teacher interview response

Steven had some prior experience using technology in a research project, where his students had created videos about physics topics. In one of his classes in the present climate change unit, he spent a lot of time talking to one of the researchers about bringing clickers (i.e., student response system) into his teaching. Steven had one text segment from his interview transcript coded as first-level knowledge, two text segments coded as second-level knowledge, and three text segments coded as third-level knowledge (see Table 4.1).

As a temporary supply teacher, Jonathan had very little experience using technology in his teaching, and scored only 12 points in this category. He believed that it was important for students to use technology as much as possible in school, and that technology could facilitate students’ learning process and provide students a real-time way of monitoring the world and what’s happening. He acknowledged that technology could help the teacher moderate students’ learning and give students the opportunity to have dialogue among each other and thus be able to collaborate with each other. Following are some excerpts from his interview transcript.

I think you know the way the world is going and the technologies that are being developed. I think it’s critical the students learn how to harness these technologies so they can be successful when they graduate from school. ... But, uh, you know I think it’s our teachers’ responsibility, you know in this day and age, to use technology as much as possible in the classroom. You know, because that’s the way the kids learn outside of the classroom, right.
I think technology, when we use that word, it is also very broad, right? It can mean any number of things. I mean technology strictly is any tool which can, you know, facilitates some sorts of process or your work, right?

I think if the kids have some sort of place, or Internet site, or their own personal website where they can collect these news feeds. It’s a real-time way of monitoring the world and what’s happening.

Using it as a forum, where they post questions, and other people can answer that, the teacher can moderate that. Uh, you know, it is as good as having almost a dialogue in the classroom in person, because you can do this online, you can shoot questions back and forth, and that is collaborative in a way

- Jonathan, teacher interview response

Jonathan had three text segments in his transcript coded as first-level knowledge of the role of technology, three text segments coded as second level knowledge, and one text segment coded as third-level knowledge (see Table 4.1).

4.2.2 Epistemic Network Analysis of teachers’ knowledge

The analysis above provided a qualitative description of the quantified levels of the three teachers’ knowledge in five distinct categories. However, teacher’s knowledge is a complex puzzle in which the different categories of knowledge likely interact and interconnect. A descriptive analysis that treats the categories separately cannot address such complex interactions or connections, nor can it address the coherence of knowledge. One recent approach to illustrating connection and coherence among categories of knowledge is called Epistemic Network Analysis (Shaffer et al., 2009; Orrill & Shaffer, 2012; see Section 3.6.2). Essentially, this analysis looks at the co-coding of categories for any given knowledge element, in order to address the level of interconnectedness of the data.

With the coded data from the descriptive analysis, I used the online tool for ENA analysis (http://epistemicgames.org/ena/) to create ENA analysis set and plot three maps that each represents the connectedness of the five measured categories of each teacher’s knowledge. Figure 4.2 shows the resulting maps of each teacher’s knowledge.
Figure 4.2 Three teachers’ knowledge maps

Mary’s map had the most number of connections, and all five categories of measured knowledge were connected to each other. In contrast, Jonathan’s map illustrated interconnections between four categories of his knowledge (content, community, role, and inquiry), while the technology category had no connection with the other four categories of knowledge. Steven also had four connected categories of measured knowledge (community, role, inquiry, and technology). Once again, however, the technology category was less integrated, with no connection to categories of inquiry or teacher’s role, and no connection between the teacher’s role and community categories. Further, his content knowledge was not connected to
any of the other four categories of knowledge. The number of connections and whether a
category of knowledge connects with other categories of knowledge reflected the coherence of a
teacher’s knowledge. Therefore, the analysis revealed that Mary had the most coherent
knowledge, and Steven had the least coherent knowledge. Jonathan’s level of coherence was
between the two.

### 4.2.3 Summary

Both the descriptive knowledge analysis and the ENA analysis indicated that Mary had
more sophisticated knowledge than the other two teachers. She had the highest total scores in the
interview coding, and her ENA map was the most connected indicating a high coherence in
teacher knowledge. Jonathan’s overall knowledge scores fell in between Mary’s and Steven’s
scores; he scored highest in knowledge of community-oriented learning. His ENA knowledge
map indicated higher levels of connectedness than Steven’s, in the five categories of knowledge.
Steven’s knowledge was the lowest among the three teachers, with lowest scores in both total
knowledge level and in four of the knowledge categories. His ENA map showed that the five
categories of knowledge were not connected well and his teacher knowledge was the least
coherent.

The next two sections will examine the three teachers’ enactment of the designed
curriculum and the patterns of the three teachers’ interaction with students. The interaction
pattern will also be examined in terms of how the patterns may be related to differences in
teachers’ knowledge.

### 4.3 Enactment Analysis

This analysis was designed to address the second sub question of my first research
question: What roles are actually enacted by teachers in the implementation of the designed KCI
curriculum? A challenge that learning sciences researchers often face is that teachers may not
adopt the new curriculum materials that the researchers designed in ways that are “true” to
designers’ original intent (Lin & Fishman, 2006). In this section I describe in detail what really
happened when the teachers enacted the curriculum we designed. I begin by describing some
basic facts of what happened and what was produced by students in this curriculum unit. Then, I
describe my overall impressions of each teacher’s enactment, in a short narrative. Next, I
describe the specific roles that the teachers actually played, in reference to the categories above.
Finally, I show the teachers’ implementation of the designed learning activities according to a
time line.

4.3.1 Summary of the classroom events comprising the intervention

The designed curriculum, which includes 21 lessons, was enacted in a period of nine
weeks. A total number of 106 students engaged in this curriculum unit. Altogether, students
added 382 reference items to the knowledge base, each of which averaged 3 semantic “key
word” tags. In addition to the original 48 tags that we asked the students to use when they
generated references, the students created another 111 tags of their own. In the brainstorm
activity, students created 304 brainstorm items, which were later grouped into 26 categories that
ultimately reduced to 16 climate change issues. Each issue group has six or eight students drawn
from two different class sessions. On average, each Issue Page was edited 95 times and was 3383
words in length. On average, each Issue Page included 10 reference items that the students
created and stored in knowledge base. In the climate change remediation activity, the students
worked on a total of 29 Remediation Pages. Each remediation group had three or four students
drawn from one class session. On average, the students edited their Remediation Page 60 times
and produced 1983 words of content. Altogether, the students cited 175 references, including 32
references that had been previously stored in the knowledge base. They also responded to 6
reflection questionnaires about the unit content as well as their ideas about inquiry, collaboration
and community learning. Each reflection questionnaire was answered by 72 students on average.
Appendix C shows details of the above information.

4.3.2 Narrative description of the three teachers’ overall enactment

Based on my classroom observation and analysis of video-recorded classroom
enactments, I created the following narrative accounts of how each teacher enacted the climate
change curriculum. In general, Mary’s enactment was the most “true” to the designed unit,
although interestingly, no teacher experienced any major challenges or deviations from the
design. This latter point could be seen as supportive evidence that the Drupal environment and
careful design of materials, prompts, and others was successful in scaffolding the less experienced teachers.

Mary was the teacher who co-designed the curriculum with the researchers. Thus, she was very clear about what students should do in a learning activity and about the specific steps of an activity. She talked to researchers a couple of times in the classroom about what the students should do. Among the three teachers, she is the one who spent most of her class time interacting with students. In her class sessions, when students were working in small groups or individually, she often walked in the classroom and talked to individual students or groups of students. She actively initiated many of the interactions she had with small groups of students. Compared to the other two teachers, she spent more time suggesting students ways to improve their learning products or how they could work more effectively when she interacted with students. She never stood at the front or the back of classroom simply watching the students working. Sometimes she had no interaction with students at all and worked on her own laptop instead. However, during these non-interactive periods in the classroom, she did check students’ work with her computer. Thus, I often observed scenarios like this: Mary was sitting at the front of the classroom and was working on her computer. Suddenly, she called a student’s name in a whole class voice and told her/him what she/he had done was good and what she/he needed to do to improve the quality of her/his work. This happened a lot when the students were working on the e-card activity and when the issue editing activity was close to its end. During the remediation activity, she often went to students groups and talked to them about their remediation wiki page. She often suggested students to go back and check the “remediation” section of at least two Issue Pages to see what they could take from the “remediation” section and use the content in the remediation wiki page.

Steven seldom talked with the researchers about what the students should do in an activity. He asked the researchers a couple of times to clarify or explain the specific steps of an activity, even though he often talked with the researchers in the classroom. While students were working in small groups, he did not often interact with them. He sometimes did walk to groups of students and watched the students, but only occasionally said something to the groups he watched. In many of the cases when he interacted with students in small groups, it was often that the students initiated the interactions. Helping students solve various logistical issues was the
most frequent thing he did when he interacted with students in small groups. There were many class time periods that he had no interactions with students. He sometimes just stood at the front or the back of the classroom, watching students working without talking to students. He sometimes worked on his own, such as sorting out his desk. He sometimes worked on his laptop too, when he was not interacting with students. He sometimes talked with the researchers about different kinds of technology that he was interested in, such as iClikers™, Google Sketch™, and others. The scenarios that I had observed in Mary’s class never happened in his class. In most cases, Steven just looked for teaching materials when he used his laptop. He liked to use a whole class voice talking to students even when the students were working in small groups.

Jonathan only taught half of the climate change unit. He taught 12 lessons of 22 lessons over five weeks. It appeared that Jonathan had a more limited understanding of the designed curriculum because he often asked the researchers to explain or clarify what the students should do and how a learning activity should be carried out during the ongoing of class. He was trying to understand the designed curriculum as best as he could. Like Steven, he sometimes did watch students working in small groups, but said nothing to the groups. When he was interacting with students in small groups, he often helped students solve logistical problems. Like Steven, many of this type of small group interactions were initiated by the students. There were many periods of class time in which he did not interact with students while students working in small groups. During these non-interaction periods, he sometimes stood at the front or the back of classroom, watching students working without saying anything to students; he sometimes sat at his desk, marking students’ assignments, tidying up his desk, or working on his own things; he sometimes talked to the researchers about the lesson plan and how to carry out the learning activities, or even about sports. He never used laptop when he was not interacting with students. He had more whole class interactions than small group interactions. Table 4.2 is a narrative summary of the three teachers’ enactment.

Table 4.2
Summary of Three Teachers' Enactment

<table>
<thead>
<tr>
<th></th>
<th>Mary</th>
<th>Steven</th>
<th>Jonathan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Talking to researchers about the designed curriculum and learning activity</td>
<td>A couple of times</td>
<td>A couple of times</td>
<td>Very often</td>
</tr>
<tr>
<td>Frequency of “no interaction” when students working in small groups</td>
<td>Seldom</td>
<td>Often</td>
<td>Often</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Property of small group interaction</td>
<td>More logistical and pedagogical</td>
<td>Less logistical and pedagogical</td>
<td>Less logistical and pedagogical</td>
</tr>
<tr>
<td>Stood at the front or back of classroom, just watching the students</td>
<td>Never</td>
<td>Often</td>
<td>Often</td>
</tr>
<tr>
<td>Worked on own laptop when was not interacting with students</td>
<td>Often</td>
<td>Seldom</td>
<td>Never</td>
</tr>
<tr>
<td>Suggested students re-read the “remediation” section of Issue Pages to see if they can use the content there in remediation wiki page</td>
<td>Often</td>
<td>Seldom</td>
<td>(Did not teach in remediation activity)</td>
</tr>
</tbody>
</table>

### 4.3.3 Roles that the teachers enacted

All three teachers performed the nine roles identified in the curriculum design analysis: establishing a collective epistemology, content teaching, co-ordination, evaluating students, guiding learning activities, organizing learning activity, making connections, setting learning context, and technical role. In addition, all three performed additional roles that were not identified in the design analysis: (a) elaboration, (b) reflection, (c) collaboration, (d) modeling, (e) monitoring, and (f) classroom management.

Guiding learning activities, making connections, and setting learning context are important roles that were identified both in the designed curriculum and in teachers’ enactment. Section 4.1.2 has detail explanations of these roles. The following paragraphs also provide sample video transcripts of these three roles that the teachers enacted.

**Guiding learning activities.** During the brainstorm activity, Mary told a group of students what they needed to do after they found information they needed from the posters of climate change in seven different regions in Canada.

**Mary:** *OK, you guys. Ok, doing OK. What you are going to do when you go to your home groups. You have one minute, to summarize stuff to your home group. Now, what you’re gonna do is put all questions you’ve done as you think about it. Ah, and actually skip it down to the farm stuff. [Saying to one student]*
You’re going to think what are two major things that stood out for you that climate change is doing in BC and what are the consequences of it. That’s what you are going to tell your group. People who are in the same group, you each have 30 seconds, so each of you guys will talk about one issue and one consequence.

In the next video transcription, Mary gave instructions on what the students should do when they work on issue pages.

Mary: You’re going to go ... I want you to spend part of the time almost playing with the page. Go find out the stuff that’s there. Go find the different parts of the page. Look at the different things that need to be filled out. In particular, I want you to take a look at the top where you are going to be writing a brief description in. And, also there’s a couple things. You can start looking for references. Cause you notice there is a place for references that will access the references you guys have already put in. There is also a spot for a to-do list. So, you know you might be working on stuff the first day, and you want to make a to-do list. And that lets you communicate with the other groups that are gonna be working on the same topic.

Making connections. When students started to work on Remediation Pages, Mary suggested students to go through the remediation sections of all Issue Pages that students have created in knowledge base and use them in their Remediation Pages.

Mary: You’re going to go through all of the issues that people did. And, you’re going to identify all issues that your remediation will have some sort of impact on. And then you’re going to prioritize them, so you’re gonna have all of the issues and then ... I mean some of the remediations will not have any impact on some of the issues. So, you’re not going to put that on. You’re gonna have a few that are going to really make big difference, a few it’ll impact but, you know not so much. You’re going to rank them as that. That’s gonna help you on next part, because what you’re going to do is take the two issues that are most impacted, and figure out how that remediation itself is going to resolve some of those issues.

Steven tried to connect the news in real life to what the students learning.

Steven: Guys, have you hear about it in the news? The fact that the UN might be wrong about one particular glacier in one part of the world. And, then they’d only be slightly wrong. Tells you two things. One they are constantly looking for errors in their data. And when they do, they make corrections. And that’s just one
specific concept. It doesn’t invalidate the physics, which is CO2 absorbs light and reemits it as heat.

Setting learning context. Jonathan introduced the unit to student and told them that they would learn this unit in a new way.

Jonathan: OK, so, exciting stuff guys. We’re starting a new unit today on a very important topic of course globally that is climate change. Something that of course you probably all have some prior knowledge about, either through the media, or popular culture, or Geography, or even in previous years. Obviously, we’re gonna be looking at it with respect to certain concepts relevant to M3 science, but we’re also gonna be learning the concepts in a very new and exciting way. And it’s called knowledge building communities.

Mary introduced the context of the video that she’s going to play to the class. She also suggested students to pay attention to issues that would be talked about in the video.

Mary: Alright, I am going to show you a video now. That’s about 15 minutes long. While you’re watching it, I want you to think of a few things. Now, just as a preface before we start the video. It is about Inuit, oh, it is not Inuit, it is a specific type of group up north. And, what it is, is the group took a look at this community for about a year. And, this video was made by community members, to talk about climate change. You’ve gotta remember a couple of things. First of all, it is a very different culture than we have in Toronto. Toronto is like fast, fast, go, go, go! Much slower up there as is this speaking. Also a lot of it is oral history. So, I want you to listen and think about some of the stuff you’re hearing. What I want you to do as you’re doing that, as you’re listening and hearing things, think about what some of the issues are? What are these people dealing with? Is it an issue that’s gonna affect us? How is it gonna affect them? That type of thing.

The following sections describe the six roles that were identified only in teachers’ enactment, accompanied with some examples from the teachers’ classroom enactment.

Elaboration involves teachers trying to help students to think more comprehensively, deeply, or in different ways or perspectives. They also helped students to understand content better by asking students to explain their ideas or by explaining phenomenon, ideas, concepts or principals to students directly. When students worked on the TELS model, they suggested
students to change parameters in the model so that students can understand how different elements can affect earth temperature.

For example, the following excerpt from Jonathan’s class demonstrates that he helped a student to think why more clouds make temperature lower instead of higher. The student in this conversation thought that clouds were made of water and water absorbed sun energy; thus, earth’s temperature should go higher when there were more clouds. Jonathan asked the students to think from the perspective of the albedo effect that clouds create.

**Student:** According to this thing, clouds like, a kind of make it go lower.
**Jonathan:** Yeah.
**Student:** But, how does that work? Because are not clouds made of water? And they absorb the gas?
**Jonathan:** Because it ..., What does it make lower? The temperature? Because it reflects the incoming radiation, remember?
**Student:** But, but is cloud made of water?
**Jonathan:** Yes, but they have what the albedo of the cloud be.

In the following example, Mary asked students why the elder Inuits’ knowledge was important. She first let a student explained her idea. Then, she explained to the students what she thought.

**Mary:** OK! Just to follow through, the Inuit elders. How were their observations important?
**Student:** They have knowledge from long time ago. Also, they see the changes better.
**Mary:** Yeah, they have knowledge. They talked a lot. You notice that the older ones actually remembered some of the stuff. I always get mixed up between this [video] and the video where they talked about the grandparents. You know when they went out with the grandparents and that whole type of thing. So, they have ... and the information from the elders is important scientific information that we need. It complements some of our ice core and everything else.

**Reflection** is the role that the teachers asked the students to report back what they just learned. The following is an excerpt from Jonathan’s class when he asked students to recall some of the observations the Inuit has noticed in the Sila Alangotok video.
Jonathan: What did you note about some of the observations that the Inuvialuits were making about the climate change in that area? The Sachs Harbor?
Student 1: Just one is that the ice is thinner, so that they can’t travel safely on it.
Jonathan: The ice is thinner, definitely. What else? Denny?
Student 2: What I see is that there aren’t any icebergs left, so that they cannot hunt seal.
Jonathan: So, they are called ice floats, right? No ice floats. Snell?
Student 3: Slower freeze up.
Jonathan: Slower freeze up? OK! So ... so, let’s say, takes longer to freeze.

In the following video transcript sample, Mary asked her students to reflect on issues that the residents of Sachs Harbor raised in the Sila Alangotok video.

Mary: Also, What were some of the issues that were raised? ... Issues that were raised?
Student 1: What do you mean issues?
Mary: Problems, things to be thought about.
Student 2: One of the stick notes said fishing until November 9.
Student 3: Boating,
Student 2: Boating on November 9. And, also slower freeze up in the Fall.
Mary: Yeah, so slower freeze up. So, again, going back to the ice bridges, transportation, ...
Student 4: Shorter Winters, longer [???], earlier Springs.
Mary: What’s the problem of the shorter Winters?
Student 4: Ah, shorter food, transportation, everything they could do in the Winter [they do] less.
Mary: Yeah. And they’re losing the ice because it is getting thinner and thinner and thinner. Ah, Yeah? Yeah?
Student 5: It’s also getting more dangerous to hunt because the ice is like unstable and it’s crappy.
Mary: Yeah, harder to hunt. What else did you hear about? You told me something earlier about the seals. Oh, What your point was though?
Student 6: It was like no ice on. In the Summer, and like it cracks, they could not catch seals or something.
Mary: Yeah, cause in the summer there’s ice out there, so you go out on the ice to get the seals. And, there is whole bunch of other stuff, like the seals, when they, they have to go so much further now to get food. And, actually they do a lot of feeding just off, like the banks, like just the underground part. But now the ice is way past
that area, they have to go down very very deep water. Some of the creatures cannot swim.

The collaboration role includes that teachers explained how collaboration could happen in this unit, helped students to understand some issues that they may encountered when working in groups; suggested students to use to-do list to co-ordinate their collaboration with others; coordinated students to collaborate with each other; and suggested students to think in terms of the whole Issue Page when working on page sections of their own responsibility.

At the very early stage of Issue Page editing activity, Mary spent some time to explain a situation that the students may encounter when they edit Issue Pages in collaboration with students from other class sessions. Following is an example of this.

Mary: Yes. (Pointed at a student) 
Student: So basically our whole group is working on the same page. So, when a person adds stuff, the other group members can see it, all those thing, right?
Mary: Yes, those things so. And there is one thing. It always seems to hurt that first time that some, you know you put real amazing stuff down. And someone is going to edit it. And you're gonna go, "leave my stuff alone, because it is really good." And then you will get over it because you're gonna look at it, oh, yeah, maybe it is a bit better. And you're gonna edit somebody else’s stuff. So you're gonna have a bunch of people looking at it. You're looking through this lens, somebody else is going, oh, yeah, but you missed this point, or that is way too tight, let’s bring it open a bit. They’ll be editing back and forth on that. And usually it works out. The stuff I've seen for the last four years, it’s better because multiple people edit [it].

At the beginning of Issue Page editing activity, Jonathan mentioned to-do list and asked students to use it to co-ordinate their editing activity (see next excerpt).

Jonathan: There is a to-do list that you should see. Everybody see that?
Student: Yeah.
Jonathan: [You] should be able to see that. OK? So on your to-do list, now you need to start delegating particular activities or tasks that you guys mutually agree upon to each member of the group. OK? Everybody’s gonna be involved in every aspect at some point.
The **modeling** role is that teachers demonstrated what the students should perform in a learning activity; demonstrated how to connect climate science topics (e.g., Greenhouse Gases, Albedo, etc.) to climate change issues that the students were working on (e.g., Economy issue); used examples to explain how the students might be tested; illustrated how to work on Issue Pages; used examples to show how to prioritize learning (e.g., what types of scientific facts are important and should be memorized and what types are not very important). Mary also demonstrated climate science related phenomenon to students. Steven used the work of other students to show how much they should write in e-card activity.

In the following example, Mary demonstrated to students how to work on issue brainstorm activity with post-it notes.

**Mary:** OK! So, if I am doing this, I have a pad of paper. Ah, what you are going to be thinking about are what are some of the issues about climate change. You can think of the video. You can think of other things you know. So, one of the issues you guys said was not enough ice so no seals. So, now here is how you are going to do this. ... I have a post-it. I am the only one who can talk. So, I am going to say “Not enough ice, no seals, less food”. And then, I’m gonna grab it and I’m gonna stick it in the middle of the table, and I pass it to the next person, who is now the only person you can talk. And, as they write, they're gonna say it aloud so everybody hears it. Everybody else is listening and you're either thinking of another idea a way to piggyback it, and so on.

In Lesson 5, students started to work on Issue Page. After assigned students into issue topic groups, Steven demonstrated what the students needed to do with issue wiki pages. In the next example, Steven used Glaciers Melting issue as an example to demonstrate that the students need to add content to sections such as greenhouse effect, thermal energy and circulation and so on, after they learned the correspondent content.

**Steven:** So, let’s suppose we are talking about greenhouse gases and those might be things like water, methane, and carbon-dioxide. Ah, once you figure out how that works, you will then think about your particular issue. Can I have an example? What is one of your issues? Glaciers melting. OK, let’s do glaciers melting. So, then, you will say: OK! Mr. B carefully elucidated and explained in a very clear and stunningly accurate way all about greenhouse gases. And, now what affect do those increasing CO2 levels and greenhouse gases have on my particular issue, which is glaciers
melting? Right? And then all that junk we will put in up there, in that area. And, then later on we’re going to talk about thermal energy and circulations. And, in fact I want to talk a little bit about that today if we get a chance.

**Monitoring** is a role in which the teachers monitored students’ learning progress. All three teachers spent time walking in the classroom to check students’ progress on certain activities. They sometimes asked the whole class how much time the students still need to complete an activity they were working on and what step of the learning activity the students were on. Because the teachers spent very short time, less than five second, each time when they played this role, I am not going to provide any samples of this role here.

**Classroom management** role includes things like: the teachers managing the students’ misbehavior in the classroom; the teachers asked student to pay attention to what he/she was going to say; the teachers checked students attendance and asked students to bring the attendance sheet to the school’s main office; the teachers asked students to focus on the activity they were doing instead of chatting or checking emails; the teachers asked the students to work independently rather than discussing with others during pre-test; and others.

### 4.3.4 Enactment of Learning Activities

In addition to identifying the actual roles the three teachers played, I also examined the lesson sequence and the learning activities that the teachers enacted to see if there are any differences between what they really enacted and what we had designed for them (i.e., as presented in the design analysis above). For the most part, the teachers followed the scheduled lesson sequence very well. However, they did not enact the lessons in exactly the same sequence or schedule as the research team had designed. Nor did they implement all of the designed learning activities. For example, we designed that students would work on the TELS modeling activity in Lesson 9 and 10. However, the teachers all pushed the TELS modeling activity to the next two lessons (i.e., Lesson 10 and Lesson 11). In terms of learning activities, the e-card activity was not implemented in Jonathan’s classes. Also, in lesson 6, we designed Energy Saving Card activity that asked the students to audit their energy use at home. Jonathan did not let the students work on this activity. Table 4.3 shows the disparity between teachers’ enactment and the designed curriculum sequence time line and learning activities. Column 1 of Table 4.3 is
the number of class period. Column 2 is the learning activities that should be enacted and the science topics that should be taught in each lesson according to the curriculum design. Columns 3 to 5 show each teacher’s enactment disparities compared to the original design. If a table cell in Columns 3 to 5 is empty, it means that the teacher followed the original design exactly. Otherwise, a cell explains what was different from the original design. Cells marked with an X are lessons that are not included in the analysis because these were taught by another teacher.

Table 4.3

*Differences Between Teachers' Enactment of the Designed Curriculum*

<table>
<thead>
<tr>
<th>Class Period</th>
<th>Lesson Content or Activity</th>
<th>Mary</th>
<th>Steven</th>
<th>Jonathan</th>
</tr>
</thead>
</table>
| 1            | *Introduction to climate change unit*             | – Introduce the online portal: username, password
– Play and discuss Sila Alangotok video
– Online portal: pre-test & reflections
– Climate change issues brainstorm |
| 2            | *Working in collaboration & references assignment* |
| 3            | *Climate change issue brainstorm*                 | Assigned e-Card activity                  | Students did not work on e-Card activity |
– Climate change In Canada Jigsaw activity with posters
– Issue brainstorm group and collation
– e-Card activity |
| 4            | *The Earth's atmosphere*                         |
| 5            | *The greenhouse gases effect*                    | Only one class session worked on Issue Pages |
– Assigning Issue groups & start working on Issue Page |
| 6            | *Energy saving and GHG impacts*                  | Not worked on Energy Saving Card activity |
– Energy saving cards activity |
| 7 | **Thermal energy & oceanic circulation**  
  – Issues Page update | Students in one class session did not work on Issue Pages | Students did not work on Issue Pages |
|---|---|---|---|
| 8 | **Thermal energy & atmospheric circulation**  
  – Coriolis effect, El Niño, La Niña | | Students worked on Issue Page |
| 9 | **TELS climate change model**  
  – Issues Page update | One class did not do both. One class did not work on TELS model. | Did not work on TELS model.  
  Both class did not work on TELS model |
| 10 | **TELS climate change model**  
  **Carbon sinks and sources** | Students worked on Issues Page update | Did a review test |
| 11 | **Carbon Sinks and Sources (cont’d)**  
  – Issues Page update | Students worked on TELS model. | Students worked on TELS model.  
  Students worked on TELS model. |
| 12 | **Review activities** | | |
| 13 | **Paleoclimateology**  
  – Timelines, Little Ice Age, tree cookies  
  – Issues Page update & peer review | | X |
| 14 | **Paleoclimateology**  
  – Ice cores and lake cores | | X |
| 15 | **Extreme Weather Patterns**  
  **Models for Climate Change** | Students worked on Issue Page.  
 Models for Climate Change | Students worked on Issue Page.  
 Models for Climate Change |
| 16 | **Models for Climate Change (cont’d)** | Students worked on Issue Page. | Students worked on Issue Page.  
 Models for Climate Change |
| 17 | **Climate Change Legislation** | | X |
4.3.5 Summary

The enactment analysis revealed that teachers played all the roles identified in the designed curriculum. Furthermore, they played newly identified roles of elaboration, reflection, collaboration, modeling, monitoring, and classroom management. While there were a few differences among the three teachers in terms of their enactment of the designed curriculum, for the most part, the teachers followed the curriculum designs and their enactment was ‘true’ to our original design intent.

However, classroom observations revealed that the three teachers were different in the ways they interacted with their students. Each teacher’s interaction with students had its own characteristics, which I examined in a more fine-grained analysis presented below in section 4.4.

4.4 Classroom Interaction Analysis

The first purpose of this analysis was to answer my second research question: What are the patterns of the teacher-students interaction in the KCI climate change curriculum? Section 4.3 described the roles played by the three teachers during their enactment of the design KCI curriculum. To go further, my analysis also employed a finer-grained analysis to portray teacher-student interaction patterns, which presented in two ways: (a) the average time duration that teachers spent each time they interacted with students, (b) the average percentage of all class time that each teacher spent on different types of interactions. In this analysis, I also examined the average percentages of all class time each teacher spent on different types of interactions in each of the three main phases of KCI (i.e., brainstorm and epistemic orientation, collective
knowledge construction, and culminating inquiry project). Finally, I then compared the results across the three teachers to compare the model teacher’s (Mary) interactions with students to the others with the purpose of establishing the model interaction patterns for teachers in a KCI curriculum.

The second purpose of this analysis was to address my third research question: Do the patterns of the teachers’ interaction with students correlate to their knowledge of KCI or other relevant background knowledge? I used non-parametric statistical analysis (e.g., Kendall’s rank and biserial test) to achieve this purpose. Section 4.4.5 presents the details of the results.

### 4.4.1 Average time duration for interactions with students

The duration that a teacher spent on each interaction demonstrates how quickly he or she switched from one group to another group when interacting with students in small groups, or switched topics when talking in whole class. This section will explore the average time duration for three different categories of interaction, for each of the three teachers: whole class interaction (WCI), small group interaction (SGI) and “None” (i.e., when the teacher was engaged in some other activity and not interacting with students). As described in section 3.6.4, 25 class sessions were coded, for a total of approximately 25 hours of video. For the initial “coarse grain” coding, each class session was simply viewed, and marked for beginnings and endings of each of the three forms of interaction.

On average, the three teachers spent 30.5 seconds each time they had small group interaction (SGI), and 37.8 seconds each time they had whole class interaction (WCI). For the times when they did not interact with students, the duration period lasted an average of 83.3 seconds. Table 4.4 shows the mean, the maximum, and the minimum time duration of each interaction the three teachers had with their students, measured by the types of interaction. Figure 4.3 shows the bar chart of the mean values of the time duration of each interaction the three teachers had with student measured by types of interaction.

Table 4.4

*The Mean, Maximum and Minimum Time Duration of Each Type of Interaction*


<table>
<thead>
<tr>
<th></th>
<th>Jonathan</th>
<th>Mary</th>
<th>Steven</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Small Group Interaction (SGI)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>00:33.2</td>
<td>00:28.9</td>
<td>00:31.6</td>
</tr>
<tr>
<td>Max</td>
<td>04:54.3</td>
<td>03:46.4</td>
<td>03:46.4</td>
</tr>
<tr>
<td>Min</td>
<td>00:05.0</td>
<td>00:05.4</td>
<td>00:06.2</td>
</tr>
<tr>
<td><strong>Whole Class Interaction (WCI)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>00:31.5</td>
<td>00:39.2</td>
<td>00:42.4</td>
</tr>
<tr>
<td>Max</td>
<td>02:40.6</td>
<td>07:11.9</td>
<td>04:34.3</td>
</tr>
<tr>
<td>Min</td>
<td>00:06.4</td>
<td>00:06.9</td>
<td>00:05.5</td>
</tr>
<tr>
<td><strong>No Interaction (None)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>01:46.7</td>
<td>01:02.5</td>
<td>01:30.9</td>
</tr>
<tr>
<td>Max</td>
<td>07:16.2</td>
<td>05:36.6</td>
<td>10:23.3</td>
</tr>
<tr>
<td>Min</td>
<td>00:15.2</td>
<td>00:10.6</td>
<td>00:15.2</td>
</tr>
</tbody>
</table>

![Graph](image)

**Figure 4.3** The average time duration of each type of interaction compared by teachers

Among the three teachers, Mary spent the shortest duration of time in each small group interaction. In comparison, Jonathan spent the shortest time duration when interacting with students in whole class mode. When the teachers did not interact with students, Mary’s average time duration was also the shortest.

Each whole class and small group interaction was also coded in terms of its main focus, with three “meaningful” categories (i.e., Logistical, Conceptual, or Pedagogical) and the additional category, Off-topic. Logistical interactions were those concerned with getting students into groups, distributing materials, finding Web locations, etc. Pedagogical interactions were
those concerned with encouraging reflection, asking questions, promoting collaboration, etc. Conceptual interactions were concerned with explication of curricular content, including lectures and conceptual explanations. Off-topic interactions were all other interactions, either dedicated to peripheral conversations (i.e., “chit chat”), or dissemination of extraneous information.

Table 4.5 and Figure 4.4 show the average time duration of each whole class interaction, broken into the four kinds. If the purpose of interaction was to lecture science concepts or principles, Steven spent longest time on average, and Mary spent the shortest time. For logistical interactions, Steven again spent longest time on average, and Jonathan spent the shortest time. And for whole class pedagogical interactions, Mary spent the longest time on average, and Jonathan spent the shortest. For interactions that were about topics that unrelated to climate change content teaching and learning, Steven spent the longest time duration on average, and Jonathan spent the shortest.

Table 4.5
The Average Time Duration of Each WCI Interaction

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Conceptual</th>
<th>Logistical</th>
<th>Pedagogical</th>
<th>Off-topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jonathan</td>
<td>00:55.5</td>
<td>00:23.3</td>
<td>00:41.4</td>
<td>00:33.5</td>
</tr>
<tr>
<td>Mary</td>
<td>00:53.9</td>
<td>00:31.6</td>
<td>00:48.1</td>
<td>00:37.3</td>
</tr>
<tr>
<td>Steven</td>
<td>01:41.6</td>
<td>00:36.3</td>
<td>00:47.4</td>
<td>00:44.2</td>
</tr>
</tbody>
</table>
Figure 4.4 The average time duration of each WCI interaction compared by teachers

For interactions with small groups, Table 4.6 and Figure 4.5 show the average time durations. For conceptual exchanges (i.e., about climate change science topics), Steven spent longest time on average, and Mary spent the shortest. When dealing with logistical issues, Steven again spent longest time, and Jonathan spent the shortest. If the purpose of interaction was pedagogical in nature, Jonathan spent the longest time, on average, and Steven spent the shortest time. For interaction was that were unrelated to climate change, Jonathan spent the longest time and Mary spent the shortest.

Table 4.6

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Conceptual</th>
<th>Logistical</th>
<th>Pedagogical</th>
<th>Off-topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jonathan</td>
<td>00:34.7</td>
<td>00:24.5</td>
<td>00:38.1</td>
<td>00:49.8</td>
</tr>
<tr>
<td>Mary</td>
<td>00:30.5</td>
<td>00:24.6</td>
<td>00:37.4</td>
<td>00:19.5</td>
</tr>
<tr>
<td>Steven</td>
<td>00:57.8</td>
<td>00:27.2</td>
<td>00:35.4</td>
<td>00:31.8</td>
</tr>
</tbody>
</table>

I also performed a finer-grained analysis of teacher-student interaction, focusing on pedagogical interactions performed by teachers (see section 3.6.4). Table 4.7 and Figure 4.6
show the average time duration of each pedagogical interaction for the three teachers (the combination of SGI and WCI). Mary spent the longest time interactions for the purpose of helping students collaborate or modeling proper learning behavior. Steven spent the longest time on interactions when they were for the purpose of making connections, setting learning context, or guiding students’ learning. Jonathan spent the longest time on each interaction when the interaction was for the purpose of asking students to elaborate their ideas or thinking, evaluating or monitoring students’ learning progress, or asking students to reflect on their learning activities.

Table 4.7

*The Average Time Duration of Each Pedagogical Interaction*

<table>
<thead>
<tr>
<th>Types of Pedagogical Interaction</th>
<th>Jonathan</th>
<th>Mary</th>
<th>Steven</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collaboration</td>
<td>00:23.4</td>
<td>00:46.8</td>
<td>00:28.0</td>
</tr>
<tr>
<td>Connection</td>
<td>00:31.0</td>
<td>00:39.3</td>
<td>00:41.8</td>
</tr>
<tr>
<td>Context</td>
<td>00:43.4</td>
<td>00:55.3</td>
<td>00:58.0</td>
</tr>
<tr>
<td>Elaboration</td>
<td>00:57.7</td>
<td>00:53.7</td>
<td>00:48.5</td>
</tr>
<tr>
<td>Evaluation</td>
<td>00:31.5</td>
<td>00:28.5</td>
<td>00:22.5</td>
</tr>
<tr>
<td>Guidance</td>
<td>00:36.0</td>
<td>00:38.2</td>
<td>00:44.4</td>
</tr>
<tr>
<td>Modeling</td>
<td>00:31.4</td>
<td>01:08.5</td>
<td>00:43.8</td>
</tr>
<tr>
<td>Reflection</td>
<td>01:17.3</td>
<td>00:48.4</td>
<td>00:47.4</td>
</tr>
</tbody>
</table>

Length of Each Interaction
Figure 4.6 The average time duration of each pedagogical interaction compared by teachers

4.4.2 Percentages of class time spent on different types of interactions

I also examined segmentation and coding in terms of percentage of overall class time allotted to various kinds of interactions (e.g., what percentage of class time was given to whole class vs. small group interactions). As the lengths of the various class sessions varied, this percentage measure reflected the relative weight given by each teacher to the various forms of interaction.

Table 4.8 and Figure 4.7 show the percentage of class time that the three teachers spent on the three different types of interaction: whole classroom interaction, small group interaction, and no interaction with students. Note that these percentages add up to 100, indicating that these percentages were calculated only from the coded segments. The percentage of all class time that Mary spent on interacting with students, 75%, was the most among the three teachers. Steven spent about 61 percent of his class time interacting with students and Jonathan spent only 54 percent of class time interacting with students. Mary spent a greater percentage of class time on both whole class and small group interactions than either of the other two teachers.

Table 4.8
Percentage of Class Time Spent on Each Type of Interaction

<table>
<thead>
<tr>
<th></th>
<th>Whole Class Interaction (WCI)</th>
<th>Small Group Interaction (SGI)</th>
<th>No Interaction (None)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jonathan</td>
<td>28.1</td>
<td>26.3</td>
<td>45.6</td>
</tr>
<tr>
<td>Mary</td>
<td>41.9</td>
<td>33.7</td>
<td>24.4</td>
</tr>
<tr>
<td>Steven</td>
<td>38.4</td>
<td>22.8</td>
<td>38.8</td>
</tr>
</tbody>
</table>
Figure 4.7 percentage of class time spent on each type of interaction

Table 4.9 and Figure 4.8 continue to use percentage of class time as a measure, examining how teachers allocated their whole class interactions. For all three teachers, the majority of this time was spent on logistical and pedagogical issues, with a very small percentage of class time given to whole class lectures about science concepts (less than 3.1%) or unrelated topics (less than 2.8%). Mary spent the highest percentage of class time on pedagogical (19.3%) and logistical (17.6%) interactions, with much less time spent on conceptual or unrelated topics. Steven spent considerably less time on pedagogical interactions than Mary, but the same amount on logistical interactions. Jonathan spent a lower percentage of class time dealing with logistical issues and approximately the same percentage as Steven on pedagogical interactions (see Figure 4.8).

Table 4.9

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Logistical</th>
<th>Conceptual</th>
<th>Pedagogical</th>
<th>Off-topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jonathan</td>
<td>10.6</td>
<td>1.6</td>
<td>15.4</td>
<td>0.6</td>
</tr>
<tr>
<td>Mary</td>
<td>17.6</td>
<td>3.1</td>
<td>19.3</td>
<td>2.0</td>
</tr>
<tr>
<td>Steven</td>
<td>17.4</td>
<td>2.5</td>
<td>15.7</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Percentage of Class Time Spent on Each Type of Whole Class Interaction
Similarly, Table 4.10 and Figure 4.9 show the percentage of class time the three teachers spent on each type of small group interaction. Mary again spent the greatest percentage of time of her class time on logistical and pedagogical interactions – considerably more than either of the other two teachers. Steven spent a little bit less class time on logistical issues and pedagogical roles than Jonathan, and both Jonathan and Steven spent considerably more time discussing unrelated topics.

Table 4.10

Percentage of Class Time Spent on Each Type of Small Group Interaction

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Logistical</th>
<th>Conceptual</th>
<th>Pedagogical</th>
<th>Off-topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jonathan</td>
<td>10.4</td>
<td>0.8</td>
<td>7.0</td>
<td>8.1</td>
</tr>
<tr>
<td>Mary</td>
<td>17.2</td>
<td>0.5</td>
<td>15.2</td>
<td>0.8</td>
</tr>
<tr>
<td>Steven</td>
<td>9.2</td>
<td>1.7</td>
<td>6.9</td>
<td>5.0</td>
</tr>
</tbody>
</table>
4.4.3 Fine grain coding of pedagogical interactions

The previous section revealed an interesting pattern of differences between Mary and the other two teachers (i.e., Figures 4.8 and 4.9), where Mary appeared to favour pedagogical interaction in her small group exchanges more than the others. One question was concerned with the details of these pedagogical exchanges: what were the purpose (i.e., what teachers are trying to accomplish with the interaction) and content (i.e., whether they are questioning, clarifying, synthesizing, or offering procedural or logistical guidance) of the interaction when teachers interacted with their students? Clearly, whole class and small group interactions are fundamentally distinct in terms of their purpose and content. In this section, I present the specific pedagogical interaction content of both whole class interaction and small group interaction.

Table 4.11 and Figure 4.10 as well as Table 4.12 and Figure 4.11 show the average percentage of class time given by the three teachers to each of the different kinds of pedagogical interactions. The largest percentage of time for all teachers was spent in “guidance” (i.e., helping students understand the specific expectations of the planned learning activities) and “context” (i.e., providing a rationale for activities and clarifying their role in the larger curriculum scheme). While the teachers did not differ greatly in how they engaged pedagogically during whole class interactions, there were some interesting differences in the small group interactions. Mary clearly gave precedence to the guidance category and spent considerably more time than the others in
the elaboration and collaboration categories. In part, these differences were simply a result of the fact that Mary had twice the overall percentage of small group interactions than the others (see Figure 4.9). However, the preference shown by Mary for the two most common categories is at a much higher ratio than the baseline differences (approximately 3-to-1), and she was the only teacher who gave any emphasis to discussions of collaboration. These are consistent with the pedagogical demands of KCI, where collaboration is central to the design, and guidance demands would be high during small group activity.

Table 4.11

*Percentage of Class Time Spent on Each Types of WCI Pedagogical Interaction*

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Jonathan</th>
<th>Mary</th>
<th>Steven</th>
</tr>
</thead>
<tbody>
<tr>
<td>WCI_Collaboration</td>
<td>0.1</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>WCI_Connection</td>
<td>0.0</td>
<td>1.1</td>
<td>0.8</td>
</tr>
<tr>
<td>WCI_Context</td>
<td>5.0</td>
<td>3.9</td>
<td>5.4</td>
</tr>
<tr>
<td>WCI_Elaboration</td>
<td>0.3</td>
<td>0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>WCI_Evaluation</td>
<td>0.5</td>
<td>1.0</td>
<td>0.2</td>
</tr>
<tr>
<td>WCI_Guidance</td>
<td>6.6</td>
<td>7.3</td>
<td>6.0</td>
</tr>
<tr>
<td>WCI_Modelling</td>
<td>0.1</td>
<td>1.4</td>
<td>1.7</td>
</tr>
<tr>
<td>WCI_Reflection</td>
<td>2.9</td>
<td>3.8</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Figure 4.10 Whole class pedagogical interactions: fine grain coding
Table 4.12
Percentage of Class Time Spent on Each Types of SGI Pedagogical Interaction

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Jonathan</th>
<th>Mary</th>
<th>Steven</th>
</tr>
</thead>
<tbody>
<tr>
<td>SGI_Collaboration</td>
<td>0.2</td>
<td>1.7</td>
<td>0.1</td>
</tr>
<tr>
<td>SGI_Connection</td>
<td>0.5</td>
<td>0.4</td>
<td>0.7</td>
</tr>
<tr>
<td>SGI_Context</td>
<td>0.7</td>
<td>0.5</td>
<td>0.0</td>
</tr>
<tr>
<td>SGI_Elaboration</td>
<td>1.7</td>
<td>2.9</td>
<td>1.2</td>
</tr>
<tr>
<td>SGI_Evaluation</td>
<td>0.9</td>
<td>1.5</td>
<td>1.4</td>
</tr>
<tr>
<td>SGI_Guidance</td>
<td>2.8</td>
<td>7.3</td>
<td>2.6</td>
</tr>
<tr>
<td>SGI_Modelling</td>
<td>0.3</td>
<td>0.9</td>
<td>0.6</td>
</tr>
<tr>
<td>SGI_Reflection</td>
<td>0.0</td>
<td>0.0</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Figure 4.11 Small group pedagogical interactions: fine grain coding

The descriptions of teacher-student interactions provided in this and the previous section suggest some differences between the three teachers, particularly in certain comparisons between Mary and the other two. This would be expected, as Mary was a member of the design team, with two years’ prior experience of thinking about and enacting KCI curricula. Thus, while the categorical measures developed for the coding revealed substantial similarities in the three teachers’ classroom interaction patterns, there were some interesting differences. The next section will examine the complexion of interactions as a function of the three main phases of
KCI: (1) brainstorm and epistemic orientation, (2) collective knowledge construction, and (3) culminating inquiry.

### 4.4.4 Teacher-student interactions in three phases of KCI

I analysed all classroom sessions for whole class and small group interactions within the three major phases of the KCI climate change curriculum unit: (a) setting the learning context and KCI epistemological perspective (i.e., brainstorm of climate issues), (b) collaborative knowledge construction (i.e., working on climate change issues), and (c) culminating inquiry project (i.e., working on remediation plans for climate change issues). As each of these three phases has its own purpose, it was reasonable for me to hypothesize that teachers might interact in correspondingly distinct ways with students in each phase. In the following paragraphs, Activity 1 refers to setting learning context and brainstorm, Activity 2 refers to working on climate change issues, and Activity 3 refers to working on climate change remediation plans.

Table 4.13 displays the percentage of class time each teacher spent on whole class interaction, small group interaction, and none-interaction in each of the three KCI learning activities. Figures 4.12 and 4.13 use stacked bar graphs to display the numbers from Table 4.13 in two different organizations (by activity, and by teacher, respectively). Figure 4.12 shows that Mary spent more class time in Activity 1 on both whole class interaction and small group interactions than the other two teachers. During activity 2, Steven spent more class time on whole class interaction than the other two teachers. Jonathan spent more class time on small group interaction than the other teachers. Mary was relatively balanced on the class time she spent on whole class interaction and small group interaction. During activity 3, Mary spent more class time on both whole class interaction and small group interaction than Steven (Jonathan’s data is excluded because he was replaced by another teacher in that activity). Figure 4.13 allows us to see Mary’s apportionment of interactions across the three activities, as gradually decreasing the amount of whole class interaction time, and keeping the small group interactions at about the same level. The other two teachers contrasted with this pattern, varying the amount of whole class and small group interaction time in seemingly arbitrary fashion.

<p>| Table 4.13 | Percentage of All Class Time Spent on Each Type of Interaction in Three KCI Activities |</p>
<table>
<thead>
<tr>
<th>Teachers on Each Learning Activity</th>
<th>Percent of Class Time Spent on Each Type of Interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jonathan</td>
<td>Whole Class Interaction (WCI)</td>
</tr>
<tr>
<td>Activity 1</td>
<td>41.72</td>
</tr>
<tr>
<td>Activity 2</td>
<td>14.44</td>
</tr>
<tr>
<td>Activity 3</td>
<td>*</td>
</tr>
<tr>
<td>Mary</td>
<td>Activity 1</td>
</tr>
<tr>
<td></td>
<td>Activity 2</td>
</tr>
<tr>
<td></td>
<td>Activity 3</td>
</tr>
<tr>
<td>Steven</td>
<td>Activity 1</td>
</tr>
<tr>
<td></td>
<td>Activity 2</td>
</tr>
<tr>
<td></td>
<td>Activity 3</td>
</tr>
</tbody>
</table>

* Data missing. Jonathan did not teach in activity 3.

Figure 4.12 Percentage of all class time spent on each type of interaction by the three teachers, organized within activity.
Table 4.14 further breaks down the percentage of class time each teacher spent on the four types of whole class interaction (i.e., WCI_Logistical, WCI_Conceptual, WCI_Pedagogical, and WCI_Off-topic) in each of the three KCI learning activities. Figures 4.14 and 4.15 visualize those numbers in stacked bar graphs, now focusing on the “with activity” view and “within teacher” view respectively (i.e., continuing from Figure 4.12 and 4.13). While the differences between teachers are interesting, it is now of interest to focus on Mary, as she represents the model KCI teacher and her interactions will be interpreted as reflecting an ideal distribution. In general, Mary is seen to use her whole class interactions in somewhat different ways across the three activities. During learning activity 1, she spent more class time on logistical interaction and pedagogical interaction than the other two teachers, and less time on conceptual interactions. In activity 2, which was focused on the conceptual issue editing, Mary added considerable levels of conceptual exchange – much more than the other two teachers. Finally, during activity 3, she spent much more class time on logistical interaction than Steven did, and the two spent almost the same amount of class time on pedagogical interactions. Overall, Mary’s level of pedagogical interactions...
interaction is seen to decrease from one activity to the next, whereas the other teachers do not show this systematic progression.

Table 4.14

Percentage of Class Time Spent on Each Type of Whole Class Interaction in Three KCI Activities

<table>
<thead>
<tr>
<th>Teachers</th>
<th>Activity 1</th>
<th>Activity 2</th>
<th>Activity 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jonathan</td>
<td>14.81</td>
<td>2.27</td>
<td>23.74</td>
</tr>
<tr>
<td></td>
<td>6.28</td>
<td>0.94</td>
<td>6.99</td>
</tr>
<tr>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Mary</td>
<td>21.57</td>
<td>0.33</td>
<td>27.95</td>
</tr>
<tr>
<td></td>
<td>15.31</td>
<td>8.76</td>
<td>15.40</td>
</tr>
<tr>
<td></td>
<td>15.78</td>
<td>0.10</td>
<td>14.68</td>
</tr>
<tr>
<td>Steven</td>
<td>16.29</td>
<td>2.70</td>
<td>13.30</td>
</tr>
<tr>
<td></td>
<td>24.26</td>
<td>3.59</td>
<td>18.67</td>
</tr>
<tr>
<td></td>
<td>5.69</td>
<td>0.00</td>
<td>14.75</td>
</tr>
</tbody>
</table>

* Data missing. Jonathan did not teach in activity 3.
Figure 4.14 Percentage of all class time spent on each type of whole class interaction, organized with activity

![Percentage of Class Time Spent on Each Type of Whole Class Interactions](image1.png)

Figure 4.15 Percentage of all class time spent on each type of whole class interaction, organized with teacher

Table 4.15 displays the percentage of class time each teacher spent on the four types of small group interaction: SGI_Logistical, SGI_Conceptual, SGI_Pedagogical, and SGI_Off-topic, in each of the three KCI learning activities. Figures 4.16 and 4.17 again visualize those numbers in stacked bar graph, with the intent on revealing Mary’s patterns and understanding how they correspond to the demands of the corresponding KCI activities. Again, there are some interesting features of Mary’s patterns, and some differences with the other teachers that may correspond to distinctions in their knowledge and experience. In contrast to the systematic decrease of pedagogical interactions seen in the whole class exchanges, Mary showed a dramatic increase in the level of pedagogical content within the small group interactions as the activities progress. Her level of logistical exchange also decreased with each progressing activity. In contrast, the other teachers show no systematic patterns. The increased need for pedagogical interaction in Activity 3 would be recognized by a teacher who is deeply sympathetic to the KCI design, as
students would need to make connections in their culminating activity to the community knowledge.

Table 4.15

*Percentage of Class Time Spent on Each Type of Small Group Interaction in Three KCI Activities*

<table>
<thead>
<tr>
<th></th>
<th>SGI_Logistical</th>
<th>SGI_Conceptual</th>
<th>SGI_Pedagogical</th>
<th>SGI_Off-topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jonathan</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity 1</td>
<td>5.89</td>
<td>0.00</td>
<td>1.33</td>
<td>3.36</td>
</tr>
<tr>
<td>Activity 2</td>
<td>14.87</td>
<td>1.67</td>
<td>12.67</td>
<td>12.87</td>
</tr>
<tr>
<td>Activity 3</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Mary</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity 1</td>
<td>21.79</td>
<td>0.00</td>
<td>7.63</td>
<td>0.86</td>
</tr>
<tr>
<td>Activity 2</td>
<td>19.02</td>
<td>1.60</td>
<td>10.55</td>
<td>0.63</td>
</tr>
<tr>
<td>Activity 3</td>
<td>10.88</td>
<td>0.00</td>
<td>27.29</td>
<td>0.78</td>
</tr>
<tr>
<td>Steven</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity 1</td>
<td>8.17</td>
<td>2.58</td>
<td>6.59</td>
<td>7.93</td>
</tr>
<tr>
<td>Activity 2</td>
<td>8.81</td>
<td>0.23</td>
<td>3.26</td>
<td>1.25</td>
</tr>
<tr>
<td>Activity 3</td>
<td>12.26</td>
<td>2.76</td>
<td>15.02</td>
<td>6.59</td>
</tr>
</tbody>
</table>

* Data missing. Jonathan did not teach in activity 3.
Figure 4.16 Percentage of all class time spent on each type of small class interaction, organized with activity.

Figure 4.17 Percentage of all class time spent on each type of small class interaction, organized with teacher.
It is of interest to examine teacher’s pedagogical interactions in a finer grain, as above in Figures 4.10 and 4.11, broken into the 3 activities. Unfortunately, the density of data (i.e., the number of cases) was insufficient to achieve any reliable representations, if the small group (SGI) and whole class (WCI) interactions are kept in separate groups. However, by pooling all the SGI and WCI codes together, it was possible to look at the kinds of pedagogical interactions engaged in by teachers during the three KCI phases. While this type of analysis introduced an obvious limitation in that we were combining two very different forms of discourse – whole class lectures and small group interactions – it does allow one means of examining the pedagogical content of different phases of KCI in terms of the fine grain codes.

Table 4.16 displays the percentage of class time each teacher spent on the eight types pedagogical interaction (i.e., collaboration, connection, context, elaboration, evaluation, guidance, modeling, and reflection) in each of the three phases of KCI. Figures 4.18 and 4.19 are the visualization of those tallies, grouped by Activity and Teacher, respectively, and can be examined together to gain some understanding of the relevant patterns. First, there are some interesting differences to note across activities (Figure 4.18). During learning activity 1, all three teachers spent most of their pedagogical interaction time on setting the learning context and guiding students’ learning activities. This was also the only activity in which any teachers spent time in Reflections. Activity 2 saw a reduction in the amount of guidance teachers felt need to provide, with an increased level of Collaboration, Elaboration, and Modeling. Activity 3 saw a resumed high level of guidance, presumably to guide students what to do to achieve specific expectations of the learning activities while designing their remediation plan, as well as increased level of Elaboration and (in Steven’s case) Connections.

Figure 4.19 re-organizes these codes to give a look at how each teacher’s pedagogical interactions were distributed across the three activities. Again, Mary is the most interesting and relevant case to examine, for purposes of this research, as she is the closest to being a model KCI teacher, and hence her choice of interactions can inform our understanding of the model. One interesting feature of Mary’s graphs is a focus on Reflection in Activity 1, encouraging students to think, speak and write about their ideas. This would be consistent with the needs of this first phase of KCI, where students are learning to adopt a collective epistemology, and gaining a sense of how and why they are engaged as a knowledge community. In Activity 2, Reflection
was largely missing from all three teachers, replaced by an increased focus on Modeling, where the teacher demonstrates for students how to proceed in certain aspects of the task. This would be consistent, in KCI, with the need for clarification and demonstration about how to add ideas to the Issue pages under specific subheader-sections. In Activity 3, Mary dramatically increases here emphasis on Elaboration, where she helps students to think more comprehensively, deeply, or in different ways or perspectives. This is consistent with the principles underlying the final phase of KCI, where students must draw on the existing wealth of knowledge from their community as a resource for their culminating inquiry project. The demands of this inquiry project are typically heavy, as the outcome must provide evidence of students’ achievement of the targeted learning goals. Hence, it is not surprising that Mary demonstrated such a focus in her classroom interactions. Finally, both Mary and Steven heavily emphasize Guidance in their Activity 3 interactions, which may be a consequence of the need for concerted progress at the end of the school year, when all students and teachers in the school are pressed for time.
<table>
<thead>
<tr>
<th></th>
<th>Collaboration</th>
<th>Connection</th>
<th>Context</th>
<th>Elaboration</th>
<th>Evaluation</th>
<th>Guidance</th>
<th>Modeling</th>
<th>Reflection</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Jonathan</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity 1</td>
<td>0.00</td>
<td>0.00</td>
<td>6.97</td>
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<td>0.65</td>
<td>11.58</td>
<td>0.00</td>
<td>5.75</td>
</tr>
<tr>
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<td>3.82</td>
<td>1.96</td>
<td>7.13</td>
<td>0.76</td>
<td>0.00</td>
</tr>
<tr>
<td>Activity 3</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>Mary</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity 1</td>
<td>0.00</td>
<td>0.35</td>
<td>4.47</td>
<td>0.86</td>
<td>2.31</td>
<td>15.48</td>
<td>0.76</td>
<td>11.35</td>
</tr>
<tr>
<td>Activity 2</td>
<td>4.25</td>
<td>2.24</td>
<td>2.47</td>
<td>1.12</td>
<td>2.96</td>
<td>7.48</td>
<td>5.43</td>
<td>0.00</td>
</tr>
<tr>
<td>Activity 3</td>
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<td>1.78</td>
<td>6.13</td>
<td>8.49</td>
<td>2.24</td>
<td>20.64</td>
<td>0.70</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Steven</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity 1</td>
<td>0.00</td>
<td>0.00</td>
<td>5.17</td>
<td>0.00</td>
<td>1.33</td>
<td>9.63</td>
<td>1.60</td>
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<td>1.71</td>
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<td>4.20</td>
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<td>1.77</td>
<td>2.61</td>
<td>1.84</td>
<td>17.70</td>
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<td>0.00</td>
</tr>
</tbody>
</table>

* Data missing. Jonathan did not teach in activity 3.
Figure 4.18 Percentage of all class time spent on each type of pedagogical interaction, organized within activity.
Figure 4.19 Percentage of class time spent on each type of pedagogical interaction, organized within teacher

4.4.5 The correspondence between teachers’ knowledge and their interactions with students

I found it worthwhile to examine the relationship between measurements of teacher knowledge and the patterns of interaction presented in sections above. While the measures of teacher knowledge drawn from a single long interview could not be seen as definitive measures of what teachers knew in various categories, they did provide a basis for examining strengths and patterns amongst the three teachers. It was of interest to see if those knowledge differences corresponded systematically with any of the observed patterns of whole class and small group interactions. Therefore, I performed a series of bivariate correlation tests to identify any remarkable relationships between the percentages of class time that teachers spent on whole class and small group interactions (called interaction variables) and the teachers’ knowledge scores (called knowledge variables).

In these correlation tests, I used six knowledge variables as independent variables: community learning knowledge, content knowledge, technological knowledge, teacher’s role knowledge, knowledge of inquiry learning, and overall knowledge (the sum of the previous five categories). Interaction variables (e.g., percent of class time in SGI) were used as dependent variables. Twenty-four variables that were related to whole class and small group interactions were tested.

The teachers’ knowledge scores were converted into three categorical ranks, with “3” representing the highest knowledge score, “2” representing the second highest, and “1” representing the lowest knowledge score. For the reason that Jonathan and Steven got the same score on their understanding of inquiry learning, the three teachers’ scores on the knowledge of inquiry learning were converted into two ranks, with “2” representing a better knowledge score (i.e., Mary’s score), and “1” representing a lower knowledge score (i.e., Jonathan and Steven’s score). Kendall’s rank (or Kendall’s tau) test was used to examine the correlation between the 24 interaction variables and five knowledge variables (community learning knowledge, content knowledge, technological knowledge, teacher’s role knowledge, and overall knowledge), while a
A biserial test was used to detect the correlation between the 24 interaction variables and the inquiry learning knowledge variable (Field, 2009).

As shown in section 4.2 (Figure 4.1), the three teachers were ranked in the same order on three knowledge variables: overall knowledge, content knowledge, and knowledge of teacher’s role. For all three variables, Mary was ranked as the highest (represented with “3”), Jonathan was ranked as the second highest (represented with “2”), and Steven was ranked as the lowest (represented with “1”). Table 4.17 shows the results of Kendall’s rank on these three knowledge variables and relevant interaction variables in column 2. It shows that these three knowledge variables were positively correlated (p<0.05) with the percentage of class time that the teachers spent on small group logistical interaction (SGI_L) and small group guidance interaction (SGI_Guidance) and negatively correlated with small group conceptual interaction (SGI_C) and small group off-topic interaction (SGI_O). These findings indicate that the better a teacher’s knowledge was in those 3 categories, the more class time a teacher spent on logistical and guidance SGI, and the less time spent on off-topic and conceptual SGI.

As indicated in Figure 4.1, in terms of the three teachers’ knowledge of community learning, Jonathan was ranked as the highest (represented with “3”), Mary was ranked as the second highest (represented with “2”), and Steven was ranked as the lowest (represented with “1”). Column 3 in Table 4.17 shows the results of Kendall’s rank test on community learning knowledge variable and relevant interaction variables. The results indicate that the rank of the teachers’ knowledge of community learning has statistically significant correlation (p<0.05) with whole class logistical interaction (WCI_L), small group context interaction (SGI_Context), and whole class connection interaction (WCI_Connection). The relationship between the rank of teachers’ knowledge of community learning and SGI_Context is positive, while the relationships between the rank of teachers’ knowledge of community learning and WCI_L and WCI_Connection are negative. This finding suggests that the better a teacher’s knowledge of community learning, the more class time a teacher spent on small group context interaction, and the less a teacher spent on whole class logistical interaction and whole class connection interaction.

According to their level of technology knowledge (see Figure 4.1 in section 4.2), Mary was ranked as the highest (represented with “3”), Steven was ranked as the second highest (represented with “2”), and Jonathan was ranked as the lowest (represented with “1”). Column 4
of Table 4.17 shows the results of Kendall’s rank on technology knowledge variable and relevant interaction variables. There was a positive correlation (p<0.05) between knowledge of technology and two variables: whole class logistical interactions (WCI_L), and whole class connection interactions (WCI_Connection). There was a negative correlation (p<0.05) between knowledge of technology and small group off-topic interaction (SGI_O). These findings suggest that the better a teacher’s knowledge of technology, the more likely a teacher will be to have Logistical and Connection WCI, and the less likely to have off topic SGI.

According to the knowledge scores the three teachers got on the knowledge of inquiry (see Figure 4.1 in section 4.2), Mary’s scores were highest and thus her knowledge rank was represented with “2”, while Jonathan and Steven were ranked as lower and thus their knowledge rank was represented with “1”. Column 5 of Table 4.17 shows the results of biserial test on inquiry learning variable and relevant interaction variables. There was a positive correlation (p<0.05) between teachers’ inquiry learning knowledge and three variables: small group logistical interaction (SGI_L), small group pedagogical interaction (SGI_P), and small group guidance interaction (SGI_Guidance). There was a negative correlation (p<0.05) between teachers’ inquiry knowledge and off-topic SGI (SGI_O). These findings indicate that the more knowledgeable a teacher is about inquiry methods, the more likely she would be to have small group logistical, pedagogical and guidance interactions and the less likely she would be to have small group off-topic interactions.

Table 4.17

<table>
<thead>
<tr>
<th>Types of Interactions</th>
<th>Overall Knowledge, Content Knowledge, Teacher’s Role Knowledge</th>
<th>Community Learning Knowledge</th>
<th>Technology Knowledge</th>
<th>Inquiry Learning Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>SGI_L</td>
<td>Coefficient 0.27, Sig &lt;0.05</td>
<td></td>
<td></td>
<td>0.53, Sig &lt;0.05</td>
</tr>
<tr>
<td>SGI_C</td>
<td>Coefficient -0.34, Sig &lt;0.05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGI_P</td>
<td>Coefficient</td>
<td>Sig</td>
<td>0.42</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td>--------</td>
<td>------</td>
<td>-------</td>
</tr>
<tr>
<td>SGI_O</td>
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<td>-0.53</td>
<td>-0.69</td>
</tr>
<tr>
<td></td>
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<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>WCI_L</td>
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<td>0.30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sig</td>
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<td>&lt;0.05</td>
<td></td>
</tr>
<tr>
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<td>Coefficient</td>
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<td></td>
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</tr>
<tr>
<td>SGI_Guidacne</td>
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<td></td>
<td>Sig</td>
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</tr>
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<td>Sig</td>
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<td>&lt;0.05</td>
<td></td>
</tr>
</tbody>
</table>

### 4.4.6 Summary

This section described the three teachers’ enactment of the designed KCI curriculum by portraying the teacher-students interaction patterns in great detail. This section revealed that the three teachers indeed differed in terms of the average time duration they spent each time they interacted with students, the average percentages of class time they spent on different types of interactions, and the average percentages of class time they spent on different types of interactions in each of the three major KCI phases. Thus, the interaction analysis helped to capture the features of a model KCI teacher’s interaction patterns with students (Mary), and how those patterns differed from the two teachers (Steven and Jonathan) who were new to this form of instruction. In addition, the bivariate correlation analyses presented in this section illustrate the relationship between teachers’ knowledge and their interaction patterns with students. The next chapter offers some discussion of these results.
Chapter 5
Conclusion and Discussion

I begin this chapter by addressing the research questions in terms of the findings from chapter 4. I then extend the discussion to offer a theoretical position concerning the roles and best practice of the teacher within a KCI curriculum. Next, I connect the outcomes of this research to the wider learning sciences literature. Finally, after examining the limitations of the study, I present possible directions for future research.

5.1 Addressing the Research Questions

When we designed the global climate change curriculum unit, we did not explicate the teacher’s role in part because we did not have a clear theoretical account within the KCI model. This was one primary goal of this study: to examine three teachers as they enacted a KCI curriculum, capture what forms of interaction occurred on any given day, and look for patterns across the various phases. As Mary was the teacher who co-designed the curriculum with the researchers, including two prior KCI collaborations, she had a much better understanding of the pedagogical model than the other two teachers. Hence, special attention was given to the analysis of Mary’s enactment (i.e., in chapter 4), in which she did show some distinct roles and patterns that could be interpreted as being characteristic of the KCI pedagogical model. Thus, the discussion here will focus primarily on Mary in an effort to address the research questions.

5.1.1 What is the teacher’s role in a KCI curriculum?

I examined teacher’s role in a KCI curriculum from two perspectives: (a) the roles that were designed, implicitly or explicitly, into the curriculum; and (b) the roles that teachers actually enacted when the curriculum was implemented. In the following two paragraphs I first present the roles identified from the curriculum design documents. Next, I present the roles identified from the video recordings of the three teachers’ classroom teaching.

Using the constant comparison technique to examine the data, I analysed the design documents and identified nine roles that the researchers explicitly and implicitly designed for
teachers in the climate change KCI curriculum: (a) content teaching, (b) co-ordinating, (c) establishing KCI epistemology, (d) evaluating students, (e) guiding learning activities, (f) organizing learning activity, (g) making connections, (h) setting learning context, and (i) providing technical support. Among these roles, establishing KCI epistemology was specifically considered as a KCI role. A new meaning that was specific to KCI model was added to the role of making connections: teachers encourage and help students apply the content in their community knowledge base as a resource in their scaffolded inquiry activity (i.e., editing remediation pages).

In general, the three teachers were successful in enacting the curriculum (i.e., according to what was designed). There were no substantive departures in their enactment of the curriculum, in terms of whether the designed learning activities occurred and whether the defined teacher’s role (to any extent those were available) were performed. In all the classes I analysed, teachers were seen to engage in whole class lecturing and orchestrating discussions. They also typically engaged in small group interactions, such as guiding students in various learning activities, evaluating students’ learning, helping students understand the context of the curriculum unit, and directing students to connect what they learned to their real life. In addition to the nine roles identified in the designed curriculum, they also performed the following roles: (a) elaboration, (b) reflection, (c) collaboration, (d) modelling, (e) monitoring, and (f) classroom management. Among the roles that the three teachers’ enacted, (a) guiding students’ learning activity, (b) setting the learning context, (c) asking students to reflect on their learning, and (d) requesting students to elaborate their thinking and ideas are the most performed roles, measured according to the percentage of class time the teachers spend on each type of role. The specifically designed KCI roles, establishing KCI epistemology and requesting students to re-use the contents of the knowledge base during the remediation activity, were also performed by all three teachers.

5.1.2 What are the patterns of teacher-student interaction?

I examined teacher-student interaction patterns from various perspectives. The interaction patterns identified were very complicated. I am going to summarize some important patterns here from four aspects: (a) the percentage of class time the teachers spent on different types of
interaction, (b) the percentage of class time the teachers spent on small group interaction, (c) the percentage of class time the teacher spent in each phase of the KCI activities, and (d) the percentage of class time the teachers spent on pedagogical interactions (i.e., combination of small group pedagogical interaction and whole class pedagogical interaction) in each phase of the KCI activities.

The percentage of class time the teachers spent on different kinds of interaction. Teachers commonly engaged in whole class lectures and orchestration of discussions. Overall, they gave as much or more attention to whole class interactions (approximately 30-35% of total class time) than they did to small group interactions (approximately 25-30%) as shown in Figure 4.7. I examined these in terms of their emphasis, with Figure 4.8 showing the relative percentages of class time given to whole class discussions of conceptual, pedagogical and logistical nature. In general, logistical and pedagogical interactions were the most common, each accounting for approximately 15% of overall class time. It was interesting to examine pedagogical interactions more closely, to look for the roles determined in the enactment coding (Section 4.3). Figure 4.10 shows that the large majority of whole class interactions are given to guidance (i.e., where the teacher is helping students to understand and make sense of the activities) and context (i.e., where the teacher helps students understand the broader context and purpose of the activity). The next most prominent whole class interactions were reflection (i.e., where the teacher asks students to comment on their understandings or learning process) and modelling, where the teacher demonstrates or models some aspect of the activity.

The percentage of class time the teachers spent on small group interaction. Teachers spent nearly as much time in small group interactions as they did in whole class exchanges: guiding students in the learning activities, evaluating their progress, helping them understand the context, and helping them to make connections between what they learned in the classroom to their real life. In addition to the nine roles that were identified in the designed curriculum, they also performed the following roles: elaboration, reflection, collaboration, modelling, monitoring, and classroom management. Figure 4.9 shows that teachers, particularly Mary, again spent most time in the pedagogical and logistical interactions, although Jonathon and Steven demonstrate substantially more off-topic interactions than Mary. Figure 4.11 presents a more fine-grained distribution of the small group interactions, with guidance once again featuring as the most
prominent form, especially for Mary, who more than doubled the others’ percentage of class time in guidance interactions. Elaboration and Evaluation were the next two most common forms of small group interactions, with Mary again leading the other two teachers in each of these categories.

The percentage of class time the teacher spent in each phase of the KCI activities. Across the three phases of the curriculum unit, the teachers varied in terms of the percentage of class time they spent on small group interaction (SGI), whole class interaction (WCI), and no-interaction (None). Interestingly, Mary decreased the time given to WCI from learning activity 1 to learning activity 3, while the percentage of class time she spent on SGI increased from learning activity 1 to learning activity 3. In terms of the percentage of class time that the three teachers spent on different types of whole class interaction, Mary and Jonathan showed a pattern of spending more percentage of class time on whole class logistical (WCI_Logistical) and whole class pedagogical (WCI_Pedagogical) interactions in learning activity 1 than in learning activity 2 and learning activity 3, while Steven did not show this pattern. In addition, Mary spent significantly more percentage of time on whole class conceptual (WCI_Conceptual) interactions in learning activity 2 than in other two learning activities, while the other two teachers did not show this pattern.

In small group interactions, Mary showed a trend of increasing the percentage of class time spent on small group pedagogical (SGI_Pedagogical) interaction from learning activity 1 to learning activity 3, which is perhaps the most visually striking feature of Figure 4.15. Presumably, this is because of increased demands that she felt for such exchanges as the curriculum progressed into the later phases, particularly in the final Remediations phase, where she gives nearly 40% of class time to SGI, most of which emphasized pedagogical content. Figure 4.15 also shows a trend of decreasing the percentage of class time on small group logistical interaction (SGI_Logistical) interactions from learning activity 1 to learning activity 3, in contrast with the other two teachers.

The percentage of class time the teachers spent on pedagogical interactions in each phase of KCI activity. To examine the more nuanced emphases of pedagogical content, it was necessary to combine SGI_Pedagogical and WCI_Pedagogical codes (i.e., because of small numbers of cases). As shown in Figure 4.15 and 4.17, Mary spent a greater percentage of class
time on conceptual (Conceptual) interaction during learning activity 2 than during the other two learning activities. The other two teachers did not show similar patterns. Mary also spent more percentage of class time on guiding interaction (Guidance) than other types of interactions in all three learning activities. Jonathan showed a similar trend during the two learning activities he taught, although Steven did not show this pattern. Another general pattern is that teachers tended to increase their emphasis on Connections in Activities 2 and 3, consistent with the analysis of the designed role presented in section 4.1.

5.1.3 How does a teacher’s knowledge influence his or her interaction with students?

Bivariate correlation analyses (Kendall’s rank) indicated that teachers’ background knowledge had some influence over the types and relative amounts of the various forms of interactions within the coded class periods. In general, the better a teacher’s overall background knowledge, content knowledge, or knowledge about teacher’s role, the more class time s/he spent on small group logistical interaction and small group guidance interaction, and the less time spent on no interaction small group conceptual interaction and small group off-topic interaction. A similar pattern is seen with regard to teachers’ knowledge of inquiry approaches to learning, with an increased amount of class time spent on small group logistical and pedagogical interaction, and on guidance, and less class time given to off-topic interactions. The technology knowledge affected interactions in that a more knowledgeable teacher tended to spend more class time on whole class logistical interactions and whole class connection interactions, but less time spent on small group off-topic interactions. The knowledge of community learning contributed to more class time spent on small group context interaction, but less percentage of class time spent on whole class logistical interaction and whole class connection interaction.

Thus, teachers who are more knowledgeable about relevant topics of inquiry, science content, technology and teaching were better able to use their class time wisely. They give more attention to logistical issues students have in their learning process; they guide students’ learning by helping them to understand and make sense of learning activities, especially when students are working in small group.
5.2 Implication and Discussion

This study provided a detailed description of teacher-students interactions, with several implications. First, based on the analysis of the three teachers’ interaction patterns, with particular attention given to Mary, I propose the following specific guidelines that can be implicated in the practices of KCI teachers:

- An effective KCI teacher switches his/her interactions with student frequently. S/he may want to spend more time on each whole class interaction than on each small group interaction.
- An effective KCI teacher spends more time on each pedagogical or conceptual interaction than on each logistical interaction.
- An effective KCI teacher often interacts with students in small groups and lets most of the class work on their own. Students need a lot of time working on their own, mostly in small groups, with no interruptions from the teacher. However, this does not mean that the teacher should not stand in the classroom, watch students, or sit at her/his desk marking homework assignments. Interactions more often with students in small groups will give students more time to work on their own and will enable the teacher to accommodate different needs of student.
- An effective KCI teacher balances the time s/he spends on different kinds of interaction with students. For example, a teacher may spend approximately one-third of available class time on pedagogical interaction, one-third on logistical interaction, and only small percentage of the remaining third on conceptual interaction.
- An effective KCI teacher varies the amount of available class time spent on small group interactions and whole class interactions, depending on the nature of the activity within KCI. For example, a teacher may increase the time spend on small group interaction from the activity of setting learning context and brainstorming to the activity of collaborative knowledge construction, and to the activity of scaffolded inquiry, while decreasing the amount of class time s/he spends on whole class interactions – from setting learning context and brainstorming to collaborative knowledge construction, and scaffolded inquiry.
• An effective KCI teacher varies the amount of available class time spent on different kinds of interaction, depending on the nature of the activity within KCI. For example, a teacher may spend most of the class time on pedagogical interactions during the scaffolded inquiry activity, and least time on pedagogical interaction during the collaborative knowledge construction activity. S/he may decrease the amount of available class time spend on logistical interactions from the setting context and brainstorming activity, to the collaborative knowledge construction activity, and to the scaffolded inquiry activity.

• Overall, an effective KCI teacher spends more time guiding students’ learning activities and setting the context when teaching with this particular model.

Second, the detailed description of the teacher’s role in KCI, and teacher-student interaction patterns, can inform teacher education program as well as teacher professional development. Research about effective professional development found that programs that only provided general approaches to teaching with nor clear explanation of the detail of an instructional model were less effective (Grigg, Kelly, Gamoran, Borman, 2013; Wilson, 2013). Providing teachers with “explicit instruction in the models of teaching” (Penuel, Gallagher, & Moorthy, 2011, p. 996) and letting teachers witness the model of teaching (Supovitz, & Turner, 2000) in professional development programs can lead to students’ improvement in science learning. However, without detailed description of teacher’s role and the teacher-student interaction patterns in a model of teaching, implementing such professional development programs with above-mentioned features will be difficult. Studying the details of teacher’s role and teacher-student interaction will help in design effective professional development programs.

Third, the detailed description of teacher-student interaction patterns can be used to evaluate the fidelity of teacher’s enactment of any innovative pedagogy. In my study, I examined the lesson sequence and the learning activities the three teachers enacted to see if their enactment was “true” to our original design intent (see Section 4.3.4). However, this method has been approved as superficial. Merely examining whether a teacher has completed designed learning activities as specified in designed curriculum is not a good indicator of whether the teacher’s enactment is fidelity. Teachers need to substantially change their pedagogy in order to incorporate innovative curriculum, rather than just using their existing knowledge and experience
to map their prior practice onto the new instructional model. Researchers have emphasised the important of measuring intervention fidelity at school level (Kisa & Correnti, 201x). So, how to measure the fidelity of individual teacher’s enactment and whether a teacher has changed his/her pedagogical practice substantially? Comparing a teacher’s practical interaction patterns with the desired interaction patterns of a pedagogical model can be a reliable method to judging whether a teacher’s pedagogical change is substantial and assess the fidelity of a teacher’s enactment. Similarly, this method can also be used as a tool to evaluate the effectiveness of a professional development program. An effective professional development program should be able change a teacher’s interaction patterns with students.

Two final observations emerged from this research. First, I noted that all teachers were able to support the KCI curriculum, despite the large differences in their respective backgrounds and level of preparedness. Mary had three years’ prior experience in collaborating on KCI, and had been a member of the design team. Jonathon was a supply teacher who had never heard of KCI before, with no prior experience in teaching the topic of climate change. Steven was somewhat experienced as a teacher, but mainly in senior level physics, and had no experience with such collaborative methods nor with climate change topics. Yet the enactment analysis revealed no major differences in how they achieved this substantive nine-week curriculum. All three teachers managed to complete all of the major learning activities. All students in the five sections did comparably well on their assessments. In fact, ANOVA tests on student achievements, including final course exams and evaluation of the quality of Remediation Pages, show no statistically significant differences among the five class sessions (See Appendix D for detail of related tests). Thus, I concluded that the clear definitions of all course materials, the specification of activities, and the scaffolding provided by the technology environments was sufficient to support the wide diversity of teachers apparent in the investigation of these three individuals’ enactments of the curriculum. An implication is that any innovative pedagogical model needs to clearly define the course materials, the specification of activities (including student grouping approaches), and the scaffolding provided by the technology environments.

Another observation was concerned with the level of challenge that KCI presents to teachers. Even Mary, a model KCI teacher (to the extent that such can be defined), was challenged in holding deep interactions with students (e.g., elaboration, collaboration,
connection, reflection, etc.). When framing this research in terms of teacher-student interaction patterns, I really expected Mary to be quite distinct from the other two. And while I did find some interesting patterns of differences, the three teachers’ interaction patterns were more similar than they were different. While this is encouraging testimony to the scaffolding provided by our KCI designs, it also leads to wonder why Mary was not strikingly different from the other two, given the fact that her content knowledge, her knowledge about the teacher’s role and inquiry learning, and her overall knowledge were better than the other teachers and that she had more experiences using technology in teaching and working with KCI model. One possible reason is that we were not clear in the KCI curriculum documents about our expectations regarding what the teacher would do in the classroom nor how the teacher would need to interact with students. Without explicit communications, teachers were left to decide for themselves how to interact. A likely consequence was that all three teachers just mapped their prior practice onto the new curricular approach. Thus, while our KCI design seemed to have reinforced or scaffolded the targeted pedagogical structure, the design did nothing to support teacher-student interactions. So even a knowledgeable, experienced teacher has difficulty managing the complex interaction forms of elaboration, collaboration, and connections.

I am interested in considering what kinds of scaffolding could prompt teachers for deeper interaction with their students and support those interactions while they occur. Perhaps some technology component could be of assistance, like a tablet or wristwatch, to provide notifications of which students may need a visit, or to prompt the teacher with reminders about interaction goals. Moving forward in KCI research, the findings from this study will add a level of detail to the model, and could lead researchers to investigate different methods for supporting teachers in their enactments of the KCI approach.

5.3 Contributions of This Study

This study can contribute to the research literature in several ways. First, it can offer a formal description of teacher’s role in KCI pedagogical model. Second, it can contribute to the literature concerning different kinds of teachers’ knowledge and interactions in the classroom. And finally, it can contribute a method of teacher-student interaction analysis as well as a method of measuring teachers’ background knowledge.
5.3.1 Contributions to the formal description of teacher’s role in KCI

This study has provided a formal description of teacher’s role in a KCI curriculum at two levels. First, at a relatively coarse level, I described the types of roles that teachers played in a KCI curriculum. Most types of the teacher’s role that described in my study are similar to the roles found in other studies (e.g., Crawford, 2000; Cooper, 2002; Lakkala et al., 2005; Krajcik & Blumenfeld, 2006; Hmelo-Silver & Barrows, 2006, 2008; Staples, 2007; Johnson & Johnson, 2008; N. M. Webb et al., 2008). However, two roles are specific to the KCI pedagogical model, but perhaps not in other pedagogical models. One is establishing the KCI epistemology, which refers to the role of helping students achieve a social orientation and understanding that they will need to work with their peers collaboratively as a learning community to advance their understanding of science content collectively. The other one is that teachers should request and help students to use content from the community knowledge base as a resource in their scaffolded inquiry learning activities. For example, in the present case, teachers asked students to search through the remediation tags in the references they had created, to check issue pages they did not work, to review at least two issue pages, and to skim the remediation section of all issue pages when they work on climate change remediations.

Second, at a relatively fine-grain level, my study described teacher’s role by detailing teacher-student interaction pattern happened in a KCI curriculum, including whole class and small group interactions of various kinds, and a summary of the pedagogical nature of those interactions. My study has thus added more detail to the model about how teachers should interact with student (Slotta & Najafi, 2013; Slotta, 2013), and how those interactions might change over the course of the curriculum. Based on the analysis of the three teachers’ interaction pattern, with particular attention given to Mary, I articulated specific guidelines for KCI teachers in Section 5.2.

5.3.2 Contributions to learning sciences literatures

One contribution made by this study to the learning sciences literatures is that it adds a detailed description of classroom interactions and a coding of a fairly large video sample for different kinds of interactions within the particular KCI learning environment. In previous studies of the knowledge community approach to learning and instruction, the description of
classroom interactions has been relatively coarse, with no studies that reported the details of teacher-student interaction in terms of the roles or functions of the interactions in helping student learn. This study described classroom interactions at two different grain sizes with corresponding analysis schemes of interactions. At the first, coarse grain size, this study described classroom interactions using two schemes. One scheme described whether an interaction was whole class interactions, small group interaction, or no interaction. The other scheme described whether an interaction was pedagogical interaction, logistical interaction, conceptual interaction, or off-topic interaction. A second, finer grain analysis used a scheme that distinguished the pedagogical interactions in terms of their focus: to help students collaborate; to make connections; to set the learning context; to request that students elaborate ideas; to evaluate or monitor students’ learning; to guide learning activities; to model desired learning behaviour; or to help students reflect.

A second contribution is that it adds a description about the relationship between the teacher’s background knowledge and their patterns of interaction with students during KCI instruction. Previous research has confirmed that teachers’ background knowledge does impact their teaching practices, in terms of making instructional decisions, implementing reform-based curriculum, selection of instructional strategies, and others (Tobin & McRobbie, 1996; Bryan & Abell, 1999; Keys & Bryan, 2001; Roehrig & Kruse, 2005). However, little research has investigated how teachers’ background knowledge affects their interactions with students, in detail. This study examined teachers with diverse background knowledge, including disciplinary knowledge and experience in pedagogy and technology, and described how they vary in how they interact with students. For example, if a teacher has better content knowledge or knowledge about teacher’s role, he or she may spend more percentage of class time on logistical interaction, pedagogical interaction, or guidance interaction with students working in small groups, and spend less percentage of class time on off-topic interaction, or conceptual interaction with students working in small groups. This study thus has important implications for training novice teachers to create KCI learning environments or even other theoretically informed learning environment (Hmelo-Silver & Barrows, 2008).
5.3.3 Contributions to data analysis methods

Another contribution of this work is the video content analysis method that can be used to describe teacher-student interaction patterns in terms of the roles or function of interaction. This begins by segmenting long classroom videos into short video clips, with segments determined by logical or observable boundaries in the nature of teacher-student interactions. Then, each video clip is coded according to a two-level scheme that codified the different kinds of interaction at two different grain size levels (see Table 3.3 and Table 3.4). Segmenting and coding videos at such a fine grain size is difficult. To facilitate the process of segmenting and coding, I developed a set of coding rules that users of this coding scheme can follow to make decisions on how to segment video clips and code the video segments (see section 3.5.4 in chapter 3). This segmenting and coding process will capture the content of videos and thus enable further quantitative analysis with statistics or graphic techniques, which will make the description of teacher-student more accessible to empirical research.

The teacher-student interaction analysis method, or a modification of this method (i.e., using different coding scheme) could be applied in studies that need to: 1) identify the features of a pedagogical model, 2) identify the patterns of teacher’s performance or behaviour in a pedagogical model, 3) describe the teacher-students interaction pattern, 4) measure whether a teacher is enacting a certain form of interactions, such as a student-centered approach, and 5) compare the differences of teachers’ performance patterns across different pedagogical models, schools or cultures.

My study also contributes a method of applying Epistemic Network Analysis (ENA) in measuring the connectedness or comprehensiveness of teachers’ knowledge. ENA is a method, developed from Epistemic Frame Theory, for finding and quantifying patterns of connection among discourse elements (Orrill & Shaffer, 2012). Based on the idea of ENA, I developed a method of measuring patterns in teacher’s knowledge. Measuring teachers’ technological pedagogical content knowledge (TPCK) is an interesting and very difficult topic in the teacher knowledge literatures. Current research uses self-assessment surveys or observations of demonstrated performance as means of measuring teacher’s knowledge (Voogt et al., 2013). I
have shown how TPCK can be represented as the connectedness among three domains content knowledge, pedagogical knowledge, and technological knowledge.

This method uses teacher interview as a means of data collection. The instrument of this method is an interview protocol that includes 11 questions about teacher’s experiences and understanding of inquiry learning, community learning, the role of teacher in general, the role of technology, and the climate change content (see Appendix A). Content analysis methods can then be used to segment the interviews or their transcripts into their smallest meaningful pieces. Each segment is then coded and assigned a numerical value using a coding scheme (see Table 3.1) that measures the levels of teacher’s understanding of the above five aspects of knowledge. Some segments may be given more than one code and be assigned more than one value. The coding results are be prepared as a spreadsheet following the required format of ENA, which is then uploaded to the ENA server to create a data set using the teacher as the analysis units, the interview questions as the stanzas, and the knowledge level scores on the five measuring elements (content, inquiry, community, teacher role, and technology) as weighted codes. With these settings, one can plot a knowledge map for each teacher that illustrates whether different domains of knowledge are connected, what are the strengths of those connections. Therefore, using a teacher’s knowledge map, one can identify the strength and weakness of a teacher’s knowledge and develop targeted professional development programs. This method can be applied not only to the measurement of TPCK, but also the measurement of PCK and other specific forms of knowledge, with proper adjustment of the interview questions.

5.4 Limitations of this study

One limitation of this study is that not all available video data were analysed. I only analysed the video from representative lessons. This selectivity of data has the risk of producing incomplete or flawed results, no matter how carefully the data were selected. If all available video data were analysed, the resulting patterns could potentially have been different, and certainly could have allowed more power to the statistics. I also would not have had to combine WCI and SGI data in order to look at the pedagogical interactions between the three activity phases, because there would have been more coded observations. The reason that I was unable to analyse all video data was simply that the coding took too much time. It took more than 10 hours
to analyse one hour of video. Furthermore, the time needed to analyse video also depended on the grain size of the analysis. The smaller the grain size of analysis, the longer the time was needed. Thus, I was able to code the entire video corpus at the coarse grain size, but only a portion of it (roughly 40%) for the fine-grain coding.

Another limitation of this study is concerned with the coding reliability in the analysis of videos of teacher-student interactions. Inter-coder agreement was applied in the analysis of teacher interview transcripts and teacher-student interaction video in this study. However, it was not applied to all video data being analysed. The inter-coder agreement method was applied only to those video segments in which I was not confident on which code to use. In such cases, my supervisor and I reviewed them together and decided which code to use. The reason for this compromise was that it was not practical to analyse all video data with my advisor or another graduate student together because of the large amount of data available, nor to get a random sampling and have a second rater code them, because of the substantial context required for this coding effort. Thus, we decided upon an approach where the second coder (my supervisor) was deeply involved on a regular basis (weekly, over a period of one year), in specific challenging coding decisions. The result is a coding where two researchers are confident in the outcomes, but nevertheless this lacks the methodological stringency of inter-rater reliability, and remains a limitation.

One other limitation of my study is that we do not really know what an “ideal KCI” curriculum is. Hence, we cannot really know what the best teacher’s behaviour or interaction patterns should be. Therefore, it is still not clear whether the implementation of our designed curriculum was done at the optimum level by teachers (i.e., in terms of the KCI model). Even though teachers followed the curriculum design very closely, and their enactment was “true” to the design, and there was reuse of contents of the knowledge base, and assessable learning outcomes – all required features of KCI – the idea of knowledge community was clearly not always in the students’ and the teachers’ minds. It seemed to me as an observer that the issue page editing and the remediation activities were treated as complementary learning activities by the students. In short, there was limited evidence that teachers and students considered themselves as members of a knowledge community (Scardamalia & Bereiter, 2006). KCI is a theoretical idea, which has its realities when it is put into action – particularly in the demanding
context of secondary science. There was a gap between the perfect enactment of KCI model and what the teachers did enact, and we are somewhat in the dark because we still do not have a perfect description of the ideal. It does seem evident that teacher knowledge of the KCI model and the difficulty of deep change in teacher’s teaching practice are primary factors that influence the realities of classroom enactment.

5.5 Future research directions

The Knowledge Community and Inquiry (KCI) model is a theoretical model under development. It is uncertain how one can judge if the pedagogical approach a teacher employed is the best practice of KCI model. Given the uncertainty of a KCI “standard,” one future research agenda could focus on establishing a standard for best classroom practices under KCI. This standard could include a rubric to help measure the levels of achievement on all aspects of KCI principles, including teacher enactment patterns and the advancement of community knowledge. For example, rubrics to assess the degree to which students work collectively as a knowledge community or how extensively the knowledge base has been re-used.

Making students re-use the knowledge base is one specific feature of the KCI model. Encouraging and supporting students to do this is also a very important role that teacher needs to play in KCI model. It would be valuable to study how can we help make the KCI knowledge base be more consequential or central to the class activities (e.g. increasing the amount of class time spent on asking students to re-use the content of knowledge base), so that students and teachers might come to see it as “important.” This intervention could also affect the quality and quantity of students’ final inquiry products (e.g., the climate change remediation pages).

An aim of learning sciences research is to develop a detailed cognitive model of effective student learning within the learning context being studied (Carver, 2006). Previous research about students learning with the KCI model has shown evidence of students’ improvement in learning (Najafi, 2011; Peters, 2010). It is therefore reasonable to conduct research to gain a better understanding of how different teacher-student interaction patterns may affect students’ outcome or cognitive changes in the KCI learning environment.
During the implementation, one issue that the research team encountered was that the teachers found it difficult to evaluate individual students’ contributions to the community knowledge base. Wiki software environments have the ability to record editing revisions and to compare selected revisions using coloured text marking the changes. However, this still requires teachers to read all revisions a student made to judge the function or quality of the changes: whether a change was just a correction of grammar or spelling, or a change was substantial structural adjustment to the content, or a change was adding new perspectives of thinking. Thus, future research could explore how technology can help teachers evaluate student contributions, either individually or as a collective, within a knowledge community and inquiry method. Further, it would be valuable to study how technology can provide teachers with diagnostic information about students’ learning, identifying significant progress or difficulties they have encountered, in a timely fashion and in a meaningful format, to assist with and augment dynamic decision-making in classrooms.

During the process of interaction analysis, I found that even the model teacher could have improved her interaction with students. The reason a gap between the perfect enactment and her enactment exists was perhaps that her pedagogical knowledge (PK) or pedagogical content knowledge (PCK) of KCI model was insufficient. However, it is not easy for teachers to develop the necessary PK or PCK, particularly when the model remains ill-defined, as discussed above. The research literature has suggests that an effective way to develop PK or PCK is through teacher’s reflection. Therefore, it could be an important element of future KCI research to help teachers become reflective during their enactment of KCI curriculum, to be aware of the theoretical ideas and to engage in helping students shift their epistemic perspectives. A research question aligned to this idea is how the KCI model could become more supportive of teacher action research or evidence-based reflection and practice or a lesson study PD model.

Finally, as stated in Chapter 3, I used correlational statistics in this study in order to explore and understand the feature of teacher’s role in KCI model. At some point, research studies would be necessary to confirm (or disconfirm) the relationships between teacher’s knowledge and their interaction patterns. In that regard, the statistics used in this study were to support the exploratory nature of my purpose. My claims on the basis of the statistics I employed were valid with respect to only the three teachers in the study. It would be important to find a
way to expand the statistical power in a parametric study. This research could also further explore new relationships between teachers’ knowledge and their interaction patterns, including the content of discourse, not just categories of interaction patterns.


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presented at the Annual Conference of the American Educational Research Association, Seattle, WA.


Appendix A: Teacher Interview Questions

A. How would you define "Inquiry learning"?

B. Have you ever taught with inquiry methods? What is one example?

C. How do you think we can use technology in our teaching to help students learn more deeply than they would through lecture?

D. Why is it beneficial for students to collaborate with their peers?

E. Web 2.0 is a term that generally refers to socially oriented software, like wikis, social networking, blogs, etc. How do you think Web 2.0 technologies might be integrated effectively into science curriculum?

F. How would you describe the curriculum model that we will be using in global climate change?

G. What will your role be, during the curriculum?

H. What will you be doing, specifically, while kids are working in small groups on their computers?

I. What are some of the challenging concepts in climate change science that you think any curriculum unit in these topics should help students understand?

J. What are your greatest concerns about implementing this curriculum successfully?

K. What are some questions you still have about this curriculum that the team should try to help with?
Appendix B: Curriculum Design Analysis Coding Results

<table>
<thead>
<tr>
<th>Name</th>
<th>References</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content teaching</td>
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<td>0</td>
</tr>
<tr>
<td>Demonstrate Albedo effect</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Didactic lecture on atmosphere layers</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Didactic lecture on solar radiation and greenhouse effect</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Discuss with students about the impact of human on GHG</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Teach content - Atmospheric circulation of Thermal Energy</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Teach content - Carbon Sinks and Sources</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Teach content - Climate Change Legislation</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Teach content - Climate Change Models</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Teach content - Energy Saving and GHG impacts</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Teach content - Extreme Weather Patterns</td>
<td>2</td>
<td>2</td>
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<td>Teach content - Greenhouse Effect</td>
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<td>4</td>
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<tr>
<td>Teach content - Paleoclimatology</td>
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<td>3</td>
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<td>Teach content - the Earth’s Atmosphere</td>
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<td>1</td>
</tr>
<tr>
<td>Teach content - Thermal Energy and Oceanic Circulation</td>
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<td>2</td>
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<tr>
<td>Teach content on the little ice age</td>
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<td>1</td>
</tr>
<tr>
<td>Teaching content on the Timeline Clothesline</td>
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<td>1</td>
</tr>
<tr>
<td>Co-ordination</td>
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<td>0</td>
</tr>
<tr>
<td>Ask students to add model info to issue pages</td>
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<td>1</td>
</tr>
<tr>
<td>Ask students to use to-do list to coordinate their group work</td>
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<td>3</td>
</tr>
<tr>
<td>Assign students into remediation group carefully</td>
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<td>1</td>
</tr>
<tr>
<td>Check to see if remediations are directly related to issues</td>
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<td>1</td>
</tr>
<tr>
<td>Co-ordinate the selection of issue</td>
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<tr>
<td>Grouping students</td>
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<tr>
<td>Assign students into brainstorm group</td>
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<td>2</td>
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<tr>
<td>Assign students into issue groups</td>
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<tr>
<td>Group students into remediation groups</td>
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<td>2</td>
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<tr>
<td>Keep record of students’ selection of issue</td>
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<td>1</td>
</tr>
<tr>
<td>Re-group students to share mini lab data</td>
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<td>1</td>
</tr>
<tr>
<td>Establishing epistemology</td>
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<td>0</td>
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<tr>
<td>Ask students to reflect on collaboration</td>
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<tr>
<td>Librarian teaches students how to analyze resource</td>
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<td>2</td>
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<tr>
<td>Researcher talk about collaboration and community learning</td>
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<tr>
<td>Teacher talk to students about collaboration</td>
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<tr>
<td>Evaluation or assessment</td>
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<td>Arrange post-test as a short quiz in the class on Thursday and Friday</td>
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</tr>
<tr>
<td>Ask students to study for test</td>
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</tr>
<tr>
<td>Explain issue group work asessment rubric</td>
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<td>2</td>
</tr>
<tr>
<td>Give students the pre-test</td>
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<td>3</td>
</tr>
<tr>
<td>Name</td>
<td>References</td>
<td>Sources</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>------------</td>
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</tr>
<tr>
<td>Go through booklet and marking scheme</td>
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<td>1</td>
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<tr>
<td>Modify assessment plan</td>
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<td>1</td>
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<tr>
<td>Organize quest</td>
<td>6</td>
<td>3</td>
</tr>
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<td>Pilot evaluation material with student</td>
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<td>Review content covered previously</td>
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<tr>
<td>Guiding learning activities</td>
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<tr>
<td>Give detail instruction on climate change in Canada jigsaw activity</td>
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<td>1</td>
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<tr>
<td>Give students detail instruction on what to do with issue pages</td>
<td>1</td>
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<tr>
<td>Give students detail instructions on how to do group brainstorm</td>
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<td>Give students instruction on how to create issue brainstorm pages</td>
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<tr>
<td>Making connections</td>
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<tr>
<td>Asking students to re-use knowledge base content</td>
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<tr>
<td>Ask student to go and search through the remediation tags from the resource</td>
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<tr>
<td>Ask students to check issue pages they did not work on when they were asked to</td>
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<tr>
<td>Ask students to review at least 2 issues when working on remediation</td>
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<tr>
<td>Ask students to skim all issue pages when working on remediation</td>
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<tr>
<td>Encourage students to look through the remediation section on each</td>
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<td>Encourage students to re-use references when working on remediation</td>
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<tr>
<td>Suggest students to choose remediation from references assignment</td>
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<td>Highlight choosing activities for individual actions</td>
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<tr>
<td>Let students examine the vehicle fuel efficiency issue</td>
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<td>Let students work on Personal Home Energy Audit activity</td>
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<td>Ask students to write their thoughts on the most important climate change</td>
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<td>Assign references topics to each student</td>
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<tr>
<td>Give students homework on analyzing graphs of past climate</td>
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<tr>
<td>Give students homework on tree core lab activity</td>
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<tr>
<td>Let students work on Atlas modeling activity</td>
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<tr>
<td>Let students work on crossword puzzles</td>
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<td>2</td>
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<tr>
<td>Let students work on e-cards activity</td>
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<tr>
<td>Let students work on ecological footprint activity</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Let students work on issue pages</td>
<td>15</td>
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<td>Let students work on Letter to the Editor</td>
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<td>Let students work on reflections</td>
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<td>Let students work on remediation pages</td>
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<td>Let students work on TELS activity</td>
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<td>Make a full period of class time for issue editing</td>
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<td>Name</td>
<td>References</td>
<td>Sources</td>
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<td>----------------------------------------------------------------------</td>
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<tr>
<td>Organize ice core lab activity</td>
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<tr>
<td>Organize issue brainstorm activity</td>
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<td>5</td>
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<tr>
<td>Organize peer review activity</td>
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<td>3</td>
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<tr>
<td>Organize remediation presentation</td>
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<td>Organize student activity that examined human activities that impact GH</td>
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<td>Organize the energy saving cards activity</td>
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<td>Organize tree cores lab activity</td>
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<td>Prepare for e-cards activity for students</td>
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<td>Setting learning context</td>
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<tr>
<td>Ask students to read e-cards reading</td>
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<td>2</td>
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<tr>
<td>Debrief Sita Alangotok video</td>
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<tr>
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<td>Introduce ice core content</td>
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<tr>
<td>Introducing learning activities</td>
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<td>Explain the purpose of brainstorm activity</td>
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<td>Introduce and explain references assignment</td>
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<td>Introduce e-Cards activity</td>
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<tr>
<td>Introduce the issue activity</td>
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<tr>
<td>Show students a list of issues generated in brainstorm activity</td>
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<tr>
<td>Let students read Traditional Ecological Knowledge (TEK) handout</td>
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<tr>
<td>Play a video about the cause of climate change</td>
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<tr>
<td>Play climate change rap video</td>
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<tr>
<td>Play the sial alangotok video</td>
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<td>Technological role</td>
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<tr>
<td>Demonstrate the technology related to references assignment</td>
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<tr>
<td>Help student setup the online portal</td>
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<td>Introduce issue brainstorm technology</td>
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<tr>
<td>Introduce issue page technology</td>
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<tr>
<td>Make themselves familiar with the technology</td>
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Appendix C: Summary of Classroom Events

1. Information of Issue Pages

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<th>Number of words</th>
<th>References used</th>
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<td>Alberta Tar Sands</td>
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<td>Deforestation</td>
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<td>2813</td>
<td>15</td>
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<tr>
<td>Desertification</td>
<td>213</td>
<td>3135</td>
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<tr>
<td>Economy</td>
<td>89</td>
<td>3452</td>
<td>10</td>
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<tr>
<td>Glaciers melting</td>
<td>47</td>
<td>1787</td>
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<tr>
<td>Individual Actions</td>
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<td>2794</td>
<td>41</td>
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<tr>
<td>Natural Disasters</td>
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<td>Ocean Warming and Thermohaline Circulation</td>
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<td>Overpopulation</td>
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<td>2496</td>
<td>8</td>
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<tr>
<td>Permafrost Melting and Ecosystems</td>
<td>85</td>
<td>3982</td>
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<td>Polar Amplification</td>
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<td>2193</td>
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<td>Pollution &amp; Greenhouse Gases</td>
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<td>3417</td>
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<tr>
<td>Rising Sea Levels</td>
<td>82</td>
<td>2980</td>
<td>11</td>
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<tr>
<td>Tropospheric Ozone</td>
<td>92</td>
<td>4202</td>
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<td>Unusual/Extreme Weather</td>
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<td>5332</td>
<td>34</td>
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<tr>
<td>Wildlife</td>
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<td>Total</td>
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<tr>
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2. Information of Reflection Questionnaires

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<td>Reflection 4</td>
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<tr>
<td>Reflection 5</td>
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<td>Reflection 6</td>
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### 3. Information of Remediation Pages

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<th>References used</th>
<th>Additional references</th>
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<tr>
<td>Individual Actions</td>
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<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Renewable Energy 1</td>
<td>68</td>
<td>2956</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>Carbon offset programs, emissions reductions, carbon taxes and credits</td>
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<td>1930</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Reducing Electricity Use 1</td>
<td>43</td>
<td>1953</td>
<td>8</td>
<td>3</td>
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<td>Recycling Programs</td>
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<td>8</td>
</tr>
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<td>Remediation Page Low emission technologies</td>
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<td>Energy Star</td>
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<td>Energy star products</td>
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<td>Rising sea levels</td>
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<td>Public Transportation</td>
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Appendix D: Statistic Tests on Student Learning Outcomes

Final Test Scores Comparing Among Three Teachers’ Class

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<th>Mean</th>
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<td>Jonathan’s classes</td>
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<td>1.25</td>
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<tr>
<td>Steven’s class</td>
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<td>17.35</td>
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<td>Total</td>
<td>106</td>
<td>17.33</td>
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* Number of students

Students’ final test scores were obtained from the school. Since the homogeneity of variance assumption was violated, Kruskal-Wallis test was performed. No statistically significant difference among the three teachers’ classes was found on the final test scores ($p = 0.79$). The above table shows the real mean values and standard deviation, instead of the mean ranks.

Remediation Evaluation Scores Comparing Among Three Teachers’ Class

<table>
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<th></th>
<th>n**</th>
<th>Mean</th>
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<td>Mary’s classes</td>
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<td>7.75</td>
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</tr>
<tr>
<td>Jonathan’s classes</td>
<td>12</td>
<td>6.83</td>
<td>4.09</td>
</tr>
<tr>
<td>Steven’s class</td>
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<tr>
<td>Total</td>
<td>29</td>
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</table>

** Number of remediation pages

Students in Mary’s two class sessions and Jonathan’s two class sessions created 12 remediation pages separately. Students in Steven’s class created five remediation pages. The quality of each remediation page was measured in terms of number of issues covered, the number of issues re-used in the knowledge base, the relevance of issues to the remediation page, the quality of explanation on how remediation plan can address various issues.

An ANOVA test was performed on the scores of remediation pages. The homogeneity of variance assumption was not violated. No statistically significant difference was found among the three teachers’ classes on the evaluation scores of each remediation page, $F(2, 26) = 0.25, p = 0.78$. 