TRANSFORMING LEARNING IN SCIENCE CLASSROOMS: A BLENDED KNOWLEDGE COMMUNITY APPROACH

by

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A thesis submitted in conformity with the requirements for the degree of Doctor of Philosophy
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ABSTRACT

In this study, I examined how science curricula designed based on the Knowledge Community and Inquiry (KCI) model (Slotta, 2007) would foster the development of knowledge communities in secondary school science classrooms. KCI situates scaffolded inquiry activities within a collective context. In two design iterations, I collaborated with high school teachers to design and implement grade-nine science curriculum units with the topic of Climate Change. Then, I probed the extent to which characteristics of classroom-based knowledge communities manifested in students’ collaborative inquiry activities and the product of their work.

In both iterations, students worked for approximately 8 weeks in a sequence of interconnected collaborative inquiry activities, creating digital inquiry artifacts. Two class sections engaged in iteration 1 and created wiki pages about the effect of climate change in Canada. They, then, used these wiki pages to examine the implications of climate change on certain industries. Five class sections engaged in iteration 2 where students identified important climate change-related issues and examined scientific aspects of those issues along with existing remediation plans. Knowledge co-constructed in this collaborative inquiry activity, contained in a Drupal platform, was used to propose improvement to existing remediation plans. Analyzing the process and the product of
collaborative inquiry allowed me to examine the extent to which a knowledge community
developed in each of the iterations.

Findings from iteration 1 revealed that students needed tighter scaffolds during
collaborative inquiry activities to stay focused on science connections. Additionally,
epistemic scaffolds were added to the designed curriculum unit in iteration 2. Also,
students were given regulative scaffolds to plan and monitor their collaborative inquiry.
Findings from iteration 2 showed more science connections in co-constructed knowledge
and higher amount of collaboration among students while constructing shared knowledge
comparing to iteration 1.

This study provided further evidence of the effectiveness of KCI model to foster
characteristics of knowledge communities in secondary school science classrooms. In
addition to elaborating pedagogical and technological scaffolds that facilitated KCI
curriculum units, recommendations were made for future research to improve existing
scaffolds and, thus, progressing towards knowledge communities that are responsive to
curricular expectations of science classrooms.
ACKNOWLEDGEMENTS

I would like to thank my exceptional supervisory committee members. Professors Jim Slotta, Erminia Pedterri, Jim Hewitt, Earl Woodruff, and Chris Quintana provided critical support and encouraged me to constantly hone my research goal and polish my research design over the years. Professor Slotta offered me a unique and great opportunity to conduct my doctoral research while building my professional network in the field of the Learning Sciences. His guidance, support, superb mentorship, and encouragement made my experience as a Ph.D. student at OISE a highly rewarding one.

This study would not be feasible without the patience and enthusiasm of participating teachers. Here, I thank them for their time and for the great ideas they brought to the lengthy curriculum co-design meetings. Also, I extend my acknowledgement to participating students who eagerly engaged in the collaborative activities of the designed curriculum.

I am indebted to all my friends at OISE for their support and encouragement. Cheryl, Vanessa, Naxin, Mike, Michelle, Arif, Stian, Rokham, and Ali thank you for making the Encore Lab a creative thinking space. Nenad and Amy, sharing an office with you was great. I appreciate your listening to my endless “thinking aloud”s. Spogmai and Najme, I will always treasure our passionate discussions over coffee. You introduced me to a different, and much interesting, side of academic life at OISE. Dr. Nobuko Fujita, you have always been my go-to person whenever I needed advice.

Dr. Wendy Nielsen, my mentor and academic role model, thank you for listening to my raw ideas and for helping me to shape them into organized and presentable lines of thought. Thank you for reading my long emails and painstakingly answering my numerous questions. Thank you for taking me seriously and giving me pep talks whenever I doubted my abilities.

A special thank you goes to my mom and dad who valued my aspirations and instilled in me a love for learning. Words cannot express my appreciation and gratitude to my mom who has always put my sister and I before herself. She is my champion. My dad is a constant source of inspiration to me. He taught me to be resilient and thorough in whatever I do. May his soul rest in peace. I am also grateful to my wonderful sister Neda, my brother in-law Kambiz, and my cheerful nephew Kasra for their kindness and constant encouragement.

Finally, I would like to thank two very special people in my life: My husband Ali and our lovely daughter Ryeika. I spent so many hours that should have been deservedly spent with you, working on my doctoral research. Thank you Ali for your unwavering love and support and for believing in me. Ryeika, I hope that I can, one day, make up for your patience and for being such a great baby as I was finishing this thesis. Everyday with you is a learning experience and you never fail to amaze me by your curiosity for the unknown and your desire to learn. My wish for you is to be happy, find your passion in life, and work hard to achieve your goals.
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DEDICATION

To Ali and Ryeika,
for your unconditional love.
CHAPTER 1: INTRODUCTION

1.1 Problem Statement

In this study I investigated the viability of technology-enhanced knowledge communities in secondary school science classrooms. At the heart of this study was Knowledge Community and Inquiry (KCI) model (Slotta, 2007), a pedagogical model for curriculum that emphasizes scaffolded inquiry activities situated within a knowledge community context. In this dissertation, I examined how KCI would foster the development of a knowledge community in secondary school science classrooms. The study also contributed to the epistemological and collaborative elements of the model. Working in close collaboration with high school science teachers, I designed a large scale curriculum unit that embodied my contributions to the model, and examined their impact on student activities and outcomes. Specifically, I probed the extent to which characteristics of classroom-based knowledge communities manifested in students’ collaborative inquiry activities and the product of their work.

In this chapter, I discuss the background and motivation of this research, outline the purpose of the study, articulate research questions that guided the study, discuss the significance of this research, provide a glossary of terms used in this dissertation, and outline the thesis itself.

1.2 Background of the Study

Research in the field of Learning Sciences has advanced the notion of “learning communities” in k-12 classrooms. Examples of theoretical frameworks that have been developed through such research include Communities of Inquiry (Garrison & Arbaugh,
2007), Fostering Communities of Learners (Brown & Campione, 1996), and Knowledge Building Communities (Scardamalia & Bereiter, 2006). Knowledge communities for K-12 classrooms emphasize a collective effort on the part of all stakeholders—students and teachers alike—to negotiate their learning goals, to co-construct a shared knowledge base consisting of “knowledge objects”, and to constantly advance their shared knowledge (Slotta & Najafi, 2010). In such context, individual learning becomes a by-product of collaborative knowledge construction within the community. Yet, as Brown (1992) contends about Fostering Communities of Learners, the high demand of these frameworks for a drastic change in long-established habits of teachers and students may be detrimental to their widespread dissemination in classrooms.

One reason for the rising interest in a knowledge community approach to education is the recognition of new demands from the workplace in the 21st century “knowledge society” (Drucker, 1986) where knowledge is a defining characteristic of society. Complex problems of a knowledge society require individuals and groups to dynamically apply their existing knowledge to situations that they have never been experienced before (Brown & Campione, 1990; Hargreaves, 2003). Thus, schools are expected to help students value knowledge creation, develop life-long learning and take initiative to identify and to resolve multi-faceted, open-ended and often unforeseen problems, characteristic of an innovation-driven society (Linn & Hsi, 2000; Scardamalia, 2002; Scardamalia & Bereiter, 2003).

Theoretical frameworks relating to the knowledge community approach share four fundamental dimensions: (1) Distributed cognitive responsibility among members conducive to the growth of a knowledge community, (2) a shared knowledge base
constructed through collective discourse, (3) pedagogical and technological scaffolds and supports that facilitate members’ participation in the practices of the community, and (4) inherent inquiry activities that motivates students’ participation in the discourse of the knowledge community (Slotta & Najafi, 2010). In knowledge communities, members engage as a collective, sometimes in small groups within the large group, to advance the state of community knowledge. Any research on promoting knowledge community approach can, therefore, progress by examining these four dimensions.

Typical science instruction is preoccupied with addressing an abundance of curricular topics in a short time, and achieving expectations in summative assessments (Slotta & Linn, 2009), compromising the depth of understanding of science topics in favor of rote learning of facts and problem solving methods. Inquiry-oriented methods have been advanced by researchers as a means of helping students construct deep understanding of science concepts and develop lifelong learning skills such as critical thinking and argumentation (Linn & Eylon, 2006; National Research Council, 1996; Olson & Loucks-Horsley, 2000). Inquiry methods have proven successful by engaging students with personally relevant problems, including data collection, argumentation, the use of simulations and visualizations, and collaboration with peers (Linn & Eylon, 2006; Slotta & Linn, 2010). Knowledge community approaches are challenged to integrate such inquiry based learning, extending it beyond small groups, to the level of the whole classroom or multiple classrooms (Peters & Slotta, 2010).

The field of Computer Supported Collaborative Learning (CSCL) has developed in the past two decades to investigate powerful applications of technology in support of student collaboration and inquiry (Hakkakainen, Lipponen, & Järvelä, 2002; Slotta &
Linn, 2009; van Aalst & Chan, 2007; White, 2006). Examples of technologies for inquiry and collaboration include web-based learning environments (Slotta & Linn, 2009), simulations and microworlds (deJong, 2011), argumentation tools (Bell, Davis, & Linn, 2004), and concept maps and journals (Davis, 2004). Technology scaffolds are also a common feature of knowledge community frameworks, such as Knowledge Building Communities and Communities of Inquiry (Scardamalia, 2000; Swan, Garrison, & Richardson, 2009), where they capture and aggregate student ideas for purpose of subsequent “knowledge work.” Technology is generally seen as a scaffold for inquiry processes, and a support for the orchestration of complex collaborative processes (Slotta, 2010).

Despite their promise, knowledge community frameworks entail challenges that make them impractical to implement in everyday classroom practices. These challenges include the lack of concrete guidelines for designing collaborative activities that capitalize on shared knowledge, ambiguous roles for teachers and students, substantial time required to situate students within the culture of knowledge community, and sustaining long-term collaborative inquiry (Brown, 1992; Lehrer & Schauble, 2006; Scardamalia, 2002; Sherin, Mendez, & Louis, 2004). To alleviate such challenges and to increase the practicality of knowledge communities in classrooms, researchers have investigated various pedagogical structures and technological scaffolds to support knowledge construction and inquiry in learning environments (Hmelo-Silver & Barrows, 2008; Kollar, Fischer, & Hesse, 2006; Linn & Eylon, 2006; Weinberger, Stegmann, Fischer, & Mandl, 2007; Zhang, Scardamalia, Reeve, & Messina, 2009).
One approach to promote knowledge communities in k-12 science classrooms is the Knowledge Community and Inquiry (KCI) model (Slotta, 2007; Slotta & Peters, 2008) that supports learning within a collective context through scaffolded inquiry activities integrated within a substantive curriculum unit. In a KCI curriculum, students conduct small-group and whole class inquiry activities and co-construct a shared knowledge base characterized by integrated and transferable knowledge objects. KCI curriculum is guided directly by curricular goals and learning expectations and targets deep understanding of scientific concepts. Such curriculum also seeks to establish a sense of collective epistemology amongst participating students and teachers, and to accommodate emerging themes or interests within the community.

1.3 Purpose of the Research

The purpose of this study is to investigate how the KCI model would support a knowledge community approach for secondary school science and also to extend the model based on the findings. To this end, KCI model was used to guide the design of a grade-10 Climate Change science curriculum, including pedagogical and technological scaffolds that supported an inquiry-oriented knowledge community among students. This study introduced new forms of collaborative activities to KCI and added an epistemological component to the model. Using a design-based research methodology, I worked closely with teachers and technology developers to create, implement and evaluate two design iterations (Cobb, Confrey, Disessa, Lehrer, & Schauble, 2003), to test the impact of my interventions and to draw conclusions about their implications for secondary science instruction.
The goals of this study are to: (1) Understand the impact of a KCI curriculum on the development of distributed cognitive responsibility among students; (2) examine the progressive epistemic nature of co-constructed knowledge within a KCI curriculum; and (3) understand how the KCI curriculum influences students’ understanding of scientific concepts.

This study was conducted as design-based research (Brown, 1992) with two iterations in the 2008-2009 and 2009-2010 school years. In both iterations, students worked for approximately 8 weeks in a sequence of interconnected collaborative inquiry activities, creating digital content and inquiry artifacts on technological platforms customized for this research. Two class sections with 1 teacher participated in iteration 1 and five class sections with 3 teachers participated in iteration 2. Analyzing the process and the product of collaborative inquiry, as captured in the students’ digital knowledge objects and reflections notes allowed me to examine the extent to which a knowledge community developed in each of the iterations.

1.4 Research Questions

The following research questions guided my study:

1. What pedagogical features support the development of a knowledge community in secondary science classrooms?

2. What forms of collaborative knowledge construction activities support the distribution of responsibility among students?

3. How does the design of collaborative inquiry activities influence the scientific depth of knowledge objects co-constructed by the students?
4. What features of collaborative inquiry activities promote active engagement with a community constructed knowledge base?

1.5 Context and Significance of the Study

In 2008, the Ontario Ministry of Education added the “Climate Change” topic to the “Earth and Space Science” strand of grade-10 science curriculum (Ontario Ministry of Education, 2008). Given the societal importance of this topic, its accessibility to student inquiry, and the fact that it was a new addition to the curriculum, it seemed a suitable topic for a study of the design and implementation of a KCI curriculum. Such a curriculum unit would provide an opportunity for the students to identify social aspects of climate change science and investigate controversial socio-scientific issues (Pedretti, 1999) around it. The co-design approach (Penuel, Roschelle, & Shechtman, 2007) would ensure that curricular expectations set by the Ontario Ministry of Education were addressed.

This research has both theoretical and methodological significance. Early enactments of the KCI model provided proof-of-concept, and also raised new questions and issues for the model (Peters, 2010; Peters & Slotta, 2010; Slotta & Peters, 2008). These prior efforts showed that KCI could guide a secondary science curriculum that meets curricular expectations, engages students in collaborative knowledge construction and scaffolded inquiry, and progresses toward establishing a sense of knowledge community. However, they identified limitations to the model regarding its support for collaboration, and the need to help students develop an epistemological perspective.
conducive to the knowledge community approach. This study sought to continue that line of investigation, extending the model and improving the efficacy of KCI curriculum.

A theoretical contribution of this study is the use of metacognitive prompts to encourage students to reflect on their own and their peers’ understanding of science concept and contributions to collaborative inquiry. Examining the potential impact of such scaffolds on the scientific and epistemic quality of individual contributions and collective shared knowledge base, would provide guidelines for researchers and practitioners to advance cognitive responsibility beyond classroom teachers and to the students. Van Aalst and Chan (2007) propose that research in the field of Computer Supported Collaborative Learning needs to address the ways in which students’ agency could be supported to improve their learning in collaborative activities. They also call for research that goes beyond examining students’ achievement at an individual level and instead, attends to collective learning that takes place during collaborative processes.

This study also built on research that integrates structured collaborative patterns to complement collective knowledge construction and inquiry process to facilitate the development of a knowledge community in classrooms (Hmelo-Silver & Barrows, 2008).

From a methodological perspective, assessing the quality of co-constructed knowledge has proven a complicated, resource-intensive process that remains a persistent challenge for researchers and classroom teachers alike (Fujita, 2009; Lee, Chan, & van Aalst, 2006; Sha, Teplovs, & van Aalst, 2010; van Aalst, 2009). This research contributes to methodological discussions about appropriate analytical frameworks for understanding the nuances of collaborative knowledge construction in a knowledge community context (Onrubia & Engela, 2009; Peters & Slotta, 2010; van Aalst, 2009). The specific
methodological contribution of this work is the adaptation and application of existing content analysis schemes used for discussion threads, to analyze progression of ideas in wiki-like environment conducive to collaborative writing.

1.6 Glossary of Terms

- Drupal: An open source content management platform that affords enough flexibility for the users to design content management systems that meets their specific needs while also offering a rich collection of readymade tools that can be used to achieve desired functionality. An international community of volunteer developers constantly improves these tools, called modules, and creates new ones (http://drupal.org/).

- Knowledge Community: knowledge community is a term that characterizes a group of individuals whose members strive to advance their knowledge collectively through shared discourse (Bielaczyc, & Collins, 1999). A discussion of characteristics of knowledge communities is included in Chapter 2.

- Knowledge Object: In this dissertation, knowledge objects are students’ written ideas contributed to a shared space. A paragraph, a list, sentences added to an existing paragraph, or items added to an existing lists count as knowledge objects. Knowledge objects are treated as inherently improvable (Scardamalia & Bereiter, 2003).

- Web 2.0: A term that applies to web services and applications that mostly encourage active user participation in content creation and content
propagation in a collective rather than individual way (O'Reilly, 2005).
Examples of web 2.0 applications are wikis, blogs, and social
bookmarking services. Affordance of such applications for learning has
been a topic of interest for educational researchers (Brown, & Adler,
2008; Davi, Frydenberg, & Gulati, 2007; Greenhow, Robelia, & Hughes,
2009; Notari, 2006; Trentin, 2009)
• Wiki: A wiki is an online platform that is accessible through a web
browser and provides editing privileges to anyone who is viewing the
content of a webpage (Ebersbach, Glaser, Heigl, & Warta, 2008). Wikis
maintain a history of edits conducted on the page. With each edit, a new
version of the page is created. Viewers see the latest version of the wiki
page and have access to previous versions through the history function.
Whenever necessary, access to wiki pages can be restricted to certain
individuals or groups.

1.7 Organization of the Thesis
This thesis is organized into six chapters. Chapter 2, Theoretical Framework and
Review of Related Literature, elaborates conceptual underpinning of the study and
reviews related literature to identify areas in need of further research and to justify the
significance of the study. Chapter 3, Research Design, discusses the choice of
methodology for this study and provides an overview of measures of reliability. Chapter
4, Design Iteration 1, provides a detailed account of curriculum co-design, explains
methods, and discusses findings and implications of Iteration 1 of this study. Design
guidelines for Iteration 2 are also outlined. Chapter 5, Design iteration 2, elaborates curriculum co-design in iteration 2, explains methods, and discusses findings of iteration 2. In Chapter 6, I present a general discussion of findings for both iterations.
CHAPTER 2: REVIEW OF RELATED LITERATURE

In this chapter, I first briefly review the foundations of constructivism, as the underlying paradigm for my study. Then, I review theoretical frameworks and empirical research on inquiry-based learning and knowledge communities to situate my study in the context of current literature. Last, I explain the rationale for and the components of the KCI model, which is the knowledge community model that guided my study.

2.1 Theoretical Foundations: Constructivism

Constructivist approaches to learning in education originated from the work of psychologists and philosophers such as Piaget, Vygotsky, Bruner, and Dewey (Fosnot, 1996; Gergen, 1999). Different traditions of constructivism vary in their assumptions about curriculum, definitions of knowledge, roles of learners and teachers, and context for knowledge construction, and accordingly, vary in terms of the activities they would propose to promote knowledge construction (Ernst, 1995; Philips, 1995). The next two sections discuss the theoretical perspectives of cognitive constructivism and social constructivism, which are rooted in the works of Jean Piaget and Lev Vygotsky, respectively.

2.1.1 Cognitive constructivism.

In Piaget’s theory of cognitive development, learners actively build knowledge by first assimilating new information to their existing mental models and, when necessary, enhancing their mental models or creating new ones to accommodate conflicting information (Duffy & Cunningham, 1996). Children undergo four stages of cognitive
development, each level constituting an increase in the complexity and sophistication of mental processes: Sensorimotor, preoperational, concrete operations, and formal operations (Piaget, 1977).

A curriculum informed by cognitive constructivism espouses experience-based learning in authentic settings and promotes methods of discovery. Internal motivation drives learners to address cognitive conflicts (Duffy & Cunningham, 1996). Misconceptions may also occur because children’s constructed knowledge is influenced by their stage of cognitive development. Yet learners would correct those misconceptions as they revisit the misconceived constructs in the future.

Cognitive constructivism treats knowledge construction as an individual, rather than social, process (Philips, 1995; Von Glasersfeld, 1996). Social constructivism, on the other hand, proposes an essential role for teachers and more knowledgeable peers to facilitate learning.

### 2.1.2 Social constructivism.

While cognitive constructivism focuses on learners’ individual knowledge construction, social constructivism emphasizes the role of collaboration in individuals’ meaning making efforts (Duffy & Cunningham, 1996; Duffy & Jonassen, 1992; Philips, 1995). Two prominent figures whose recognition of the role of teachers and peers in facilitating learning gave rise to social constructivism are John Dewey and Lev Vygotsky.

Dewey emphasized the pedagogical importance of inquiry-based learning through meaningful experiences that are situated in a social context (Dewey, 1929). In contrast to
the notion of conflict in Piaget’s cognitive development theory, learning is organized around issues of interest to learners (Duffy & Cunningham, 1996; Duffy & Orrill, 2004). The teacher’s role, Dewey argues, is to attract students’ attention to the issues under study so that students actively engage in addressing and resolving them.

According to Vygotsky, social interaction with peers through dialogue, negotiation, and questioning is integral to individuals’ knowledge construction (Fosnot, 1996; Jonassen et. al., 1995; Philips, 1995). Social context within the learning environment provides cognitive support in the form of peers, teachers and tangible resources that support learners. Vygotsky introduced the notion of a learner’s Zone of Proximal Development, "the distance between the actual developmental level of a child as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers." (Vygotsky, 1978, p. 86).

The notion of scaffolding has been introduced within the educational research community as a way of expanding a learner’s ZPD, or of enabling progress in learning within the ZPD. With scaffolds playing an essential role in students’ cognitive development, the quality of human resources and tangible resources that can act as scaffolds becomes important. Teachers, for instance, become intellectual role models who participate in students’ efforts to resolve cognitive tensions and construct meaning. Also, digital technologies can be used to facilitate social interactions across time and place to enhance cognitive development. As the learner becomes more knowledgeable and gains cognitive control over a particular problem of study, scaffolds fade away (Duffy & Cunningham, 1996).
Students are often described as active learners in constructivist models of education. Social constructivism adds a social dimension to this notion of active learning. In addition to being active at an individual level, students also need to be aware of their peers’ knowledge and understanding of issues of interest to be able to assist each other in advancing the collective knowledge of their community. Hence, social constructivism emphasizes a learning context that accounts for students’ lived experiences as relevant to what they learn. Meaning and knowledge is co-constructed by students with their peers during collaborative learning activities.

2.1.3 Implications of constructivism for curriculum design.

Constructivism, in its varying conceptions, provides a theoretical perspective from which educators can draw guidelines for designing curricula that allow learners to construct knowledge that is transferrable to other contexts. One reason for the popularity of the constructivist perspective is that it supports curriculum designs that are sensitive to the learning context, where students are active learners, engaged in critical thinking, problem identification, and problem solving—challenges that students will face as professionals in a knowledge-based society (Dawson, 2004).

Given the potential of the constructivist perspective to facilitate rich teaching and learning experiences, there remains the question of how it can guide the design of classroom teaching and learning. Scardamalia and Bereiter (1991) observe that the term “constructivist learning” can be applied to any approach that promotes cognitive agency on the part of students. Yet formulating concepts and problems to guide such inquiry, and designing activities that engage learners in collaborative activities demands careful
design that leads to a fulfilling, rather than chaotic, experience for both students and teachers (Applefield, Huber & Moallem, 2001).

Several instructional frameworks and design strategies have been advanced to capture the constructivist epistemology. These frameworks differ in their detail, yet all aim to establish resource-rich inquiry-based environments in classrooms (Duffy & Orrill, 2004). Of relevance to my research are two such frameworks: inquiry-based learning and knowledge communities, which are the topics of the next two main sections. The discussion of inquiry-based learning is substantive, in part because it constitutes a dominant proportion of the existing research literature in the Learning Sciences (Linn & Eylon, 2011; Peters & Slotta, 2010). The literature on knowledge communities is more central to my research topic and also addresses KCI as a framework that marries the two traditions.

2.2 Inquiry-Based Learning

Inquiry-based learning (IBL) in science education applies to teaching and learning approaches that support students’ active engagement in scientific investigations and draw on constructivist and social constructivist perspectives such as experiential learning (Dewey, 1929), cognitive development (Piaget, 1971), Zones of Proximal Development (Vygotsky, 1978), discovery learning (Bruner, 1967) and situated learning (Lave, 1997). Inquiry-based approaches first gained momentum during the curriculum reform movement in 1960s, in part through the effort to infuse scientific methods into science education. This happened during a time period dominated by traditional “knowledge transmission” instructional models that offered little experience to students of the actual
practices of science (Bybee, 2000). Two major shortcomings of traditional transmission methods are (1) fragmented and decontextualized conceptual knowledge that students acquire but fail to connect to their previous knowledge or to apply in a different situation; and (2) unfamiliarity with methods of scientific investigation that prevents them from engaging in knowledge advancement and critical thinking. Such methods include identifying science problems, asking questions, and locating relevant resources and evidence to address them (Lock, 1990; National Research Foundation, 1998).

To address such shortcomings, inquiry-based approaches to science were developed to scaffold students’ efforts to construct, refine, and apply their understanding of scientific concepts through question-driven, evidence-based, argument-laden and iterative scientific inquiry processes (Edelson, 2001; Edelson, Gordin, & Pea, 1999; Krajcik, Blumenfeld, Marx, & Soloway, 2000; Linn, Clark, & Slotta, 2003; Linn & Eylon, 2006; Singer, Marx, Krajcik, & Chambers, 2000). Such authentic experience would support students to develop integrated knowledge of both scientific concepts and inquiry skills (Anderson, 2002). Inquiry-based approaches to science education adopt a constructivist approach, addressing deficiencies regarding of teaching methods that separate scientific concepts from scientific ways of knowing. Teacher role also changes to inquiry role model (Gordin & Pea, 1995) rather than content knowledge provider.

A second wave of interests in IBL occurred two decades later motivated by science education standards (American Association for the Advancement of Science, 1993; Council of Ministers of Education, Canada, 1997) and also by the development of new technologies that could alleviate known problems to inquiry-based approaches, such as the development of complex curriculum materials and improved support for teachers.
Inquiry-based learning approaches often utilize digital technologies (Welch, 1981; Edelson, Gordin, & Pea, 1999; Hug, Krajcik, & Marx, 2005; Slotta & Linn, 2009; White & Frederiksen, 1998) to provide cognitive and procedural support and scaffolds that teachers and students need to accomplish inquiry-based science learning.

2.2.1 Types of inquiry-based approaches.

The wide range of inquiry-based approaches has been interpreted along a continuum that represents the degree of students’ agency and control over cognitive processes in conceptualizing and conducting inquiry activities (Bonnstetter, 1998; Chinn & Malhota, 2002; Colburn, 2000; Herron, 1971; Martin-Hansen, 2002; National Research Council, 2000; Schwab, 1962; Windschitl, 2003). Various types of inquiry-based approaches have been proposed in order to express the type of inquiry-based learning that is represented in research studies or promoted in teacher education programs (Bonnstetter, 1998; Colburn, 2000; Herron, 1971; Martin-Hansen, 2002; Schwab, 1962; Windschitl, 2003). For purposes of this dissertation, I consider the following classification scheme: (1) structured inquiry, (2) guided inquiry, and (3) open inquiry, often referred to as discovery learning. These categories are not necessarily empirically distinct or mutually exclusive. Yet they are quite common in the literature (Kirschner, Sweller & Clark, 2006), and provide a frame of reference that clarifies my own reference to inquiry-based teaching and learning approaches:

- Structured Inquiry: In structured inquiry, the teacher provides inquiry problem, methods of investigation, and material to the students. Students follow teacher’s direction to either confirm a known answer or use the
evidence to make their own conclusion in response to the inquiry problem. This category of inquiry-based teaching and learning methods assumes minimal agency for students (Eylon & Linn, 2006; 2011).

- **Guided Inquiry:** This approach is quite typical of modern Learning Sciences research, offering a higher degree of agency to students, where the teacher defines the problem of inquiry and the students are responsible for designing their own investigation or conducting more open-ended activities. The students should decide on what data to collects, how to analyze collected data, and how to interpret the findings of their inquiry. Guided inquiry prepares students to gain more cognitive responsibility towards conducting inquiry activities and supports them to hone their inquiry skills.

- **Open Inquiry:** Also known as full inquiry (Martin-Hansen, 2002) or discovery learning (Kirschner et. al., 2006), delegates to the students the responsibility to define an inquiry problem, design and carry out an investigation to address the their problem, and to communicate the results of their inquiry in various formats.

In this dissertation, the forms of inquiry-based approaches that are targeted in the theoretical model and the curriculum design fall under the category of guided inquiry. Consequently, all further reference made to inquiry-based learning and teaching refer to guided inquiry, unless otherwise clarified.

### 2.2.2 Inquiry processes.
Within the IBL research literature, curriculum activities are designed to engage students in a range of cognitive processes, including posing and revising questions about a phenomenon, designing and conducting investigations, collecting and analyzing data, constructing arguments, establishing models, inferring conclusion, and communicating the results with peers or other audience (Linn & Eylon, 2006; National Research Council, 2000). Research on inquiry has also adopted a notion of collaboration and many projects refute a sequential model where the steps of the inquiry process are clearly specified. Instead, they embrace non-linear designs with feedback among various constituent inquiry processes (Krajcik, Blumenfeld, Marx, & Soloway, 2000). Inquiry processes thus include many forms and configurations, from activities that target students’ competence in designing and constructing an artifact (Puntambekar, Stylianou, & Goldstein, 2007) to activities that emphasize specific skills, such as constructing sound arguments (Lin, Clark, & Slotta, 2003).

Several characteristics are commonly present in inquiry-oriented research projects (e.g. World Watcher – see Edelson, Gordin, & Pea, 1999; Center for Learning Technologies in Urban Schools – see Hug, Krajcik, & Marx, 2005; and the Web-based Integrated Science Environment – see Slotta & Linn, 2009). First, the curriculum employed by these projects is typically designed in close collaboration amongst a partnership of educational researchers, computer programmers, subject matter specialists, and classroom teachers (Edelson, Gordin, & Pea, 1999; Linn, Clark & Slotta, 2003; Singer, Marx, Krajcik, & Chambers, 2000; Williams & Linn, 2002). The notion of co-design has been advanced (Penuel, Roschelle, & Shechtman, 2007) to describe a process where teachers’ and researchers’ expectations and concerns are aligned in the process of
designing an innovative curriculum. Second, research often pursues a design-oriented approach, where iterative cycle of design and improvement are guided by the results of research studies (Edelson, Gordin & Pea, 1995; Hug, Krajcik & Marx, 2005; Linn, Clark & Slotta, 2003). Third, inquiry-based approaches often rely on scaffolding – particularly that provided by technology enhanced materials and environments. In order to help students become independent and autonomous learners, these projects typically guide them with scaffolded materials, such as a sequence of steps—as in WISE (Slotta & Linn, 2009—, questions, or prompts, to support cognitive, metacognitive and collaborative activities (Edelson, 2006).

2.2.3 Challenges of implementing IBL.

Enacting IBL is challenging due to the complexity of engaging students in inquiry, guiding the inquiry process, and assessing students’ learning gains. Inquiry-based science interventions usually require several classroom sessions, and may require students to share the responsibility of cognitive and metacognitive tasks to design and conduct investigations. Moreover, students bring with them a repertoire of knowledge composed of discipline-oriented concepts, perceptions of scientific ways of knowing, and ideas about scientific investigation methods (Linn & Eylon, 2006). IBL curriculum must therefore address content knowledge, procedural knowledge, and epistemic knowledge.

Challenges confronting IBL research can be discussed in terms of procedural, regulatory, and collaborative aspects (Edelson, Gordin, & Pea, 1999; Kali & Linn, 2007; Krajcik, Blumenfeld, Marx, & Soloway, 2000; van Joolingen, de Jong, & Dimitrakopoulou, 2007). Procedural challenges relate to students’ lack of skills in
executing various steps of a generic inquiry cycle (Edelson, 2006). Krajcik, Blumenfeld, Marx, Bass and Fredricks (1998) followed a group of 7th grade students as they engaged in two inquiry projects. For these students, asking research-worthy questions proved challenging. Students’ lack of experience in question generation or their concerns about being able to answer the question in the limited time available were identified as potential causes of this situation. Aside from initiating inquiry projects with poorly conceived questions, students also faced problems in conducting systematic investigations. In another study, the same research team found that 8th grade students who were engaged in technology integrated science project did not use all of the collected evidence to draw conclusions (Hug, Krajcik, & Marx, 2005). These studies reported the difficulties of getting students to achieve the basic procedures of their IBL designs.

In addition to engaging in specific inquiry activities, another goal of IBL is to help students plan how they would accomplish the inquiry process and then monitor their adherence to that plan. Regulatory challenges surface when students are unable to plan, monitor their progress and, finally, reflect on their inquiry activity (Krajcik, Blumenfeld, Marx, & Soloway, 2000; Quintana, Zhang, & Krajcik, 2005). Planning involves, first, understanding the requirements of a task. Afterwards, students should monitor their progress to identify problems and unanticipated situations, and adjust their plan accordingly. On completion of any task, students should reflect on their investigation to identify any needed areas of improvement. To become independent, intentional learners, students should develop such metacognitive knowledge (Lin, 2001). As defined by Brown (1992), metacognition is “knowledge about and control of one’s own learning” (p. 146). Students face problems with managing their inquiry investigations, such as failing
to monitor their data collection process and thus making incorrect inferences (Hug, Krajcik, & Marx, 2005), due to their inexperience taking on such responsibility (Edelson, Gordin & Pea, 1999).

IBL values collaboration both in small group and in whole class settings (Krajcik, Blumenfeld, Marx, & Soloway, 2000; White, 2006). However, conducting collaborative inquiry in classrooms has proved difficult due to long-established knowledge transmission culture of classrooms and practical limitations such as time and ratio of teacher to students (Singer, Marx, Krajcik, & Chambers, 2000). The impracticality of collaboration in classrooms presents a serious challenge to IBL, which emphasizes the collective nature of knowledge construction (Scardamalia & Bereiter, 1994) as it happens in scientific community. Krajcik, Blumenfeld, Marx and Soloway (2000) contend that, without support, the scientific quality of collaborative discussion will most likely suffer as students fail to pool their ideas, distinguish valid and invalid ideas through discussion, and settle conflicts. All of these challenges are confronted by scaffolding approaches, as discussed in the next section.

2.2.4 Scaffolding IBL.

Scaffolds can be used to assist students in their inquiry efforts and to ameliorate the known challenges of IBL. Scaffolds can be defined as support structures that enable students to undertake tasks that they would have been otherwise unable to accomplish unaided (Vygotsky, 1978; Wood, Bruner, & Ross, 1976). As students become competent, scaffolds can be gradually removed. For example, feedback from teachers could encourage students to revise and improve their inquiry questions (Krajcik, Blumenfeld,
Marx, Bass, & Fredricks, 1998). Likewise, collaboration with more knowledgeable peers can increase lower achieving students’ knowledge of science and inquiry, provided that the group regularly reflects on their progress (White & Frederiksen, 1998).

Technology scaffolds have been used in IBL research to support guided inquiry (Krajcik, Blumenfeld, Marx, & Soloway, 2000) and to issue metacognitive prompts (Linn, Clarke, & Slotta, 2003; Quintana, Zhang, & Krajcik, 2005; Singer, Marx, Krajcik, & Chambers, 2000). Digital technologies can facilitate students’ access to information, provide multiple ways of representation, mitigate the complexity of tasks at hand by structuring them, and facilitate error detection and correction (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991). Two common forms of technology scaffolds are: (1) Standalone applications that support specific actions, such as Thinker Tags for collaborative simulations (Hug, Krajcik, & Marx, 2005); and (2) integrated environments that orchestrate the inquiry process, such as WISE (Slotta & Linn, 2009). Instructional patterns provide yet another form of scaffold, as they provide a recognized pedagogical structure to the design of activities. Linn and Eylon (2006) identify ten such patterns, including Predict, Observe, Explain, Explore a Simulation, Create an Artifact, Construct an Argument, Critique, Collaborate, and Reflect that, when combined with other scaffolds, support IBL.

Technological and pedagogical scaffolds, when carefully designed, can provide support for content knowledge, inquiry methods, progress regulation, and collaborative work. The following sections briefly discuss how scaffolds have been used within IBL to address the three challenges identified above.
**Addressing procedural challenges: Scaffolding inquiry activities.**

A common approach to addressing the procedural complexities of inquiry-based activities is to chunk and sequence the inquiry into constituent steps. For each step, scaffolds are designed that address students’ need for scientific content knowledge and support the relevant inquiry strategies such as approaches to data analysis. The Inquiry Map in WISE curriculum activities is an example of such sequencing (Linn & Eylon, 2006). Students can see the complete picture of an inquiry investigation, but only work on one step at a time.

To build students’ competence in carrying out open-ended inquiry investigations, such sequences can be repeatedly used in a succession of inquiry projects, with the scaffolds gradually removed. Three research projects that emphasize promoting students’ progressive independence include: Thinker Tools (White & Frederiksen, 1998) where computer simulations are blended with an analytic tool to engage students in discovering laws of force and motion; World Watcher (Edelson, Gordin, & Pea, 1999) that scaffolds students in scientific investigations using visualization of weather patterns; and project based learning approaches such as the Center for Curriculum Materials in Science (Krajcik, Slotta, McNeil & Reiser, 2008) where technological scaffolds are employed to scaffold design and enactment of science inquiry projects.

**Addressing regulatory challenges: Scaffolding metacognition.**

IBL researchers have employed embedded and explicit forms of scaffolds to address regulatory challenges. Embedded scaffold can be integrated in inquiry steps of a technology environment that scaffolds IBL. Such embedded scaffolds visualize
components of an inquiry investigation, thus helping students to understand the building blocks of each step. Such an understanding would enable students to better plan their inquiry. For example, Symphony, a technology-enhanced environment that supports environmental investigations, includes an inquiry map that shows the activities that are necessary to accomplish an inquiry investigation (Quintana, Zhang, & Krajcik, 2005). The inquiry map facilitates planning the inquiry activity as students can drag components of each activity into a planning grid.

Explicit scaffolds and scripts vary based on their use of technology or their degree of integration in the inquiry process. Using the reflect pattern (Linn & Eylon, 2006), for example, teachers can prompt students to carefully monitor their progress with regards to their starting point and the new ideas that have been presented to them. Another form of scaffold is metacognitive prompts used in WISE curriculum (Linn, Clark, & Slotta, 2003). In another example, White and Frederiksen (1998) employed a regular reflective assessment that encouraged students to think about their performance in terms of criteria that characterized sound scientific research. These reflective assessments showed significant benefit for lower achieving students. The criteria used by students for assessing reflection included understanding scientific content, understanding scientific inquiry, and awareness of social context.

The frequency and type of metacognitive scaffolds vary for different IBL approaches. In WISE, for example, knowledge integration scaffolds which support inquiry and conceptual development processes outnumber metacognitive scaffolds (Linn, Clark, & Slotta, 2003) owing to the emphasis of WISE curriculum on knowledge integration. Kali & Linn (2007) acknowledge the lack of theoretical guidelines for the use
of regulatory scaffolds, and suggest that researchers and curriculum designers base their decisions on the context in which the curriculum would be implanted.

**Addressing collaborative challenges: Scaffolding collaboration.**

In order to support student collaborations within IBL designs, technological scaffolds have been developed to help make students’ ideas public and provide dialogical means for them to discuss and reflect on the shared ideas (Kali & Linn, 2007). The Knowledge Forum, developed and researched at OISE/UT (Scardamalia & Bereiter, 1996) is a prominent example.

Ideally, IBL promotes opportunistic collaborations, which demand a high level of agency from students. For example, students might be given the “open opportunity” to participate in discussions at any point that they have something to contribute (Krajcik, Blumenfeld, Marx, Bass, & Fredricks, 1998). More recently, the role of collaborative design patterns in supporting inquiry has attracted researchers’ attention (van Joolingen, de Jong, & Dimitrakopoulou, 2007). These patterns can be generic, such as the “collaborate” pattern described by Linn and Eyoln (2006), or can provide detailed description of the steps required for students to take to complete a collaborative task. A well-known pattern of such collaboration scripts (Kollar, Fischer, & Hesse, 2006) is reciprocal teaching (Palincsar & Brown, 1984), where students are orchestrated in specific forms of feedback and exchange with peers.
2.3 Knowledge Communities

IBL researchers have long been interested in developing learning communities in science classrooms, for two main reasons: (1) Enculturating students in a social structure that resembles a scientific community; and (2) maximizing the benefits of collaboration by making individual and small group knowledge accessible for classroom-wide evaluation (Singer, Marx, Krajcik, & Chambers, 2000; White & Frederiksen, 1998). Researchers have advanced different conceptualizations of a “knowledge community” approach, where students work collectively within a classroom, emphasizing shared discourse and inquiry (Bielaczyc & Collins, 1999; 2006; Brown & Campione, 1990; Garrison, Anderson, & Archer, 2000; Scardamalia, 2001; Scardamalia & Bereiter, 1991). A prior review (Slotta & Najafi, 2010) identified three elements common to such approaches:

- Community members collectively develop and advance a shared knowledge base.
- Community members share an epistemological perspective about the importance of learning within a community, and a metacognitive awareness of the processes underlying learning and knowledge creation.
- Community members develop shared patterns of discourse that allows idea sharing, critique, and improvement.

The two most prominent examples of the knowledge community approach are Fostering Communities of Learners (FCL) and Knowledge Building (KB) – both of which have been widely recognized and researched in k-12 classrooms. FCL was implemented in urban elementary schools to promote critical thinking and reflective
practice rooted in deep content knowledge within a purposeful scientific learning community (Brown, 1997; Brown & Campione, 1996). Introduced in the late 1980s and developed through a series of design-based research studies (Brown, 1992), FCL emphasized a research cycle with three stages: students engage in research activities, share their findings with the whole class to create collective expertise and finally use the knowledge that they have acquired to complete a final project.

KB also engages students in identifying questions and developing a cumulative understanding (Scardamalia & Bereiter, 2008). In this approach, individuals’ ideas are added to the public domain of the knowledge community and undergo the scrutiny of all members, who share the responsibility of advancing their collective knowledge. A supportive social context allows students to work as a knowledge community, identifying conceptually important ideas, and improving them through constructive review (Bereiter, 1997; Scardamalia, 2000). A clear distinction is made between learning, an internal personal process, and knowledge building, an intentional effort to advance public knowledge (Scardamalia & Bereiter, 2006). Below, I offer a synthesis of FCL and KB across three dimensions: Distributed cognitive responsibility, shared knowledge base, and integrated pedagogical and technological scaffolds.

2.3.1 Distributed cognitive responsibility.

In a knowledge community approach, students can articulate their own learning goals and plan learning activities. Members of a knowledge community are not only responsible for the quality of their individual learning, but also are held accountable to communicate with other community members to scrutinize the quality collective
knowledge (Bielaczyc & Collins, 1999). Students in FCL classrooms are acknowledged for what they know and are involved in identifying their learning needs, setting goals, and locating necessary resources to accomplish those goals, thus developing a metacognitive awareness (Brown, 1992; Brown & Campione, 1994; Campione, Shapiro, & Brown, 1995). Therefore, establishing an environment to promote learners’ cognitive responsibility is crucial in FCL (Brown & Campione, 1990; Brown & Campione, 1996). Metacognition and reflection serve to increase students’ awareness of how they learn and thereby enable critical inquiry, and the flexible application of knowledge in new situations (Brown, 1992). Metacognitive knowledge is used collectively to regulate the classroom community as a whole, with individual students sharing the responsibility for monitoring and giving feedback to their peers (Brown & Campione, 1994). Because the community depends on the quality of its shared knowledge base, students hold themselves accountable for developing a coherent understanding of the topic assigned to them (Brown & Campione 1994).

Although FCL advocates increased cognitive agency on the part of students, it emphasizes a balance between the accountability of teachers and students. Teachers are not expected to know the answers, but rather to serve as inquiry role models, competent in identifying problem areas and helping students to locate and utilize relevant resources (Brown, 1992; Brown, 1997; Brown & Campione, 1994). Further, teachers should distinguish among the situations where the students need help to avoid misconceptions, when the students are ready to undertake more advanced topics, or where the students should be left on their own (Brown, 1992; Brown & Campione, 1990; Brown & Campione, 1994). Without the support, monitoring, and feedback from teachers, students
might develop misconceptions about the topic of inquiry or fail to progress in their understandings.

In KB classrooms, the students also assume responsibility for identifying their learning goals, conducting inquiry, developing their knowledge as a classroom community, and monitoring their own progress (Scardamalia & Bereiter, 1999, 2000, 2006). They identify relevant problems that would expand on their knowledge, develop insight into those problems, share their understandings with others in the form of knowledge objects, and, finally, attend to inconsistencies in the shared ideas (Scardamalia, 2000, 2002; Scardamalia & Bereiter, 2006).

A higher level of cognitive agency for students differentiates KB from FCL (Scardamalia, 2002; Scardamalia & Bereiter, 2008). Where FCL imposes a certain level of structure and hierarchy to ensure cognitive responsibility, KB distributes cognitive responsibility amongst all members of the community. This collective cognitive responsibility (Scardamalia, 2002) takes the form of an ongoing negotiation for each student between personally held ideas and those that are external to them (Scardamalia, 2000). Although teachers may have less control in directing classroom discussions, they are actively developing their own understanding of discussed concepts and also improving their knowledge of processes underlying students’ understanding (Scardamalia & Bereiter, 1999).

After studying the effect of various social arrangements on the development of collective cognitive responsibility, Zhang, Scardamalia, Reeve, and Messina (2009) proposed three defining characteristics: (1) Awareness of shared knowledge objects that requires the students to be attentive to the work of peers and how their contributions
change the state of problem under study as the collective work progresses; (2) complementarily of shared knowledge objects, where students use the current state of shared knowledge as the starting point and contribute knowledge objects that complement and advance the knowledge base, leading to a coherent explanatory understanding of the problem being investigated; and (3) distributed participation in progressive knowledge co-construction that requires every student to participate in identifying issues of interest, planning inquiry, and monitoring the progress of knowledge co-construction and revise their actions to improve their collective work.

Three dimensions of distributed cognitive responsibility that are relevant to the my study are: Distributed participation, on the part of students, in planning, implementing, and monitoring their collective inquiry; distributed participation in contributing high quality knowledge objects to a shared knowledge base; and, distributed participation in the improvement of the knowledge base, including resolution of inconsistencies in knowledge objects that were contributed by themselves or their peers.

2.3.2 Shared knowledge base.

A knowledge community approach encourages students to pursue their personal interests in the context of shared classroom interests. Knowledge sources are not limited to the teacher and curriculum materials and include knowledge objects shared and developed by students (Bielaczyc & Collins, 1999).

Students in FCL classrooms collaboratively build a shared knowledge base characterized by integrated and transferable knowledge as opposed to declarative facts (Brown, 1992). During benchmark lessons, the teachers reintroduce selected curricular
“themes” to the students as “generative ideas” that constitute the foundation of community knowledge base, on which students elaborate during the FCL research cycle (Brown, 1992, 1997; Brown & Campione, 1990, 1994). Generative ideas are broad enough to be divided into sub-topics that students address during research cycles (Sherin, Mendez, & Louis, 2004; Shulman & Sherin, 2004). Students and teachers together develop a deep understanding of disciplinary topics, which requires communication channels and collaborative structures for creating and improving a shared knowledge base.

In FCL classrooms, students formulate research questions about their chosen topics, informed by the seeded ideas, and then refer to selected references to thematically categorize their questions divided into sub-units. Each student then selects a sub-unit to research, thereby increasing their personal agency in learning. To avoid misconceived ideas or unproductive inquiry efforts the teacher and students monitor their collective knowledge. Structured collaborative activities intentionally distribute expertise among students, requiring them to negotiate their individual knowledge within collaborative groups and organize their new understandings in a shared knowledge base (Brown, 1997; Brown & Campione, 1994).

In KB classrooms, students take initiative in solving shared problems that motivate a persistent open inquiry geared toward idea improvement. Non-knowledge building questions can be answered either explicitly or implicitly through available print, digital or human resources (Bereiter & Scardamalia, 2000; Scardamalia & Bereiter, 1991, 1999). Knowledge building questions, in contrast, engage students in proposing solutions at the level of underlying principles—e.g., gravity—rather than concrete cases—e.g., why
objects fall—. The two kinds of questions can be distinguished by the degree of finality required in answering them (Bereiter & Scardamalia, 2000, 2003).

Students learn to develop their own theories in response to problems that emerge during ongoing inquiry. These theories become objects of students’ inquiry and are subjected to continuous improvement, similar to the process of scientific research (Bereiter & Scardamalia, 2000, 2003; Scardamalia & Bereiter, 1999, 2006). Bringing problems of understanding to the center of inquiry requires abandoning the more familiar topic-centered structure of classroom where curricular themes dictate the topic of discussions at a given time during school year.

The community knowledge base in KB is public where students share their ideas to be critiqued by peers, compared to other ideas in the knowledge base, and integrated into shared knowledge (Scardamalia, 2002, 2003; Scardamalia & Bereiter, 2003). Any idea contributed to the community knowledge base will survive and be built upon further by classmates only if it is deemed important to the community (Scardamalia, 2000). Upon presenting a new idea, students should deliberately negotiate the significance of their contribution by citing its connections to the discourse of the community (Scardamalia & Bereiter, 1999). The teacher’s attention shifts from engaging students in activities that ultimately showcase their understandings to activities that focus on idea improvement as the goal of classroom discourse (Bereiter & Scardamalia, 2003). Thus, any knowledge object produced during such activities is treated as improvable. Moreover, unlike FCL, where ideas are only shared with the whole class at certain intervals, students in KB classes have access to all ideas at all times.
The shared knowledge base should promote diversity of ideas and facilitate access to those ideas in order to encourage the growth of community knowledge (Brown & Campione, 1994; Scardamalia, 2003). Authoritative sources, in the form of print and digital resources or expert opinions, are included as long as they are treated with a critical stance (Bereiter & Scardamalia, 2003; Collins, Joseph, & Bielaczyc, 2004; Scardamalia, 2002). Knowledge building holds students responsible for assessing the congruency of the developed knowledge base to scientific discourse and taking corrective action (Scardamalia, 2002; Scardamalia & Bereiter, 1999). In contrast, FCL requires teachers to identify and address misconceptions to prevent an incorrect concept from prevailing within the community discourse.

In this study, two facets related to the quality of progressively co-constructed shared knowledge are important: Epistemic complexity, and scientific sophistication. The epistemic nature of shared knowledge objects can range from factual, low complexity, to explanatory, high complexity, reflecting an increasing depth of understanding (Hakkarainen, Lipponen, & Jarvela, 2002). Knowledge community frameworks encourage students to offer explanations for inquiry problems (Hakkarainen, 2003) and to continually modify their explanations. An important determinant of such explanatory knowledge objects is the level of “collaborativeness” of inquiry activities within the classroom. While interacting with peers, students can recognize shortcomings of their understandings and improve them accordingly (Scardamalia & Bereiter, 1994). Shared knowledge is thus typically more focused on explanation rather than fact or description.

Examining the scientific sophistication of co-constructed knowledge is also essential to my research, as knowledge objects with high epistemic complexity are not
necessarily scientifically sound or relevant to the goal of the inquiry activity (Hakkarainen, Lipponen, & Jarvela, 2002). As KCI, the pedagogical model that guided my curriculum design, emphasized the depth and sophistication of scientific knowledge within the community, I consider scientific sophistication of co-constructed knowledge as an measure for quality of shared knowledge objects.

2.3.3 Pedagogical scripts and technological scaffolds.

To help teachers and students achieve the nuanced flow of ideas and activities within a knowledge community approach, researchers often introduce specific forms of guidance or constraints in the form of pedagogical scripts and technological scaffolds. In FCL, most of the research was conducted before the arrival of the Internet in educational research. Hence, scaffolds in FCL were focused on “scripting” student collaborations, to familiarize students with knowledge sharing and knowledge construction, help them understand expectations, and guide their transition from one activity into another (Campione, Shapiro & Brown, 1995). Examples include:

- Reciprocal teaching: Students work in pairs or small groups to interpret materials or work on a problem, summarizing assigned sections of the text, asking questions about the text, clarifying misconceptions, and predicting how the text would continue (Lehrer & Schauble, 2006). Reciprocal teaching promotes comprehension, cognitive monitoring and complex reasoning (Brown, 1992; Brown & Collins, 1994)

- Jigsaw groups: Students are assigned to a research group that is a subtopic of the overall theme. Although every student in the group is responsible
for learning the whole subtopic, they work independently within their research group, investigating their own questions and engaging in reciprocal teaching with other members of their group. Then, new groups are created that include one student from each of the subtopic groups. The new group works on a “consequential task” that is seen as a product of the overall cycle (Brown & Campione 1994).

- Cross talk: Students share their progress across groups and sometimes with whole-class to exchange feedback on their research and, if necessary, modify their investigation approaches. Cross talk often takes place alongside jigsaw groups.

Technological scaffolds designed for FCL were limited, although computers were used from the outset to produce materials. In later phases of the research, the Web was added as a searchable resource, as well as email communications where students consulted with content knowledge experts (Brown, 1997).

Technology plays a more central role within KB and provides a medium for representing and organizing ideas as well as a tool for collaborative knowledge construction (Scardamalia & Bereiter, 1999). The development of the technological environment, known as Knowledge Forum (previously called CSILE, the Computer Supported Intentional Learning Environment) progressed side-by-side with the development of KB theory (Scardamalia & Bereiter, 2003, 2006). The Knowledge Forum technology presents a visualization of the KB discourse in the form of “Notes” that students create in the environment. In contrast with electronic discussion forums, where posts are stored chronologically, Knowledge Forum represents the Notes spatially, with
those that have been of greatest interest and more frequently linked, regardless of the
time they were first created, placed closer to the center of the screen. Teachers benefit
from such a visualization (Scardamalia & Bereiter, 1999) as they gain insight into the
ideas that students most focus upon, which enables them to tailor their feedback to the
students.

The Knowledge Forum makes the knowledge within the community public so that all members can grasp the current state of understanding within the community, and participate in idea improvement. In KB, idea improvement happens when every member of the community takes actions, such as searching, commenting, synthesizing, critiquing or modifying, on publicly shared notes (Scardamalia, 2002; Scardamalia & Bereiter, 2006). Through these actions, the community takes ownership of the ideas and becomes responsible for the quality of their progress. The technology environment facilitates students’ participation in a progressive discourse by providing scaffolds that help clarify underlying cognitive processes of the composed notes (Scardamalia, 2002).

While FCL employed collaborative scripts for the exchange of ideas amongst students, KB uses the technology environment to scaffold continuous collaboration for improving the state of shared knowledge (Scardamalia & Bereiter, 2008). Organization and the structure of collaborative groups are less important as long as the students identify opportunities when they can contribute to idea improvement (Bereiter & Scardamalia, 2003). Although not necessarily designed to support small group collaboration, Knowledge Forum makes the content of small groups’ discourse available to the whole class so that the ideas remain public. This way, transition between small
group and whole class discussions takes place more smoothly (Scardamalia & Bereiter, 2003).

2.3.4 Researching knowledge communities: Challenges and opportunities.

Despite the prominence of the knowledge community approach within reviews of learning sciences (e.g., Bransford, Brown, & Cocking, 1999; Sawyer, 2008), they have made relatively little progress empirically (Slotta & Najafi, 2010). In part, this is due to the substantive epistemological shift required for students and teachers alike and the logistical challenges of orchestrating a knowledge community in classrooms. Studies conducted on FCL classrooms report major challenges with regards to instructional design and implementation (Sherin, Mendez, & Louise, 2004). Knowledge Building studies, on the other hand, provide promising accounts of students’ success in sustaining an idea-centered discourse, at least for elementary level classrooms (Cohen & Scardamalia, 1998; Zhang, 2010).

Knowledge community frameworks require an epistemological, rather than procedural, change in students and teachers conception of learning and teaching (Hewitt, 2002). Both FCL and KB scholars exert great emphasis on the importance of the underlying principles to transform classrooms to knowledge communities (Brown & Campione, 1996; Scardamalia, 2002; Slotta & Najafi, 2010). One further problem confronting researchers who would like to study a knowledge community approach is concerned with how to translate the core theoretical principles into pragmatic design guidelines (Lehrer & Schauble, 2006). With such a challenging pedagogical approach, it is possible that that the design efforts of researchers would fall short, simply imitating the
technological and pedagogical scaffolds of FCL or KB, while not achieving the essential epistemological commitments (Witcomb, 2004).

A review of studies that tried to implement FCL in various disciplines reveals that curriculum design was mainly concerned with following the FCL unit structure, i.e. an extensive jigsaw activity (Rico & Shulman, 2004; Sherin, Mendez, & Louis, 2004; Witcomb, 2004). According to Schoenfeld (2004), selecting a jigsaw-able topic is difficult because the topic should be manageable in the timeline of a given unit and the topic should contain sub-topics to allow for knowledge sharing and conducting a consequential task. Two science teachers, for example, struggled with selecting big ideas that transcended curricular topics and accommodated interdependent students research (Rico & Shulman, 2004). Further, a jigsaw design of curriculum is not the essence of FCL, rather just one of the pedagogical scripts employed to facilitate distributed expertise.

Sherin, Mendez and Louis (2004) studied an FCL-inspired approach in middle school math classrooms. Having designed and implemented a probability unit using FCL pedagogy, the teacher observed that the students lacked collaboration skills, which prevented them from engaging in meaningful discussions. This led into a change in the teacher’s perception of the nature of the big idea from solely mathematical concepts to include knowledge-sharing processes that are necessary in learning those concepts. Realizing that the FCL structures alone would not lead to a learning community, the teacher developed an FCL discourse in his classroom. The researchers argue that a learning community formed in this math classroom although the claim is only supported by one example of interaction between two students and the teacher.
The challenge for teachers to depart from their long-established practice is reflected in classroom-based research where three participating English teachers appropriated an innovative approach to conform to their established practice (Witcomb, 2004). Each of the three teachers in Witcomb’s (2004) study faced unique challenges in implementing a middle school English Literature FCL unit. In addition to technical problems such as locating suitable resources for students’ research, the teachers struggled with conceptual dilemmas as how to delegate the responsibility of learning to the students and renounce their central role. Having designed an FCL unit before the school year, the teachers deviated from the planned units during implementation. Witcomb (2004) identifies three strategies used in this fashion: Renaming an existing practice using FCL terminology, selecting and emphasizing one participant structure without connecting it to the whole unit, and abandoning the implementation of the planned unit.

In another study (Rico & Shulman, 2004), two science teachers found it difficult to maintain students’ attention to the big ideas. “Research” turned into “finding facts” and filling in the blanks, and when the students were regrouped during jigsaw to share their learning, they would exchange information without significant amount of discussion. Also, as in the Sherin et al. (2004) study, students made minimal connections among knowledge objects that were created by each individual and in the small groups. FCL pedagogical structures alone are not sufficient to establish or sustain a culture of collaborative inquiry among students.

Attention to design principles is more evident in KB research, where scaffolds are designed to foster certain principles of a knowledge building discourse. For example, in three iterations of a design-based study, researchers studied the effect of three different
social arrangements to support the development of collective cognitive responsibility among grade-4 students as they used KF for four months to develop their knowledge of optics (Zhang, Scardamalia, Lamon, Messina, & Reeve, 2007; Zhang, Scardamalia, Reeve, & Messina, 2009). Comparing the findings of the three iterations, the researchers argue that opportunistic collaboration was most conducive to the emergence of collective cognitive responsibility, at least within elementary schools.

Theoretically speaking, KB is not bound by temporal limits of school year and discourages topic-centered discussions (Bereiter, 2003) in favor of inquiry problems. Few empirical studies have investigated a knowledge building approach in secondary schools. For example, in the first iteration of their design-based study, van Aalst and Chan (2007) examined the impact of grade-12 students' self-assessments on their understanding of collective knowledge in the field of physical geography where the teacher promoted a problem-based approach to inquiry. The second iteration was conducted in a grade-12 Chemistry class and was shorter in duration, ten weeks vs. 18 weeks for the physical geography class. The nature of discussions that took place in Knowledge Forum, topic vs. problem oriented, is not openly discussed in the paper. It is unclear whether the teacher had to settle with topic-based discussions. These students were introduced to three of the 12 dimensions of knowledge building (van Aalst & Chan, 2007).

Despite some positive empirical evidence that students’ agency over their cognitive processes may increase as a result of a knowledge community approach, these instructional frameworks have not yet received widespread popularity among researchers and practitioners. Perhaps this is due to the amount of time and human resources a knowledge community approach demands, in terms of the design, implementation and
evaluation. Scardamalia (2002) contends that it would take up to 6 months to establish anything resembling the right epistemological conditions for a KB approach to succeed. The fact that KB and FCL studies are mainly conducted in laboratory schools indicates a fundamental need for a supportive school culture.

Considering the challenges that researchers face when studying a knowledge community approach, applying models that integrate computer supported collaborative learning technologies with known collaboration scripts is compelling (Najafi & Slotta, 2010; Slotta & Najafi, 2010). More specifically, web 2.0 technologies that inherently demand user participation in content creation and content propagation can provide increased awareness of shared knowledge and support students in using technology to collaboratively construct new knowledge. The following section reviews a pedagogical model that attempts to make the knowledge community approach more accessible for secondary science by adding a layer of scripted inquiry—similar to FCL—and leveraging supportive technological environments.

### 2.4 Knowledge Community and Inquiry: A Blended Model

Based on the above discussions on strengths and challenges of IBL and knowledge communities, a blended model of curriculum design that integrates the two frameworks may hold promise to facilitate a culture of collective inquiry in science classrooms. Knowledge Community and Inquiry (KCI) (Najafi & Slotta, 2010; Peters & Slotta, 2010; Slotta & Peters, 2008) has been developed at OISE/UT for secondary science, offering a structured model for the integration of inquiry-based learning activities and collective knowledge construction activities. The following design
principles of KCI guide the development of science curricula. They are described here as pedagogical elements, which may be seen as happening cyclically.

1. Identify common interests: First, students engage in whole-class collaboration to identify issues of interest related to the curriculum topic. As a result of this step, it is possible that students develop knowledge objects, such as annotated resources, questions, and web pages, which reflect emerging themes that can be used to guide the design of subsequent inquiry activities.

2. Design inquiry-based learning activities: Once teachers and researchers identify issues that are deemed important by the students, they design scripted inquiry activities that address those issues while targeting the desired learning goals for the curriculum. These activities should fulfill three conditions: (1) They should address the inquiry themes and issues identified in the first step as both starting point and resource for the inquiry activity; (2) they should directly address the targeted learning goals, such that students’ participation in the inquiry activity will assure their development of relevant conceptual understandings; and (3) they should yield knowledge objects that can be assessed for such learning.

3. Integrate the community knowledge base: Ideally, the class is engaged in constant knowledge integration, connecting their new ideas and understandings to existing knowledge objects and continually modifying their collective knowledge base. The knowledge base itself must be a
topic of metacognitive instruction, such that students and teachers alike understand it as the primary resource for and product of inquiry activities.

The practicality of design and accessibility to enactment are of prime importance to KCI, as is the need to address official curriculum expectations. Moreover, designers must take into account the requirements of conventional assessment, maintaining a goal of developing activities that yield knowledge objects that allow teachers to measure students’ achievement of curriculum expectations. Technology plays an essential role in KCI curriculum design and enactment. Specifically, technology tools that facilitate the collaborative writing of documents, such as wikis, or other custom-designed software applications are utilized to represent collective knowledge and promote students’ contributions to the construction of a shared knowledge base.

This research is the second doctoral study conducted to examine the KCI model to foster knowledge communities in secondary school science classrooms. In a previous work, Peters (2010) studied implementation of the KCI model in two design iterations and offered five recommendations for curriculum design in future KCI research. Her recommendations, which provided an initial direction for curriculum design in my own doctoral study include:

- Assigning appropriate time limits to collaborative inquiry activities. In a KCI curriculum, students engage in collaborative inquiry where knowledge constructed in one inquiry activity is used in a subsequent inquiry activity. Peters (2010) observed that it would be important to consider the time allocation for such inquiry cycles, ensuring that
activities which occur later in the curriculum are not deprived of sufficient instructional time.

- Integration of KCI into the broader curriculum unit. To avoid a sense of disconnect with regular classroom instruction, the designed KCI curriculum should be integrated as seamlessly as possible within the broader curricular design. This will serve to establish a culture of knowledge community, as opposed to one of simply introducing discrete, research-oriented supplemental activities to the curriculum.

- Reinforcing a culture of community and collaboration. Only if collaborative work is assessed as a group product, will students commit to collective work rather than caring only for the quality of their own individual contributions to the group. Unfortunately, this is a challenging recommendation, as school assessment policy may prevent teachers from assigning grades to collaborative work.

- Diversifying resources in the collective knowledge base. Students often use the community knowledge base as resources within their inquiry activities. To facilitate students’ access to all resources in the knowledge base, it is recommended that resources are annotated and added to a searchable database. Such a resource database can persist and be improved over the course of the curriculum, allowing for better access to, and hence improvement of relevant ideas.

Fostering an inquiry-oriented knowledge community in science classrooms requires a combination of technological and pedagogical scaffolds that leverage students’
knowledge of being effective community members while supporting their collaborative knowledge construction efforts. My doctoral study examined the design and efficacy of such scaffolds in two implementations of the KCI model in a grade-10 Global Climate Change curriculum unit. In the next chapter, I discuss the study design with regards to choice of methodology and measures of trustworthiness.
CHAPTER 3: METHODOLOGY

This chapter presents an overview of my chosen research methodology, including the strengths and limitations. I describe the setting and participants, as well as the role of the researcher. I then review issues of credibility, reliability and ethical considerations, and some possible limitations of the research. Finally, I discuss the data sources and analytic approaches in a general way. Specific methods, materials, and procedures for each of the two iterations are discussed in detail chapters 4 and 5, respectively.

3.1 Design-based Research

Design-based research brings researchers and teachers together to design innovative approaches to known problems of practical and theoretical value and allows them to recursively examine the interactions among multiple design elements to improve the design (Brown, 1992; Collins, Joseph, & Bielaczyc, 2004). The central goal of design-based research, also called design research, in the field of education is to advance knowledge on designing, implementing, and sustaining educational innovation (Bereiter, 2002; Design-Based Research Collective, 2003). Edelson (2002) identifies two different objectives for design research: Theory testing and theory development. Design-based research with the goal of theory development integrates innovation design into the research process (DBRC, 2003; Edelson, 2002). Design-based research provides appropriate methods to capture the nuances of educational technology innovation designed to improve the quality of students’ learning and also contribute to the theoretical
knowledge base of the field (Barab & Squire, 2004; Collins, Joseph, & Bielaczyc, 2004; Hoadley, 2002).

Considering the present research goal of understanding how a KCI curriculum could support the development of a knowledge community in science classrooms, a design-based research approach geared toward theory development would be an appropriate choice for methodology. Below, I discuss characteristics, methodological considerations, and limitations of design-based research.

3.1.1 Characteristics of design-based research.

The inadequacy of positivistic laboratory-based experiments for studying classroom innovations in-situ led to the introduction of design experiments that allow for designing innovative learning environments and studying them in the actual context of classrooms (Barab & Kirschner, 2001; Brown, 1992; Collins, 1999; Collins, Joseph, & Bielaczyc, 2004). Moreover, an increasing interest in technology integration in education and the need for systemic design of such innovations further motivated the emergence of this new methodology to capture the multitude of variables that underlie the processes of conception, implementation, and modification of educational technology innovations (Collins, 1992).

Consistent with the assumptions of pragmatism (Creswell, 2003; Rorty, 1990; Tashakkori & Teddlie, 2003), design-based research identifies important problems of applied and theoretical value to education and proposes solutions to improve the practice of education in complex learning environments (Barab & Squire, 2004; DBRC, 2003; Edelson, 2002). The main characteristics of design-based research are outlined below.
Systemic intervention: To implement an innovative intervention, design-based research takes into account the intricate web of contextual elements—students, teachers, curricular material, and technologies to name a few—as they interact in a learning environment. The implications of innovative interventions, therefore, propagate across the system, affecting the whole learning environment (Bell, Hoadley, & Linn, 2004; Brown, 1992).

Interdisciplinary design: Conducting a design-based research requires collaboration of and input from an interdisciplinary team including researchers, technologists, subject matter specialists, and teachers (Bell, Hoadley & Linn, 2004; Bereiter, 2002; Collins, 1992, 1999). This team identifies the challenge that innovation intends to address, design the innovation and finally conduct the study.

Iterative design modification: At any point during the study, researchers or teachers may notice that a design may not support assumed learning goals. In that case, it is possible to modify the design provided that the researchers keep detailed account of the conditions under which such decisions are made (Collins, 1992, 1999). An iterative feedback cycle characterizes design-based research where interim findings during implementation are constantly used to improve the design (Bereiter, 2002; DBRC, 2003; Edelson, 2002; Hoadley, 2002).

There are two methodological considerations that researchers need to take into account: controlling dependent variables and drawing on multiple sources of data. Three types of dependent variables have been identified (Collins, Joseph, & Bielaczyc, 2004): Climate variables, learning variables, and systemic variables. Controlling dependent
variables in design research is impractical due to their abundance. Instead, researchers should observe these variables in the situations that embody interactions among dependent variable and the designed intervention (Barab & Kirschner, 2001; Collins, 1999) to understand their impact on the goal targeted by a specific design (Collins, Joseph, & Bielaczyc, 2004).

Design experiments allow for simultaneous attention to several aspects of the learning environment (i.e., rather than controlling for all but one). These include students, teachers, curricular material, and technology tools (Brown, 1992). Respectively, researchers should use multiple sources of data, including pre-post surveys, interviews, and classroom observations, that attend to such variables as students and teachers’ motivation and sustainability of the design outside the scope of research timeline (Collins, 1992; DBRC, 2003). Based on the questions asked, quantitative and qualitative methods can then be combined to investigate the problem of study (Bereiter, 2002).

3.1.2 Limitations of design-based research.

Design-based research demands mixing various sources of qualitative and quantitative data. The substantive data corpus typically collected in a design-based research challenges the researcher in selecting cases to be included in analysis and drawing conclusion (Collins, Joseph, & Bielaczyc, 2004). Researchers are warned against building their arguments on successful cases while ignoring inherent contradictions and failures (Bereiter, 2002; Brown, 1992).

Design based research is deeply situated in the local context where it is conducted. Therefore, generalizability of findings, scalability of the designed innovation
to alternative setting, or relevance of findings from one study in another context are issues of concern (Barab & Kirschner, 2001; Barab & Squire, 2004; Hoadley, 2002). Besides, context specificity of designs and local decisions made to appropriate the design for the extant environment, further complicates the comparison across contexts (Collins, Joseph, & Bielaczyc, 2004). Different strategies have been suggested to lessen the generalizability and replicability limitations. Situating the design within a theoretical frameworks and justifying modifications based on empirical and conceptual constructs allow future researchers to examine reported findings of a design based research and determine the applicability of findings to the new context (DBRC, 2003; Edelson, 2002).

To improve replicability, researchers should provide detailed and systematic description of the context, design goals and characteristics, design modifications, research instruments, contextual conditions and the impact of the innovation on learning goals (Barab & Kirschner, 2001; Barab & Squire, 2004; DBRC, 2003; Edelson, 2002; Hoadley, 2002). Researchers should also evaluate their decisions throughout the design and implementation of their interventions. Such formative evaluation enables researcher teams to understand possible shortcoming of their decisions, beyond the impact of designed innovation on the respective learning environment (Edelson, 2002).

Another potential weakness in design-based research is the loss of objectivity that may implicate the credibility of findings. In a design-based research, the researcher is directly involved in designing the innovation and also in implementing and fine-tuning the design during the classroom-based study (Barab & Squire, 2004; Bereiter, 2002). Such deep involvement may introduce threats to validity of reported findings. The literature on design-based research does not provide a resolution to this challenge other
than advising researchers to apply measures of trustworthiness, adapted from qualitative research methodology.

3.2 Context of the Study

This study was conducted in two design iterations in 2008-2009 and 2009-2010 school years. The setting was a private high school in Toronto, Canada, where administrators and teachers are committed to ongoing research collaborations with researchers from OISE/UT. Students in this school are engaged in school-wide and community initiatives related to environmental issues and are highly aware of climate change issues. In this school, science curriculum is advanced by one grade level over the national expectations. Consequently, grade-10 sciences are taught to the grade-9 students.

Participants of this study were 42 students in two sections of a grade-9 science class in iteration 1, and 109 students in five sections of a grade-9 science class in iteration 2. The co-design team consisted of my research supervisor, a fellow Ph.D. student, a veteran teacher with two years of experience with KCI-based curriculum, and myself. During iteration 2, two more teachers occasionally joined the design meetings. At the outset of the project, the co-design team decided to create a KCI curriculum unit on Global Climate Change, which would fit within grade-10 curricular expectations, and was well suited as a topic for student inquiry.

3.3 Ethical Considerations

My doctoral study is one of a series of studies that are investigating different dimensions of an overarching research program called “Technology-Enhanced Activities
and Interactions in the Science Classroom: Pedagogical Scripts for Knowledge Communities”, led by my research supervisor, Professor James Slotta. Ethical approval for this funded research was obtained from the University of Toronto’s Office of the Vice President, Research in June 2008 (Protocol Reference #22708) and extended for subsequent years.

Three separate consent forms were used in both iterations of this study: School principal’s consent form (Appendix A), teachers’ consent form (Appendix B), and Students’ Consent form (Appendix C). Before the Climate Change unit started, I contacted the school principal and asked her to sign the consent form for the study. The teachers also signed their consent forms in advance. I photocopied consent forms for the students in all participating classes and asked the teachers to distribute them among the students so that they can sign and return the forms before data collection commences. As participating students were minors, parent or guardian signature was also required in the consent forms.

Students were informed that participation in this study would not have a negative effect on their final grades. Moreover, they were reminded that their names would be kept confidential and pseudonyms be used in research reports.

To maintain the confidentiality of participants, I assigned pseudonyms to all participating students and teacher. Access to the wiki space and Drupal platform used for the unit was strictly limited to the research team—myself, a fellow Ph.D. student, and my supervisor—, participating teachers, and participating students. During the first session of every classroom, I provided a general statement about the purpose of this study.
3.4 Role of the Researcher

I participated in the design, implementation, and evaluation of the co-designed Climate Change curriculum in both design Iterations. Before the formal co-design meetings convened, I reviewed relevant literature to familiarize myself with fundamental elements of knowledge communities in classroom, the result of which is reflected in a recent publication (Slotta & Najafi, 2010).

In the design phase, I discussed affordance and shortcomings of specific scaffolds to be used in the curriculum unit with my research supervisor and shared and discussed those scaffolds with the teachers during co-design meeting. In the implementation phase, I was a participant observer, and attended most of the class sessions. I provided occasional technical assistance and sometimes assisted teachers to orient students in their collaborative activities. I also provided some overview comments to students during the epistemological orientation, in the first class session—particularly in the second iteration.

3.5 Measures of Trustworthiness

Guba and Lincoln (1989) propose four constructs as criteria for trustworthiness of research as: Credibility, transferability, dependability, and conformity. Here, I explain the strategies I used to address criteria for trustworthiness.

3.5.1 Credibility.

Credibility deals with the match between constructed realities of participants and reconstruction of those realities by the researcher. Techniques that I used in this study to establish credibility are:
• Prolonged engagement: I spent almost 18 months in the context of this study.
• Persistent observation: I kept detailed record of any meeting or encounter that was related to this study. My notes were both reflective and descriptive.
• Peer debriefing: I shared interim data collection and analysis plans in local and international conferences and asked for feedback on my research design from both peers and knowledgeable experts in the field of Learning Science.

3.5.2 Transferability.

The degree to which results of a study can be generalized to similar settings determines the transferability of a study. Providing a thick description of the context of the research could improve transferability. In this study, I have provided a detailed description of the interventions that were scaffolded in the co-designed curriculum and the classroom settings where the curriculum was implemented. Marshall and Rossman (2006) recommend triangulation of data sources to increase generalizability of findings. I have tried to follow this guideline and used multiple data sources—system logs, collaboration history, personal reflections, interviews, and observation notes.

3.5.3 Dependability and conformity.

I discuss both of these constructs at once. To address dependability, I tried to provide a complete account of data collection and analysis processes so that other
researchers can follow these processes and replicate the findings. I also had an inter-rater external to this research to code parts of collected data. Establishing inter-rater reliability is easier in a number of analysis methods, such as students’ learning gains, but will be time consuming and complicated for other analysis methods such as analysis of wiki discourse.

3.6 Limitations of the Study

Findings of this study may not be readily generalizable to other settings. Moreover, the data analysis methods that I use here are intricate and complex and make inter-rating time consuming and resource intensive. Such problems have been noted previously (Strijbos & Stahl, 2007).

Another limitation to this study is the lack of data that captures students’ offline interactions while collaboratively writing their inquiry reports. Examining students’ discourse could shed light on the within-group dynamics, such as power relationships, which could be pertinent to understanding the quality and quantity of students’ contributions to collaborative inquiry (White, 2006). However, I did not have the means to collect such data from students’ face-to-face interactions during class time.

3.7 Overview of Data Sources and Analytical Approaches

I provide a detailed discussion of data sources, analytical approaches, and coding schemes, for iteration 1 in Chapter 4, and for iteration 2 in Chapter 5. Here, I offer an overview of analytical approaches and data sources that I have used to achieve my research goals: Examining the extent to which characteristics of classroom-based
knowledge communities were manifest in students’ collaborative inquiry activities and the product of their work.

Below are three characteristics of a knowledge community that would be fostered in classrooms where KCI curricula is implemented. For each characteristic, I outline sources of data that informed the analysis and analytical approaches that I used:

1. Distributed participation in knowledge co-construction.
   a. All students would participate in knowledge co-construction by contributing knowledge objects to a shared space: I used the history of versions of the technological environment where students co-constructed their shared knowledge to examine their patterns of participation in small group collaboration. Where applicable, I used additional data sources, such as students’ reflective notes and group planning pages, to probe students’ awareness of their actions and to see if their participation patterns improved over time.
   b. All students would participate in improving the quality of knowledge objects that have been contributed to shared knowledge base: Using the history of versions, I investigated whether students edited existing knowledge objects. A student could either edit a knowledge object that she had contributed previously or could edit a knowledge object that had been contributed by her peers. A KCI curriculum would promote peer edits. Again, I used additional data
sources, where applicable, to examine students’ awareness of their actions and if their participation patterns improve over time.

2. Shared knowledge based that is epistemically complex and scientifically sophisticated: Inquiry activities in KCI curricula call for explanatory rather than factual knowledge objects when addressing an inquiry problem. Also, the knowledge objects created in the inquiry activities would contain rich, coherent science content, consistent with teacher’s assessment needs. Consequently, scientific quality of these knowledge objects was of importance to the model.

a. I examined how epistemic complexity of knowledge objects evolved through revisions of inquiry reports that students collaboratively wrote during an inquiry activity. Additional data sources, in particular students’ reflective notes, peer review notes, and comments left for peers in various revisions of shared pages, provided supporting evidence for students’ awareness of the quality of their own contributions and their peers’ contributions.

b. To examine scientific sophistication of students’ inquiry reports, I applied a modified Knowledge Integration rubric to the final version of those pages.

3. Transferable knowledge objects: In KCI curricula, knowledge objects co-constructed in one inquiry activity are meant to be used as resources for consecutive inquiry activities. KCI curricula in my study contained two such interdependent collaborative inquiry activities.
a. To investigate patterns of knowledge reuse, I located knowledge objects within inquiry reports of the second collaborative activity that were relevant to the first. Then, I considered inquiry reports of the first collaborative inquiry activity to examine whether they have been used as resources for knowledge object found in the second inquiry activity.
CHAPTER 4: DESIGN ITERATION 1

Iteration 1 of this research was conducted in 2008-2009 school year in two sections of a grade-9 science class, taught by the same teacher. First, I describe the co-designed curriculum, including the scaffolds that were integrated into the curriculum. Then, I outline the data collection and analysis methods. Finally, I discuss findings from Iteration 1 and their implications for iteration 2.

4.1 Participants

Participants of Iteration 1 were 42 grade-9 students in two sections of a science class: “Section A” and “Section B”. Classes met twice a week for eight weeks.

The participating teacher had been involved in co-designing a previous KCI curriculum lesson involving Canadian biodiversity (Peters, 2010). Following a co-design approach (Penuel, Roschelle, & Shechtman, 2007), the teacher joined the research team, myself included, at OISE/UT to design a Climate Change curriculum, implement it in her classroom, and evaluate the designed curriculum. Bereiter (2002) indicates two levels of contributions for teachers in a design partnership: Those who simply implement the innovation and those who continue to use the innovation even after the research is over. The participating teacher had used KCI-based curricula for two years. She was a suitable candidate for this design research project, as she had a good understanding of the theoretical perspective, as well as the pedagogical challenges of enacting such an approach.
4.2 Research Timeline

Iteration 1 was conducted over the period of one year in three main phases:

• Curriculum co-design: August 2008 - November 2008
• Curriculum implementation: November 2008 – January 2009
• Preparation for iteration 2: February 2009 – August 2009

4.3 Curriculum Co-design

Climate Change was added to the Ontario science curriculum in 2008. This topic has ample science connections that can motivate students to build collective knowledge around it. In addition to specific curricular topics, including a full unit on climate change, the Ontario Ministry of Education articulates the following educational goals for grade 9 and 10 science curriculum: “1. to relate science to technology, society, and the environment 2. to develop the skills, strategies, and habits of mind required for scientific inquiry 3. to understand the basic concepts of science” (Ontario Ministry of Education, p. 4). The KCI curriculum unit, designed for this study to support an inquiry-based knowledge community, sought to achieve those learning goals.

The co-designed Climate Change curriculum had three phases, designed to implement KCI. Scaffolds were designed to support the students in practices of knowledge communities. To improve the implementation of KCI compared with previous ones (Peters & Slotta, 2009), collaboration was emphasized in all phases of the KCI curriculum, the model was integrated into a broader curricular unit, and an epistemological perspective of collective inquiry and knowledge community was promoted throughout the unit.
A variety of collaborative activities—small group, whole-class, and across class sections—were designed and implemented for purposes of the curriculum. An outline of curriculum and research activities is provided in Figure 1. A detailed curriculum unit timeline is provided in appendix D. The following sub-sections explain the curriculum design in each of the three phases.

![Figure 1. Climate Change curriculum outline, iteration 1.](image-url)
4.3.1 Phase 1: Establishing a knowledge community.

Phase 1 of the curriculum consisted of activities that introduced the students to an epistemological perspective of a knowledge community, particularly regarding the importance of collaboration and sharing in a public knowledge space. The first four sessions of the class were dedicated to this phase.

Wiki platform.

The students were introduced to the password protected wiki space developed for this unit, which was implemented in the Confluence Wiki, by Atlassian. The teacher had used this wiki in teaching previous KCI curriculum units, and was familiar with its functions. Wikis facilitate asynchronous collaborative writing and track changes made in wiki pages, thus providing a suitable technology environment for this kind of research. Each time a person changes the content of a page, the wiki saves a new version of the page and stores the time and the login name under which the changes were made. Such capability allows for tracking students contributions to a collaboratively edited page. Students could also leave comments on the bottom section of every wiki page.

A drawback of this wiki was that it allowed only one person to edit a page at any point in time. The co-design team was aware that this limitation could interfere with students’ in-class collaboration. Thus, strategies were employed to alleviate potential bottlenecks, where students were waiting for one another to finish editing a page.

The complete design of the wiki space could not be finalized during the co-design meetings, as an important aspect of KCI was that the community, participating students and the teacher, should be able to adjust this knowledge base to meet their learning needs.
Therefore, the wiki space that was introduced to the students had a few elements that were left under-designed. Figure 2 shows the outline of the Climate Change wiki space upon completion of the unit.

The research team created wiki login names for all students. Two research assistants, including myself, attended class sessions to facilitate the use of the wiki and to help with technological questions or issues.

Figure 2. Climate change wiki space upon the completion of the unit.
**Pre-test of climate change knowledge and epistemological perspectives.**

In the first session, the students used the wiki to answer a pre-unit questionnaire (Appendix E), which also served to orient them to the editing and saving processes for the Confluence wiki platform. The ratio of laptops to students in both class sections was one-to-one. Internet access was provided through the school’s wireless network.

**Introduction to knowledge community: Presentation and Discussion.**

In the first session, the students watched a video about the impact of climate change on the lives of indigenous people in the Northern territories of Canada followed by a teacher-led discussion. In the next two sessions, the students studied regional climate change posters, created by the National Ministry of Education, in small groups and became more familiar with potential climate change problems and regional implications.

Next, the research team led an in-class discussion on the importance of functioning as a knowledge society, with an emphasis on the nature of science in the 21st century, and examples like Wikipedia and The Human Genome Project. This discussion provided a rationale for the collaborative nature of the activities designed for the unit and justified the choice of a wiki space to contain shared knowledge. Other researchers have found that informing students of underlying philosophical and pedagogical perspectives would help them better understand the rationale for collaborative work (Fujita, 2009). Students were informed that the learning activities in this unit were interwoven, and that the outcome of each activity would inform subsequent ones, so that it was important to make sure that all work was contributed with the mindset that it would be re-used by classmates.
Reference annotation activity.

In the fourth class session the teacher outlined key scientific issues that would be explained and discussed in the Climate Change unit. She assigned different bibliographic topics, each corresponding to a key issue, to the students, who were instructed to find and annotate references on those topics. The teacher handed out a rubric that specified the qualities of a credible annotated reference.

Students were directed to the “Knowledge Base” page on the wiki where they could find a list of bibliographic topics. The “Climate Change Bibliography” page acted as table of contents, where the students added their annotated resources as page-links. Students added 60 distinct references to the bibliography page as homework. These pages were evaluated by the teacher and contributed to students final unit mark. The students were informed that these references would serve as resources in subsequent activities.

4.3.2 Phase 2: Co-construction of a community knowledge base.

Phase 2 of the curriculum consisted of a whole class brainstorm and a small group collaborative inquiry project that created “Canadian Region” wiki pages. The objective of this inquiry phase was for the students to co-construct a shared knowledge base that would be used in a subsequent inquiry activity.

Identifying important climate change issues.

In this brainstorm activity, students in both class sections speculated about important issues caused by climate change that demanded immediate attention and added
them to a shared wiki page. Sharing issues in a public page required students to read existing material before adding their own idea. Every student entered his/her issue beneath the previous entry. This activity was assigned as homework, and students were given a week to add their entries.

**Collaborative inquiry to co-construct shared knowledge base.**

This collaborative inquiry activity, referred to as Regional Groups activity, examined climate change issues in seven geographical regions of Canada, as defined by National Resources Canada: Atlantic provinces, Prairies, Ontario, Nunavut, Quebec, Yukon and Northwest Territories, and British Columbia. The teacher divided the two classes into seven groups. Then one group from each class section was assigned to each region of Canada. The teacher dedicated four in-class periods, approximately 40 minutes per period, to the Regional Groups activity, with the remainder completed by students as homework.

Each regional group was assigned a wiki page, which was created using a template, designed by the research team to help students in identifying the specific topic areas that should be addressed within their page. The template contained the following sections:

- Overview description of the region
  - Helpful links about the region
  - Main industries
  - Other economic sources and activities
  - Cultural and political issues
• Climate Change science in this region
  o Green house gases
  o Ocean currents
  o Weather patterns

• Climate Change issue

• Helpful links: (This section had links to the brainstorm wiki page and a wiki space created by another class in the previous academic year)

Later in the collaborative inquiry activity, the teacher added another section to the template: “Information from Models,” that allowed the students to link information from digital climate change models to climate change issues in their region.

Students were encouraged to use the annotated sources from the “bibliography” page. However, they were free to use other online and print sources as long as those sources satisfied the credibility criteria defined by the rubric provided during the bibliography activity.

The Regional Groups activity progressed in parallel with other classroom lectures and lab activities. Students completed their regional pages as they learned about scientific aspects of climate change.

Early in the activity, the wiki’s shortcoming to support simultaneous collaborative writing was seen to impede some students’ progress during in-class work periods. To overcome this problem, the teacher suggested that the students make sub-pages, add their content for specific sub-headers in the sub-pages, and then link the sub-pages within the main wiki page. This real-time design revision had consequences on students’ collaboration, as I discuss later in this chapter.
4.3.3 Phase 3: Using co-constructed shared knowledge as a resource.

The objective of phase 3 was for the students to draw upon their collective knowledge to understand how climate change would impact the work of key stakeholder groups within the country and to propose ways to alleviate the identified adverse effects of climate change.

**Collaborative inquiry activity.**

Three class sessions were allocated to the final phase of the curriculum, which is referred to as the “Specialist group” inquiry activity. Student in Regional groups were asked to select a specialty from a list provided by the teacher: Energy industry, Environmentalist, Tourism, Other Industry, Minister of environment, and Farmer/Fisher. Specialists used the final two work periods in their Regional group activity to become more knowledgeable about climate change issues in that region as relevant to their specialty. Upon completion of the Regional groups activity, six Specialist groups were formed, across two sections. Each Specialist group included members from all of the regions.

Specialist Groups used their wiki pages to highlight issues that were relevant to their specialty across Canada and to identify or propose remediation plans that could alleviate known adverse effects of climate change. The teacher emphasized the importance of using existing knowledge from the resource pages and the Regional pages. Students could use climate change models to support their predictions, arguments, and remediation plans.
Similar to Regional pages, each Specialist group had a wiki page shared between both class sections. A template was used to focus students’ efforts on important aspects of this activity, by providing headers, as well as “guiding questions” for the first two headers:

- Overview: What are some of the key concerns for the energy industry related to global climate change in various parts of the country? The importance of their role in Canada from and economical, cultural, and environment point of the view.
- Implications based on scientific models: What predictions do scientific climate change models make that will impact your industry groups?
- Impacts
- Recommendations
- Resources

The unit culminated with an individual post-unit questionnaire (Appendix E).

4.4 Data Sources

Literature on design-based research encourages researchers to combine multiple data sources to capture the richness and complexity of innovation implementation with regard to the impacts of the innovation as experienced in research context (DBRC, 2003). In the wider literature of research design, triangulation of data is recommended to corroborate findings from different sources (Denzin, & Lincoln, 1998). I collected the following data from different sources, using different methods to investigate how the
enactment of the KCI-based curriculum fostered characteristics of a knowledge community in secondary science classrooms.

4.4.1 Pre-unit and post-unit questionnaires.

To collect baseline and exit data on students’ knowledge of climate change and beliefs about collaboration and ways of learning science, I designed a questionnaire with two sections (Appendix E):

- Knowledge of climate change: These questions were adapted from “Global Warming Assessment” developed by Technology Enhanced Learning in Science group at the University of California Berkeley upon obtaining permission from the lead researcher.
- Students’ beliefs about science and collaboration: These questions were adapted from an existing instrument (Madhok, 2006). Based on the literature on knowledge communities, I designed two open-ended questions to examine students’ perception of collaboration in science classrooms.

To administer this test, the questionnaire was copied into every student’s personal wiki page. That page was then made invisible to them once it had been completed. Close to the end of the unit, a new page was added to each student’s wiki space that contained the posttest. Students were asked to answer the posttest online during the last day of the unit.

These two questionnaires provided a more objective ground, comparing to test results marked by the classroom teacher, to understand how this curriculum impacted
students’ understanding of climate change and their attitude towards collaboration and ways of learning science.

4.4.2 Wiki pages.

Of importance to this research were the following wiki pages:

- Regional groups wiki pages: Seven groups of students from two classes co-constructed a series of pages for their assigned regions. These pages, created over a one-month duration, provide data on:
  
  - Epistemic complexity and scientific sophistication of co-constructed knowledge as evident in successive revisions and the final version of wiki pages.
  
  - Patterns of students’ participation in developing their Regional pages and the types of action they conducted during page edits. Page history provided data on patterns student’s contribution and to identify various types of actions.

- Specialist groups wiki pages: Content of these wiki pages allowed me to examine how students applied the knowledge constructed in earlier phases of the curriculum in the context of a new inquiry project, one of the features of KCI.

4.4.3 Field notes.

According to Lincoln and Guba (1985), field notes can help researchers identify and describe patterns of practice within their target domain. I observed both class sections
during all the sessions in which students were engaged in the curricular activities outlined above. Classroom observation notes that I collected followed a simple template with the objectives of a class session on top followed by my observations of how the planned curriculum was implemented. These field notes allowed me to capture a more comprehensive picture of how the design vision was translated into design decisions and how the curriculum was implemented in practice.

4.4.4 Supporting documents.

I collected a variety of documents during the planning and enactment of the curriculum, including: Notes from co-design meetings; the curriculum planning wiki page, co-authored by the teacher and the research team; email communications among co-design team members; my research journal where I reflected on design and implementation decisions; and curriculum documents.

4.5 Data Analysis

This section presents the analysis methods, including the data sources used, and construction of measures and coding schemes.

4.5.1 Student learning gains.

To determine the overall effect of the Climate Change on students’ learning outcomes, I used students’ responses to pre-unit and post-unit questionnaires. This analysis provided a measure of the overall effectiveness of the Climate Change curriculum.
I scored all pretests and posttests myself and trained another doctoral student from my department to score one-third of the pretests as a secondary rater. I sat down with this second rater afterwards, to compare our scores. After discussing disagreements, we achieved an inter-rater reliability of 97%.

Overall, 11 students did not complete the pre-unit questionnaire and 2 students did not complete post-unit questionnaire. I decided to discard their data from statistical analysis in order to examine the within-subject improvements on this test that resulted from participation in the climate change unit.

4.5.2 Scientific quality of co-constructed knowledge.

The scientific sophistication of co-constructed knowledge is important to KCI. Hence, a successful implementation of a KCI curriculum would result in a shared knowledge base rich in science connections. As the students spent more time in their Regional group activity compared with other collaborative activities, I decided to use the final version of Regional Groups wiki pages to examine the depth of students’ collective understanding of Climate Change science.

I found the Knowledge Integration rubric (Linn, Lee, Tinker, Husic, & Chiu, 2006; Liu, Lee, Hofstetter, & Linn, 2008) to be appropriate for this purpose. Knowledge Integration rubric uses the number of scientifically normative links—accurate to the scientific theory—among ideas to place a coded segment in five levels of integration that increase in sophistication ranging from “No Knowledge Integration” to “Systemic Knowledge Integration”. At the lowest level, students demonstrate little normative understanding of the scientific phenomenon under study, whereas the highest level
represents students’ ability to make at least two elaborated and valid links between relevant scientific ideas.

The Knowledge integration framework has been used in a wide range of research over more than a decade (e.g. Cheng, 2008; Chiu & Linn, in press; Lee, Linn, Varma, & Liu, 2010; Slotta & Linn, 2009). These studies provided me with rich source of contextual information about how the generic rubric could be adapted to my own research, including a methodological paper on Knowledge Integration assessment (DeBoer, Lee, & Husic, 2008). Here, higher knowledge integration scores would represent a greater sophistication of scientific content or higher number of connections amongst ideas about regional implications of climate change. Table 1 shows four levels of knowledge integration for such a coding, and the criteria for coding a segment of written work under each level. To ensure the validity of my rubric, I checked it with my research supervisor, who developed the original version of the knowledge integration coding methodology (Slotta, 2004; Slotta & Linn, 2010).

In developing and applying this coding scheme, I decided to focus on the subheadings and subpages added under the “Climate Change Issues” heading. The main science concepts that I looked for were: Greenhouse Gases, Ocean Currents, Weather Patterns, Carbon Sinks, Carbon Sources, Energy Sources. To segment the text, I decided to use contents added under each identified climate change issue as the coding segment.

To apply the rubric to Regional groups wiki pages, I first copied relevant content in a word file. Then, I assigned a highlight shade to each code and highlighted sections of text that were best described by a knowledge integration level with the corresponding
Another Ph.D. student scored 25% of issues, randomly selected from all seven regions. An inter-rater reliability of 87% was achieved.

Table 1

*Knowledge Integration rubric for Climate Change unit.*

<table>
<thead>
<tr>
<th>Score</th>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Knowledge Integration</td>
<td>- Idea is not relevant to the scientific context of the inquiry task</td>
</tr>
<tr>
<td>1</td>
<td>Partial Knowledge Integration</td>
<td>- Idea is personal experience or opinion.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Isolated facts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- One or more main concepts are recognized. No explanation provided</td>
</tr>
<tr>
<td>2</td>
<td>Limited Knowledge Integration</td>
<td>- Possible connections between sub-concepts of a main concept is recognized but are either not elaborated or lack evidence</td>
</tr>
<tr>
<td>3</td>
<td>Complex Knowledge Integration</td>
<td>- Elaborate account of connections between sub-concepts and main concept. Other main concept may have been mentioned. Evidence is provided.</td>
</tr>
</tbody>
</table>

4.5.3 **Distribution of participation in knowledge co-construction**

The purpose of this analysis was to investigate the level of collaboration among students during the Regional wiki page activity. Here, I analyzed the act of collaborative
writing, in terms of the level of shared access and responsibility of individual students
during the collaborative process.

In addition to examining patterns of participation in collaborative work, van Aalst
and Chan (2007) advise researchers to examine how students’ engagement in
collaborative activities may impact the quality of their co-constructed knowledge. This
analysis allowed me to identify various edit actions through which the students created
and organized the content, and to investigate the extent to which the co-designed
curriculum promoted distributed participation in collaborative inquiry. By comparing
participation patterns across regional groups, I could select representative cases for
further in-depth analysis that examined the epistemic complexity the co-constructed
knowledge.

I used revisions of the Regional groups wiki pages as the main source of data for
this analysis. These pages were created during a longer-duration collaborative inquiry
activity, which maximized the chances for all group members to contribute to the
knowledge co-construction process. I used the history function of each page that
highlighted additions or deletions performed by user, to identify various types of edit
actions that could be coded. A sample comparison between two versions of a wiki page is
shown in figure 3. Added content is highlighted in green and deleted content is
highlighted in red.

To identify edit actions, I randomly chose one of the seven issues pages along
with its sub-pages. Content additions could be made in the form of plain text, list, table,
heading, external links such as online resources outside the Climate Change wiki space,
and internal links such as links to wiki pages within the Climate Change wiki space. I did not consider picture and graphs attached to the page.

Figure 3. Two versions of a wiki page are compared and changes are highlighted.

A wiki page’s history is shown as a list of all revisions to that page. I started with the earliest revision and progressed by comparing successive revisions in order to find how the page was edited. Note that a revision is created when a user clicks the “Edit” button and starts an edit session. The edit session terminates when the user clicks the “Save” button.
Table 2

*Coding scheme for Patterns of Participation in Editing Wiki Pages*

<table>
<thead>
<tr>
<th>Category</th>
<th>Subcategory and defining features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiate</td>
<td><strong>Heading (IH):</strong> Adding a heading</td>
</tr>
<tr>
<td></td>
<td><strong>Content (IC):</strong> Adding content under a heading (template or other) for the first time</td>
</tr>
<tr>
<td>Edit</td>
<td><strong>Edit Self (ES):</strong> Revising content that was added by self. Any revision counts (word, sentence, and paragraph level).</td>
</tr>
<tr>
<td></td>
<td><strong>Edit Other (EO):</strong> Revising content that was added by peers.</td>
</tr>
<tr>
<td></td>
<td><strong>Edit Template (ET):</strong> Editing the template provided by the teacher</td>
</tr>
<tr>
<td>Add</td>
<td><strong>Adding Content (A):</strong> Each paragraph, text list, or table is coded as “add” when it is added under a heading that already has content.</td>
</tr>
<tr>
<td>Link</td>
<td><strong>Link to Self (LS):</strong> Linking to a page within one’s regional group pages.</td>
</tr>
<tr>
<td></td>
<td><strong>Link to Other (LO):</strong> Linking to a page within the Climate Change wiki space outside one’s regional group pages.</td>
</tr>
<tr>
<td></td>
<td><strong>Link to Blank Page (LB):</strong> Linking to an empty page within the Climate Change wiki space.</td>
</tr>
</tbody>
</table>

During a typical edit session, a user can perform multiple edits. For example, the user can both add to and delete from the existing content. In identifying wiki edit actions, I accounted for every individual edit action the user performed. Peters (2010) used a similar segmentation, referred to as transaction, while coding wiki data.
Analysis of 72 versions of the main page and 8 versions of a subpage of a random Regional group resulted in 4 main categories and 9 sub-categories of edit actions that are shown in Table 2.

4.5.4 Growth of ideas.

Following the previous analysis, I perform an in-depth content analysis of selected cases to examine the progression of ideas during the Regional groups collaborative inquiry.

An in-depth analysis of student collaboration, as manifested in revisions of their wiki pages, can help reveal the extent to which they co-constructed knowledge about climate change during the Regional group activity. I sought to design an analysis similar to those who have analyzed students’ discourse in synchronous or asynchronous computer mediated exchanges (De Wever, Schellens, Valcke, & Van Keer, 2006; Weinberger, & Fischer, 2006; Zhang, Scardamalia, Reeve, & Messina, 2009). While wikis do not capture discourse, they can serve to reveal students’ collaborative effort to create a piece of writing or knowledge object. Following Hakkarainen (2003), I probed the growth of ideas in student wiki pages by examining the changes in the level of epistemic complexity in students’ contributions to their Regional pages. I investigated if the contributions moved beyond sharing information and correcting typos to elaborating on one another’s explanations and acknowledging relevant ideas. This analysis also served to reveal students’ attempt in regulating and monitoring their collaboration.

Three sections of the Regional groups pages was selected for this analysis:

• Climate change science within the region.
- Climate Change issues within the region.
- Information from models.

I coded all contents of these sections, including all sub-headers and subpages. Due to geographical variation between regions, not every science concept was relevant to all of the regions analyzed. Thus, the number of issues and science topics covered in the first two sections varied among the Regional groups chosen for this analysis.

To develop a coding scheme for this analysis, I started with existing schemes that would partly explain students’ contributions to wiki pages (Fujita, 2009; Hakkarainen, 2003; Hakkarainen, Lipponen, & Järvelä, 2002; Lakkala, Muukkonen, & Hakkarainen, 2005; van Aalst, 2009) and created a customized coding scheme that attempted to capture the developing sophistication of content within the pages. I, then, applied the codes to several revisions of a randomly selected Regional wiki page and gradually modified the codes by adding sub-codes where needed and discarding unused codes. The resulting coding scheme is shown in Table 3.

To code the data, I made an Excel file to track the growth of ideas in the Regional wiki pages. For each group, I made one Excel file where each row of the Excel sheet represented student’s contribution in a single transaction within an edit session. I used the columns of the Excel sheet to record detailed information about each action including:

- Version: Version of the wiki page in which a contribution took place.
- Contribution code: A code from the Content section of Table 3 described the nature of each contribution.
- Section code: Under each heading, students had created sections each dedicated to one subheading. A contribution could possibly change the
level of the epistemic complexity of the section where it was added. A section that was coded as “Elaborated Fact” would be coded “Unelaborated Explanation” if the most recent contribution was coded “Unelaborated Explanation”.

• Collaboration index: I used Add, Edit Self, and Edit Other codes from the “distribution of participation” analysis to specify how collaborative a contribution is. I assigned 0 to Add, 1 to Edit Self, and 2 to Edit Other.

This in-depth content analysis would reveal trends in the progression of ideas during the Regional Groups collaborative inquiry. For each section, the codes in the excel sheet showed changes in the epistemic complexity of the section from the first to the last revision. Another goal was to investigate whether any observed increase in epistemic complexity of ideas was the result of an individual or collaborative effort.

Table 3

*Coding scheme for evolution of ideas in wiki pages.*

<table>
<thead>
<tr>
<th>Main code</th>
<th>Sub-codes &amp; features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content</td>
<td></td>
</tr>
<tr>
<td><strong>Unelaborated Fact (UF)</strong></td>
<td>A list of facts and figures without explanation or link to existing ideas.</td>
</tr>
<tr>
<td><strong>Elaborated Fact (EF)</strong></td>
<td>An organized and connected list of fact. Elaboration of terms or phenomena without providing explanation or mentioning causal relationships. Description of terms, phenomena, or scientific concept without elaboration.</td>
</tr>
<tr>
<td><strong>Unelaborated Explanation (UE)</strong></td>
<td>These ideas go beyond introducing</td>
</tr>
</tbody>
</table>
describing a phenomenon and attempt to provide reasons and identify relationships. Explanation is not elaborate. The student introduces new information, rephrases or summarizes information from various resources. The sources used for explanation might be listed.

**Elaborated explanation (EE):** An elaborate account of relationships and reasons to explain phenomena under study. Goes beyond providing information and uses resources as evidence to back up and to advance personal ideas and arguments. Sources are listed.

**Regulation Planning (P):** A contribution that proposes a plan of action for the group, including making subpages, suggesting division of responsibilities, suggesting a timeline, and suggesting resources.

**Monitoring (M):** A contribution that evaluates the quality of group’s collaborative inquiry.

**Persuading Collaboration (PC):** A contribution in which students ask others to participate in adding content to a line of inquiry under a heading.

**Dissuading Collaboration (DC):** A contribution in which students ask others to refrain from editing a line of inquiry under a heading.

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### 4.5.5 Patterns of knowledge reuse.

The KCI model emphasizes the importance of collective knowledge construction to serve as a resource in subsequent inquiry projects. The Specialist group collaborative
inquiry activity in the third phase of the Climate Change curriculum aimed to promote such re-use.

Because of implementation challenges, this part of the curriculum was compromised, particularly in terms of the amount of class time given to the process of editing the Specialist group pages. I decided to analyze the Specialist pages only in terms of instances of knowledge reuse and not in terms of the quality of students’ synthesis of the impacts of climate change on their respected specialty.

All Specialist groups’ wiki pages contained regional information, and one goal of this analysis was to find out if this information originated from the Regional groups’ pages, or if the students had developed their own relevant regional knowledge without referring to the KCI knowledge base. Thus, for the final version of each Specialist page, I highlighted all knowledge objects that contained regional information and compared those knowledge objects with the contents of the Regional groups pages. The proportion of referenced vs. newly created content allowed inference about the extent to which students relied on Regional pages as resource. Note that in a number of cases, especially where the content was quite general or of a common sense nature, differentiating between referenced vs. newly created knowledge objects was difficult. Next, I read the contents of each Region page and marked knowledge objects relevant to seven Specialist groups.

4.6 Findings

4.6.1 Students’ knowledge gains.

A two-tailed dependent t-test performed on the content items of the pre-unit and post-unit questionnaires revealed a significant gain (p<0.001, t=8.18). The Mean score on
the pretest was 7.10 out of a possible 14 (SD= 2.81) where the mean posttest score was 11.48 out of a possible 14 (SD= 2.72). Thus, students did learn conceptual content relating to the global climate change content domain. Although they would have learned such content in many curricular formats, particularly in the elite school where this research was conducted, it is encouraging that this innovative curricular approach succeeded in helping students gain in their capacity to respond to the kinds of conceptual questions that were included in pre and post unit questionnaires.

4.6.2 Scientific sophistication of co-constructed knowledge.

In six Regional groups, the Knowledge Integration coding revealed a limited degree of coherence or connections, with knowledge objects with “No” or “Partial” Knowledge Integration scores accounting for the greatest portion of the final pages, and those with “Complex” Knowledge Integration scores accounting for the smallest portion of wiki content.

The Atlantic group, followed by the Ontario, and the Yukon and NWT groups, showed the most evidence of moving beyond adding isolated facts, towards integrating their collective knowledge. Figure 4 is an overview of the number of knowledge objects in each Regional group, color-coded for Knowledge Integration scores.

4.6.3 “Distribution of Participation” in Regional pages activity.

Students in seven Regional groups created 7 main and 82 non-empty subpages. The number of subpages varied between 1 for the Atlantic group, and 20 for the Nunavut group. Creating wiki pages in the Regional pages activity was presented to students as a
collaborative writing task, where all group members were encouraged to contribute to and to co-edit wiki pages that would make up their Regional wiki space. Yet the number of subpages in each Regional group, and the number of group members who co-authored those subpages suggests that cognitive responsibility was not shared among students to the degree originally intended (See Appendix F).

Figure 4. Scientific quality of Regional Groups wiki pages.

I used system-generated information about the number of authors per wiki page to gauge how collaboratively these pages were created. Table 4 provides information about Regional wiki pages including group members, number of subpages, and number of authors of main and sub pages, and number of revisions for each page or sub-page.
Table 4.

*Summary of information on revisions and contributors to main and sub pages of Regional Pages*

<table>
<thead>
<tr>
<th>Regional Group</th>
<th>Group size</th>
<th>Revisions to main page</th>
<th># of contributors to main page</th>
<th># of subpages</th>
<th>Average # of revisions to subpages</th>
<th>Average # of contributors to subpages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlantic</td>
<td>6</td>
<td>72</td>
<td>6</td>
<td>1</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>BC</td>
<td>6</td>
<td>106</td>
<td>6</td>
<td>17</td>
<td>4.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Nunavut</td>
<td>6</td>
<td>74</td>
<td>6</td>
<td>20</td>
<td>3.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Ontario</td>
<td>6</td>
<td>67</td>
<td>6</td>
<td>9</td>
<td>4.6</td>
<td>1.2</td>
</tr>
<tr>
<td>Prairies</td>
<td>4</td>
<td>51</td>
<td>4</td>
<td>8</td>
<td>4.1</td>
<td>1.8</td>
</tr>
<tr>
<td>Quebec</td>
<td>6</td>
<td>72</td>
<td>6</td>
<td>16</td>
<td>2.3</td>
<td>1</td>
</tr>
<tr>
<td>Yukon &amp; NWT</td>
<td>7</td>
<td>62</td>
<td>7</td>
<td>13</td>
<td>3.6</td>
<td>1</td>
</tr>
</tbody>
</table>

While in each group, every member was a co-author of the main page, the number of co-authors of subpages revealed a tendency towards single authorship. Of 82 subpages, 6 had 3 co-authors, 14 had 2 co-authors and 60 pages – almost 73% of subpages – had a single author (Figure 5).
Patterns of subpage co-authorship were different among Regional groups. Some groups, such as Quebec, tended to have most of their subpages single authored while in others, such as Nunavut, subpages were authored more collaboratively. In general, however, the number of co-authors per subpage suggested a divide-and-conquer collaboration style. However, these numbers alone do not provide a comprehensive picture about how consequential contents of subpages were towards the quality of final inquiry report. Without in-depth information about the quality of content co-constructed in Regional groups’ wiki pages, it is difficult to determine whether the division of labor worked in favor or against the quality of collective knowledge in Regional groups.

Examining how wiki Edit Actions were distributed among students in Regional groups allowed me to understand if students were equitably involved in knowledge co-construction. Figure 6 and figure 7 summarize, respectively, the distribution of content organization and of content creation Edit Actions for the seven Regional group wiki spaces. A comparison of figures 6 and 7 reveal that students carried out more content creation that content organization Edit Actions. There existed variations in these
measures between groups, which could reflect differences in students’ patterns of participation within the respective groups.

Figure 6. Content Creation in the Regional group pages.

Figure 7. Content organization edits in Regional pages.
When designing this analysis, I assumed that distinguishing between content creation and content organization actions would be straightforward. During the analysis, I occasionally used wiki tracking files to clarify the function of “Edit Self” and “Edit Other” actions whenever I suspected that these two actions were not used to elaborate and expand on existing content. To further elaborate on the findings for this analysis, I decided to revisit “Edit Self” and “Edit Other” actions in wiki tracking files of all Regional groups and split them into content creation and content organization categories. Knowing this, I could calculate a “Content Creation” and a “Content Organization” score for each student to help me better understand the range of students’ participation in knowledge co-construction:

- **Content Creation Score:** “Initiate Content” + “Add” + “Edit Self-content creation” + “Edit Other-content creation”

- **Content Organization Score:** “Initiate Heading” + “Edit Template” + “Edit Self-content organization” + “Edit Other-content organization” + “Link Self” + “Link Other” + “Link Blank”

Figure 8 illustrates individual students’ placement along two axes, Content Creation and Content Organization. The two axes cross at the mean value for each of the scores. I used this diagram to suggest four levels of contributions:

- **Overall high contributors:** Students who are in the upper right quarter of the diagram contribute to both content creation and content organization with both scores above the mean.

- **Content creators:** Students in the lower right quarter of the diagram whose contributions are more of Content Creation type.
• Content organizers: Students in the upper left quarter of the diagram who tend to organize the content more frequently than creating content.

• Overall low contributors: Students in the lower left quarter of the diagram with both content creation and content organization scores below or equal to the mean.

Figure 8. Students’ level of participation in knowledge co-construction through content creation and content organization.

Based on the above four levels of contribution, I identified two group-level patterns of participation in knowledge co-construction:
• Dominant sub-group: In dominant sub-groups, at least two individuals are overall high contributors or Content Creators and the rest fall into the other two categories. Groups with this kind of participation pattern were: Atlantic, Nunavut, Ontario, and Quebec.

• Dominant Individual: One individual has considerably higher contribution to content creation. The individual could be an overall high contributors or a Content Creator. Regional groups in this category were: BC, Prairies, and Yukon and NWT.

I used these two patterns to guide my selection of cases for in-depth semantic analysis. From the Dominant Sub-Groups, I selected the Ontario and the Atlantic groups. The Atlantic group demanded special attention as students in this group created only one subpage and their collaborative writing took place in their main wiki page. From the Dominant Individual groups, I selected the Yukon and NWT Regional group.

Note that classification of groups based on patterns of participation in knowledge co-construction would not yield claims about the dynamics of collaborative inquiry within the group as to whether the dominant subgroup was in any state of communications with the other members. The dynamics of group collaboration, while interesting, would require a design specifically focused on exposing those dynamics, and the data sources allowed by the wiki revisions cannot reveal much about how students within a group interacted with one another. I employ the group data from Figure 8 primarily as a means of identifying interesting cases for which I will conduct a deeper analysis of the growth of ideas.
4.6.4 Growth of ideas in wiki pages.

This analysis provided further evidence on whether the group worked as a whole to co-construct their knowledge or if there were individuals, or subgroups, whose contributions made up the bulk of the content, particularly the explanatory portions. The analysis also examined how students regulated their collaboration within the group, by leaving messages, assigning responsibilities and evaluating the work in progress.

Growth of epistemic complexity.

I examined whether the knowledge produced by groups of students within their Region pages grew in sophistication and whether the growth in sophistication was the result of group members’ collaboration. Previous findings showed that none of the Regional groups contained highly equitably participation in knowledge co-construction. Hence, findings of this section would not be expected to reveal highly collaborative knowledge construction, especially in Dominant Individual groups. However, it might be possible to detect whether students who were active in their groups worked together, rather than individually, and whether they paid attention to the quality of knowledge objects that were contributed by their peers.

To examine this, I applied the coding scheme explained in section 4.5.4 to wiki pages created by the students in the selected Regional groups. Of 39 coded sections in 3 groups, 9 showed an improvement in the final state of epistemic complexity while for the rest, the level of epistemic complexity remained the same. The summary of findings for coded knowledge objects across all selected Regional groups where the epistemic
The complexity of the knowledge objects improved over revisions of the wiki page is shown in figure 9.

![Figure 9](image)

*Figure 9.* The number of sections in Regional wiki pages showing growth in epistemic complexity.

The majority of coded sections, 30 out of 39, did not show any change in the level of epistemic complexity over revisions of wiki pages. Figure 10 illustrates the number of such sections for four levels of epistemic complexity.

Figure 9 shows some growth in final state of sections with a factual initial complexity level. However, based on figure 10 an equal number of sections coded Unelaborated Fact, 5 sections, and Elaborated Fact, 4 sections, showed no growth in the level of Epistemic Complexity. Sections that were coded for this analysis demanded explanatory account of scientific concepts or climate change issues. Thus, factual content shows lack of attention on the part of students to properly address the inquiry thread posed in those sections.
Figure 10. The number of sections in Regional wiki pages showing no growth in epistemic complexity.

Although only one third of the sections show a growth in the level of epistemic complexity, figure 10 shows that students succeeded to compose 20 sections that contained Unelaborated or Elaborated Explanation, 19 of which being Unelaborated Explanation. Adding to this the sections that did grow in epistemic complexity, 74.35% of all coded sections were of explanatory type. Bearing in mind that students were not exclusively asked to provide explanations, these findings shows that those students who participated in knowledge co-construction went beyond providing factual information. While this is encouraging, the point of the co-designed curriculum was for the students to collaboratively create content in their Regional pages. Therefore, if improvements in the
epistemic complexity of ideas were performed by individuals rather than through a
collaborative effort, one important purpose of the co-designed curriculum would be
defeated.

Previously, I defined a Collaboration Index to describe the extent to which a
coded section of a wiki page contained peer edits, as opposed to being solely written and
edited by an individual student. Here, I examine the relationship between the
Collaboration Index measure and the level of epistemic complexity achieved in coded
sections. I hypothesized that sections with higher Collaboration Index measures would
have higher levels of epistemic complexity, as their contents could had been improved by
peer edits. However, in the selected groups, this was not always the case.

In general, sections with high epistemic complexity did not have a higher level of
collaborative work than sections that were more factual and unelaborated. For example,
in the Atlantic group, only one section coded as Elaborated Explanation had a
collaboration index of 2. The tracking file, however, showed that the section reached the
level of Elaborated Explanation in the very first revision and subsequent edits to this
subheading were coded either as Unelaborated Explanation or Unelabeled Fact. In the
Yukon and NWT group, a Dominant Individual group, the Collaboration Index never
exceeded 1 for any section. The students in this group did not peer edit knowledge object
contributed to the coded sections of their Regional wiki page and subpages.

Another reflection of the lack of peer edits was redundancy in the contents of
Regional pages. Redundancy could occur within the same wiki page, as the case in the
Atlantic group main wiki page, or in different subpages as in subpages of the Ontario and
the Yukon and NWT groups. For example, the Atlantic group wiki page contained two
pairs of repeated subheadings: Ocean Currents and Weather Patterns. In both cases, one subheading belonged to the page template and the second one was added later on by the students. Moreover, students who contributed to the peer-created subheading did not contribute to or edit the template subheading.

Figure 11 shows an excerpt of the tracking file with contents of template subheading Weather Patterns and student-created subheading Air Currents/Weather Patterns/Winds. Content provided by Student1 is relevant to the second section as Students2, in her second paragraph added in version 50, talked about the Labrador region and could perhaps use the facts provided by Student1 to backup her explanation. The reason for lack of integration is unclear, as these subheadings were in close physical proximity to each other. At first, I suspected that the students who wrote the redundant subheading were from a different class sections. But in the case of weather patterns topic, Student1 and Student2 were from the same section and therefore had better chance of communicating face to face while creating content under these subheadings. This suggests that students were not conceptualizing this task as one in which they were supposed to attend to their peers’ contribution on the pages.

The Yukon and NWT Regional group wiki space contained three such instances of redundancy. Thermal Energy was a theme that was repeated in two subpages: The dominant individual in this group first created a subpage titled “Thermal Energy Yukon and NWT”, which contained content that addressed regional consequences of this scientific concept. A week later, another group member created a second page for this topic and added content that was irrelevant to the regional page inquiry. However, this subpage was never deleted or edited for improvement by any other group member.
Weather patterns

Newfoundland and Labrador are divided into 7 Climate Zones

- Northern Labrador
  - Tundra Climate
    - Above the tree line
    - Very little rain, especially in the northern portion of the region
    - Locally variable weather conditions are created by mountains and fjords

- Interior Labrador
  - Most continental climate in the province
  - Lengthy, cold winters
  - Upper Lake Melville area has shorter winters and warmer summers

- Coastal Labrador
  - Influenced by Labrador Sea
  - The area outside of Groswater Bay has the heaviest precipitation
  - Occasional extreme temperatures

- West Coast
  - Influence from Gulf of St. Lawrence reduces extreme temperatures but causes more precipitation
  - Increased elevation results in lower temperatures, stronger winds, more precipitation and cloudiness
  - Heavy snowfall during winter

- Northeast Coast and Central Lowlands
  - Driest area
  - Sea ice persists into May
  - Low winter temperatures and warm and sunny summers

- South Coast and Avalon
  - Mild winters
  - Heavy rainfall from October to December
  - Summers are cool due to low cloud and fog

Air Currents/Weather Patterns/Winds

In the winter, cold air masses are sometimes positioned adjacent to the warm air masses caused by the Gulf Stream along the Atlantic coast. These conflicting air masses, along with enough moisture, can create a strong storm called nor'easters. These storms form and intensify quickly and can dump copious amounts of precipitation, mainly snow, on the Atlantic provinces.

- Labrador often chills the warmer air overlaying it, and as a result, creates fog in the Atlantic provinces

- Maritime climate is characterized by cool summers and mild winters, as a result of a small temperature range during the year. This is because it is influenced by the ocean airflow, as water has a higher heat capacity than land.

- Severe weather frequency has been increasing all over Canada, but in the Maritimes in particular. Here is a chart showing weather-related disasters from 1900-1999.

[http://www.ec.gc.ca/TKEI/images/swgraph1_e.gif]

In Atlantic Canada...

- 49 hurricanes occurred from 1950-2000. These record-breaking years followed the quietest 4 years in the century.
- The ice storm in 1998 was a very costly disaster. In total, it cost $4 billion.
- Source: [http://www.ec.gc.ca/TKEI/cc_weather/s_weather_e.cfm]

Figure 11. Two similar subheadings in the Atlantic wiki page.

The insufficient attention paid to peer’s contributions could denote that the students did not fully grasp the idea of distributed cognitive responsibility and continued to function individually within small group settings.
Regulating collaborative inquiry

During curriculum implementation, the students did not receive any guidelines on how to regulate their group work, apart from the research team mentioning the “comment” function available in every wiki page. The co-designed curriculum anticipated a peer review activity, but due to time shortage, that activity was not carried out. Thus, any regulatory activity in groups, related to the planning or collaboration within the Regional page editing was initiated by the students and not explicitly scaffolded by the curriculum.

Students in the selected Regional groups used planning notes in two ways: Adding a group member’s name to the title of subpages, and signing up for or assigning peers to specialist roles. Students in the Yukon and NWT group made abundant use of planning notes to distribute the responsibility of creating content in the subpages among themselves, 66 in total vs. 17 in the Atlantic and the Ontario groups combined. These notes existed both in the main page, where students would add their name or a peer’s name in front of a subpage title, and in subpages with an optional embedded template where group member’s name would be added in front of their assigned specialist role. Not surprisingly, the dominant author in this group initiated 24 of the planning notes, 21 of which remained unaddressed by her group members. The other 3 were notes to herself, where she completed her response as a specialist to the issue that was discussed in the corresponding subpage.

Regulatory notes that encouraged or solicited collaboration existed in the Ontario and in the Yukon and NWT wiki pages. Except for one instance, these notes were initiated by and addressed by high contributors. For example, in the Ontario group two
students from section A, StudentO1 and StudentO2, and one student from section B, StudentO3, were high contributors. Realizing section B students’ lack of participation, a student in section A wrote the following message in the first line of the main wiki page on January 8 2009:

This is a message to the Period one class: YOU HAVE TO DO SOMETHING!!! (StudentO1, v39)

From January 8th to January 12th students in section B added content to both main and subpages of the Ontario regional group. The number of words added by the high contributor, StudentO3, significantly exceeded the number of words added by the two other low contributor group members—1514 words vs. 451 words. Section A students noticed the amount of work StudentO3 had done and on January 12th she erased StudentO1’s note and instead wrote:

thank you StudentO3 :D (StudentO2, v57)

This was the only interaction among the students in the Ontario group that showed their concern about equitable distribution of contributions among group members. Apparently, StudentO3 took on the responsibility herself without encouraging her three other group members in section B to be more active.

Even without being prompted or given a specific scaffold, students in the Regional groups realized the need for regulating and organizing their collaborative effort. Various strategies were used to assign responsibility to group members or to remind them to contribute to group’s collaborative effort. Yet regulatory note were mostly created and addressed by high contributors and thus had little effect on increasing the participation levels of low contributors.
Findings discussed so far have focused on students’ activities in Regional group collaborative inquiry. An important aspect of KCI Climate Change curriculum was for the students to use their shared knowledge and apply it to a new inquiry problem. The following analysis probes the extent and the quality of knowledge reuse in Specialist groups inquiry activity.

4.6.5 Knowledge reuse.

The “Specialist group” inquiry activity aimed to engage small groups of students in understanding the ways in which climate change would impact their concerns across Canada. The teacher explained to the students that they should use the knowledge that was co-constructed in Regional wiki pages. They were again grouped across the two sections, although students within each section presented their Specialist product during class. For each Specialist group, Table 5 summarizes information related to the number of regional knowledge objects, referenced vs. newly created, Canadian regions represented, and percentage of group members who contributed region-related knowledge objects. This analysis was based on a careful reading of Regional pages, with some level of inference, as the students did not cite any references for knowledge objects they put forward in their Specialist pages, nor did they provide a hyperlink to wiki page(s) that were used as resources.
### Table 5.

*Regional knowledge objects in Specialist group wiki pages  (*KO: Knowledge objects)*

<table>
<thead>
<tr>
<th>Specialist Group</th>
<th># of referenced regional KO*</th>
<th># of newly created regional KO</th>
<th>% of members adding regional KO</th>
<th>Regions mentioned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Industry</td>
<td>1</td>
<td>1</td>
<td>28.57%</td>
<td>Nunavut; Yukon &amp; NWT</td>
</tr>
<tr>
<td>Environmentalists</td>
<td>5</td>
<td>3</td>
<td>66.66%</td>
<td>All regions</td>
</tr>
<tr>
<td>Ministries of Environment</td>
<td>3</td>
<td>1</td>
<td>33.33%</td>
<td>All regions</td>
</tr>
<tr>
<td>Other Industry</td>
<td>3</td>
<td>0</td>
<td>42.85%</td>
<td>Ontario; Nunavut</td>
</tr>
<tr>
<td>Primary Industry</td>
<td>2</td>
<td>6</td>
<td>85.71%</td>
<td>Prairies; Nunavut; Yukon &amp; NWT; BC; Ontario; QC</td>
</tr>
<tr>
<td>Tourism</td>
<td>5</td>
<td>3</td>
<td>42.85%</td>
<td>Atlantic; Prairies; Nunavut; Yukon &amp; NWT; BC</td>
</tr>
</tbody>
</table>
As evident in Table 5, the overall number of knowledge objects present on any Specialist group page was relatively low. Environmentalists, Tourism, and Primary Industry groups had noticeably higher number of regional knowledge objects compared to the other three groups. With higher numbers of regional-related knowledge objects, the three groups discussed between 5 to 7 Canadian regions in their wiki pages. Unlike the Environmentalists and the Tourism groups, the students in the Primary Industry group constructed mainly new regional knowledge during this activity. Group members created subpages for primary industries in each region and subsequently, summarized them in their main page. Environmentalists and Tourism groups, on the other hand, made more references to existing material from regional pages.

The wiki pages of Energy Industry, Ministries of Environment, and Other Industry groups contained less than half the number of such knowledge objects in the other three groups. Energy Industry and Other Industry groups discussed only two Canadian regions in their wiki pages.

In the Energy Industry group, a student from the Quebec region and a student from the Nunavut region were the only members who added Regional knowledge object to their Specialist page. The two regions referred to were Nunavut and Yukon and NWT. I checked Quebec’s wiki space and realized that the same student had authored a subpage on Energy Industry in Quebec. Her having failed to integrated self-authored Regional information in the Specialist wiki page could mean a lack of commitment to use existing knowledge to improve the quality of the Energy Industry wiki page. I also located relevant material in Atlantic and Prairies Regional wiki pages that were not referred to in
Energy Industry group. The students representing those two regions were Overall Low Contributors and they may have lacked awareness of the contents of their Regional pages.

The Other Industry group, too, made connections to two Regional groups: Ontario and Nunavut. Students from the Atlantic, Quebec, and Ontario Regional groups contributed Regional knowledge objects to this Specialist group. The student from the Ontario group alluded to existing content in the Ontario wiki pages, while the other two students used content created in the Nunavut group about mining. Considering that none of these students were from the Nunavut group, I assumed that they could not identify relevant content in their own Regional group wiki space. Checking the contents of both Regional pages verified my speculation.

The Ministries of Environment group had a more challenging task compared to other Specialists groups, as this topic was not discussed in the Regional pages. Here, two students from the Nunavut and the Atlantic Provinces summarized information about changes in temperature, precipitation, and soil moisture from all seven Regional pages. These knowledge objects were strictly factual and did not lead to discussion of implications. The group also failed to co-construct new knowledge objects. In addition to the lack of relevant existing Regional knowledge, composition of this group may have contributed to this situation. Except for the abovementioned two students, other group members were Overall Low Contributors in their Regional groups.

I further explored the potential impact of the theme of Specialist group inquiry on the presence or lack thereof reference to Regional pages. The Environmentalists and Tourism groups could have benefited from the existing content the most, because climate change directly impacts the environment. According to the Tourism group, tourism
industry in Canada relies on environmental resources such as one-of-a-kind arctic scenery and animals. These topics were well covered in Regional pages within subheadings of Climate Change Science and Climate Change Issues template headings. The other four Specialist groups were less advantageous in this regard unless their Specialty was directly related to the abovementioned subheadings. There were, of course, exceptions where students did not use existing industry-related content, such as the Energy Industry group, which showed a low level of commitment to the quality of collaborative inquiry.

4.7 Discussion and Implications.

Neither the co-design nor the implementation of iteration 1 proceeded as smoothly as the co-design team had intended, as the unit began even before the design was finalized. Consequently, at times, the teacher felt that she had to postpone implementing certain aspects of the curriculum and proceeded with alternative lesson plans to cover the expected content. The design of the Specialist groups activity suffered the most, as it was only finalized near the end of the unit.

The sections below discuss the findings according to four main themes: Distribution of participation, quality of co-constructed knowledge, attendance to quality of contributions, and knowledge reuse. The chapter concludes with a discussion of the implications for iteration 2 of this study.

4.7.1 Distribution of participation.

One important element of distributed cognitive responsibility targeted by this curriculum was that of distributed participation in knowledge co-construction. Inequitable
participation was evident both in the distribution of wiki edit actions, and in the analysis of knowledge growth. Based on the analysis of participation, almost half of all students fell into the Overall Low Contributors category, leaving a smaller number of their peers responsible for creating and organizing most of the shared knowledge base.

Regional groups were dominated by either one member or by a sub-group. Note that the real group dynamics was unknown to me as multiple students could be sharing computers and thus contributing under their peer’s name. Still, in every Regional group, there was always at least one member who was an Overall Low Contributor (Figure 8). Another indicator of inequitable participation was the lack of improvement in students’ engagement in collaborative activity, as evident in Specialist group inquiry activity. Those groups that included Overall High Contributors or Content Creators, managed to include more regional knowledge objects in their wiki pages. Low Contributors didn’t show signs of improving their participation level.

In the absence of data that would capture students’ perception of collaborative work and their experience of collaborative work in this curriculum, it is difficult to say to what extent the students felt that the two inquiry activities were conducted collaboratively. There is some evidence that students worked together on pages, as well as evidence that it could certainly have been more equitable, and that students could have built upon their peers’ ideas more often, and to a greater level of epistemic complexity. It remains an open question what these students had in mind, regarding their responsibilities to peers, and the role of other members of their group, in their own progress. Perhaps students could benefit from reminders throughout the unit to participate in activities that lead to creating a shared knowledge base.
4.7.2 Quality of co-constructed knowledge.

I examined the quality of co-constructed knowledge in the Regional group inquiry activity from two perspectives: The level of knowledge integration and the epistemic complexity.

During the co-design meetings, the researchers and the teacher had emphasized the importance of reasoning and argumentation in collaborative work, with the goal of encouraging students to engage in creating wiki pages that yielded evidence-based explanations. Yet, no specific scaffold was designed to foster this aspect of KCI. The analysis of knowledge growth in three regional groups showed that students were able to provide explanatory knowledge objects. Although unelaborated explanations did outweigh elaborated ones, students’ ability to move beyond factual contributions, in the absence of explicit guidelines, was promising.

However, the levels of epistemic complexity do not necessarily correlate with high levels of science integration. Examining the final version of the Regional pages of four groups revealed that students in those groups added more discrete pieces of information to pages and did not fully integrate climate change science concepts. The other three groups had comparably more subheadings and subpages that showed their efforts for knowledge integration. Constructing deep science connections is at the heart of KCI model and low levels of knowledge integration suggested that supports for these processes needed to be strengthened.

Considering the past successes of KCI curricula in yielding integrated knowledge objects in physiology and biodiversity units (Peters, 2010), this limited level of coherence and complexity was notable. I reviewed design notes in terms of underlying themes and
scaffolds that were used to support students’ collaborative knowledge construction. The Regional groups activity was conceptualized as a scientific inquiry activity that also attended to social aspects of climate change. The template provided for this activity represented such design as in the “Overview Description of the Region,” where students were asked to highlight cultural and industrial trends of their selected region. Late in the curriculum, students were introduced to their Specialists role, which were socially or economically oriented. It is possible that the scientific aspect of this inquiry was overpowered by its social aspect. Perhaps, students should have first became engaged with climate change science within each region and then asked to look for social and industrial implications.

While some design and enactment flaws likely compromised the fulfillment of the KCI model, specifically those regarding science integration, it was still helpful to look deeply into patterns of knowledge co-construction and examine collaborative work in various forms, including its effect on the growth of ideas and distribution of cognitive responsibility.

4.7.3 Attendance to quality of contributions.

Findings from the content analysis of the growth of ideas indicated that overall, collaboration and co-authorship did not positively affect the epistemic complexity of content. Subheadings and subpages that were peer edited or had multiple authors did not show higher levels of epistemic complexity compared to single-authored pages. This does not imply a negative effect of collaboration, but rather that students would create
explanatory content and would then improve the quality of content individually, for the most part.

In the Regional groups, certain students consistently contributed more explanatory knowledge objects, meaning that they did pay attention to the overall quality of work within their group pages. However, they were also expected to help increase the epistemic complexity of the content of all pages and subpages that other group members had created. But there was a general lack of evidence that even these high contributing students extended their cognitive responsibility to such a shared level. Still, it should be pointed out that these students would sometimes use regulatory comments to notify less active members to participate.

One explanation for a lack of collaborative effort to improve the quality of the group pages could be students’ existing beliefs and perceptions about their responsibility as group members. In the school where this research was conducted, it is not permitted for teachers to evaluate students according to the quality of their group work. Rather, the teacher would have to consider their individual contributions during a collaborative activity. Such assessment practices could partially account for why students with higher quality contributions might have been reluctant to edit the work of their peer, and thereby to improve the knowledge objects that had lower epistemic complexity.

Another contextual obstacle was the limited time that these students had to conduct their collaborative inquiry. The Regional group activity started later in the unit that anticipated and therefore, the time originally dedicated to this activity had to be shortened. It is possible that with little time, students preferred to first establish a good personal record by contributing high quality content. Students who were either less
motivated or had lower levels of knowledge would therefore not benefit from working with their more capable peers. In general, the data collected in this curriculum could not be used to support or refute such conjectures.

Redundant content was another indicator of the lack of attention given by students to their group’s collective knowledge. Redundancy was visible both in main pages and in subpages of regional groups. Whenever subheadings or title of subpages within the main page were similar, there was a chance that different students had addressed the same theme without integrating their contributions. Also, it was possible that students contributed semantically similar content within the various pages that did not, at the first sight, appeared related.

I propose two reasons for such lack of attendance to redundancies. First, students were more willing to record their contributions under their own name rather than integrating it with the contributions of other group members so that the teacher would acknowledge what they had individually contributed to group work. The other reason could simply be that the students didn’t have time to review their shared knowledge collectively and integrate it to compose a cohesive inquiry report.

The design of the next iteration of the curriculum should attend to further promoting and fostering distributed responsibility toward the quality of shared knowledge.

4.7.4 Knowledge reuse.

The goal of using the collective knowledge as a resource was introduced as an important element of the curriculum at the outset of the unit. For example, students were
encouraged to use annotated references in their Regional groups inquiry. The Specialists group activity explicitly required students to use co-constructed knowledge represented in Regional wiki pages as their main resource. Yet, findings show that four groups had difficulty making connections to the existing knowledge base.

A possible explanation for such minimal re-use of the Regional group knowledge is that specific knowledge objects in the Regional pages that were relevant to the Specialist inquiry task were difficult to find. This was a result of design decisions, which did not build in sufficient structure in the regional pages and reinforcing needs in the Specialist assignment. The KCI model tries to make the knowledge community concept more accessible to teachers and their classrooms by providing a certain amount of structure to guide students in their knowledge co-construction efforts. In the present study, the co-design team had projected that certain themes would emerge from Regional groups inquiry that could be further investigated from social, political, and industrial stakeholders point of the view. In practice, however, some of the anticipated stakeholder roles turned out to be less relevant to emergent themes in Regional group inquiry. In the absence of relevant Regional material, students could either construct knowledge in their Specialist pages, such as Primary Industry group, or create Specialist pages with minimal regional knowledge objects, as in the case of Ministries of Environment. For the next Iteration of this research, the jigsaw inquiry activity should be redesigned to increase thematic relevance of the two inquiry activities.

The fact that students failed to locate relevant knowledge objects within the Regional wiki spaces could also reflect a low assumed cognitive responsibility towards collaborative work, where group members cared more about making sure they made their
own high quality contribution. Considering that the Specialist inquiry activity was given to students only three class sessions from the end of the unit, students may have taken it rather lightly, and may indeed have had limited understanding of how this activity was meant to connect to the Regional group activity. Moreover, the wiki platform did not facilitate searching through the shared knowledge base. Although the wiki provided a tagging function, the tags applied to pages rather than knowledge objects. As the students had little time to complete their Specialist pages, reading through all potentially relevant Regional pages might have been impractical.

4.7.5 Implications for iteration 2.

The findings above reveal two important implications for iteration 2 of the KCI Climate Change curriculum. First, additional scaffolds should reinforce the notion of a knowledge community and a collective epistemology amongst students. This could be achieved through more frequent epistemological treatments that elicit students’ reflection on how their work contributed to a collective knowledge base, in relation to their peers. Second, the jigsaw activity should be redesigned thematically to encourage a greater level of science connections and to maximize the potential connections between the theme of the final inquiry activity and the co-constructed knowledge developed in other inquiry activities leading to it. The following scaffolds could serve those purposes within iteration 2 of the curriculum:

• A “Group Planning” scaffold where group members were supported in planning their inquiry, assigning roles, monitoring their progress, and addressing problems related to group dynamics or quality of content. This
scaffold could be complemented with a visualization of students’ activity level so that group members have a real sense of the contributions of each individual member.

- “Embedded Reflection Notes” to help students reflect on their contribution to group work, the scientific and epistemic quality of their contributions, and their use of co-constructed knowledge as a credible resource.
- A “Peer Review” scaffold that supports peer comments and requires students to address areas of improvement in their co-constructed knowledge that are identified by peers. This scaffold would also serve to raise students’ awareness of shared knowledge.

From a technological standpoint, a tagging function applicable to discrete knowledge objects, rather than whole pages, would facilitate the location of relevant knowledge objects. Consequently, knowledge reuse would be better supported.

Overall, iteration 1 was a modest success. This was the first time anyone in the school had ever taught this topic, because of its new introduction to the Ontario Ministry standards. Thus, it should not be a surprise that the design and enactment of the first iteration had some challenges. The next chapter presents the design of second iteration of the Climate Change curriculum and the outcomes of its enactment.
CHAPTER 5: DESIGN ITERATION 2

Iteration 2 of this study was conducted in 2009-2010 school year, at the same school as iteration 1. The basic goal was to revise the Climate Change unit so that it emphasized collaboration in the knowledge construction activities and added epistemological framing into the KCI model. Once again, the research team consisted of my research supervisor, another Ph.D. student, the same teacher from last year, and myself. Beginning in August of 2009, the co-design team met weekly to redesign the Climate Change curriculum unit based on interim findings from iteration 1, and began the classroom trials in November 2009. This chapter presents the specific research method, findings, and discussion of iteration 2.

5.1 Participants

For this iteration, three teachers volunteered to participate and implement the Climate Change curriculum in their grade-9 classes. Two of them, Jerry and Mindy (pseudonyms), were unable to regularly attend the co-design meetings, leaving most of the design decisions to the teacher who was already a KCI collaborator, Barbara. Table 6 summarizes the number of students in five participating class sections.

5.2 Research Timeline

Curriculum co-design for iteration 2 was organized in three main steps:

- Step 1 (August 2009 - November 2009): Curriculum co-design
• Step 3 (February 2010 – July 2011): Analysis of data collected in iteration 2.

The Co-design team, with the same members as iteration 1, reviewed interim findings from iteration 1 to revise curricular activities and improve scaffolds. The co-design team kept the two other teachers well informed about design decisions throughout the process. In addition to attending an introductory meeting where the KCI research discussed, these two teachers were copied on all email correspondence among the co-design team and followed the curriculum design in a password-protected wiki.

Table 6

<table>
<thead>
<tr>
<th>Class Section</th>
<th>Number of Students</th>
<th>Teacher</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>27</td>
<td>Barbara</td>
</tr>
<tr>
<td>B</td>
<td>16</td>
<td>Barbara</td>
</tr>
<tr>
<td>C</td>
<td>28</td>
<td>Mindy</td>
</tr>
<tr>
<td>D</td>
<td>18</td>
<td>Jerry</td>
</tr>
<tr>
<td>E</td>
<td>20</td>
<td>Mindy</td>
</tr>
</tbody>
</table>

5.3 **Curriculum Co-design**

Iteration 2 design decisions were geared towards promoting distributed cognitive responsibility, science-focused collaborative inquiry, and creating opportunities for integrating the community’s ideas into the inquiry designs. The curriculum theme,
educational goals, and a large portion of the curricular material were retained from iteration 1.

Once again, a three-phase curriculum was designed. The next section details the support structures and scaffolds designed for each phase, focusing on those collaborative inquiry activities that directly produced data for this study. An outline of the curriculum and relevant research activities is presented in Figure 12.

*Technology platform.*

The co-design team recognized the limitations of the existing wiki platform to support a heavily collaborative curriculum. In addition to only allowing a single author per page, the tagging features in the wiki platform did not allow for content in units smaller than a page. The latter shortcoming made locating and thus building on existing knowledge objects difficult. One member of the co-design team built an alternative platform that ran on the Drupal content management system, version 6. This technology platform did not allow teachers or students to create pages other than those defined by the co-design team. It, however, allowed sub-sections of pages to be defined, so that multiple authors could work on the same page. Finally, it added new functionality for tagging, as well as a functional reference tool that allowed students to easily find and add references to their pages.
The resulting website included the following sections in the main navigation menu:

- My Account: A list of the groups that a given user belonged to plus account information

*Figure 12. Climate Change curriculum outline, iteration 2.*
• My Reflections: A list of reflection to be written throughout the unit. Pre-unit and post-unit questionnaires were also implemented as reflections

• References: A list of annotated references

• Brainstorm: A list of brainstorm issues

• Issues: A list of issues that were the topic of collaborative inquiry during the second phase of the curriculum

• Remediations: A list of remediation plans that were the topic of inquiry in phase 3

• Resources and Help files: To decrease students’ and teachers’ dependency on two research assistants’ technology support, this section contained how-to documents

The main technological affordances added by Drupal for this curriculum iteration were: personalized login, versioning, forms, tags, and allowing multiple editors per page.

Drupal supports flexible user-input forms, including various input types such as multi and single line text box, check box, radio button, and grids, that facilitated the design of pre and post-unit questionnaire and reflection notes.

The KCI model called for facilitated access to the shared knowledge base, in order to make the community’s efforts relevant and accessible to subsequent inquiry activities. Applying semantic tags to knowledge objects could facilitate the search process and increase accessibility to components of shared knowledge. Drupal allowed for the splitting of a page into sections and the design team assumed that it was possible to apply tags to sections of text instead of whole pages. Search results using tags would
yield relevant knowledge objects. In practice this functionality was not achieved in this implementation.

Drupal provided an enhanced user-interface for designing pages for curricular activities that captured semantic and functional aspects of the activity. For example, in a typical page titles and headings were implemented using an uneditable text field, unlike a wiki page where the headers were editable. Sections of the page that required students to compose a text were implemented using an embedded multimedia html editor.

Iteration 2 of the Climate Change curriculum contained several individual activities in addition to whole class and small-group collaborations. With Drupal, it was possible to offer students personalized logins that gave them access to their reflection forms and to their group materials. Figure 12 shows a schematic of the curriculum design, which is described in detail shortly.

5.3.1 Phase 1: Establishing a knowledge community.

Phase 1 consisted of activities that introduced the students to a knowledge community culture with regards to understanding the importance of collaboration and sharing knowledge in a public space. The first three sessions of classes were dedicated to this phase.

The curriculum started with a video about the impacts of climate change on the life of Canadian aboriginals. The teachers initiated a discussion so that students reflect on climate change issues as highlighted in the video. The research team created usernames and passwords for all students, allowing them to write the pre-unit questionnaire in the first class session.
Introduction to knowledge communities: Presentation and discussion.

The introduction to knowledge community scaffold had two parts: A short lecture that explained the fundamentals of knowledge communities; and a hands-on activity to engage students in their first attempt to initiate shared knowledge in the Drupal website. First, my research supervisor attended the classes and talked to the students about the concept of knowledge community. He explained that through this unit students would conduct inquiry in collaboration with their peers using a custom designed technology platform. He emphasized that collaborative work allowed participants to learn more by building on ideas that have been shared by others, and shared examples from the scientific community, namely the Human Genome project, Ocean floor mapping, and Wikipedia. The purpose of the research was also discussed, providing a rationale to the students for why the designed curriculum engaged students across multiple sections in constructing, sharing, and reusing knowledge.

The teachers then explained how this collaboration-heavy curriculum was consistent with the school’s values and that it could provide a rich learning opportunity. Moreover, the students were reminded that their individual contributions to group work are recorded in the technology platform and would be used by the teachers for evaluation. These remarks were followed by a short presentation where I showed major changes in design, along with the rational for them. I showcased two main design features:

- A highly structured and navigable Drupal site.
- A planning page that would be provided for all student groups

The second part of introduction to knowledge community activity was reference annotation. The teachers assigned a climate change topic to each student—one topic
could be assigned to multiple students across five sections—and explained the task of finding a reference, annotating it, and assigning tag(s) to the it in the Drupal website. In addition to a default tag, the assigned reference’s topic, students could tag their reference with other relevant reference topics. My fellow research assistant demonstrated the reference section in the Drupal website. Required fields for the reference annotation activity remained the same as iteration 1. The appearance of the scaffold, however, was enhanced by Drupal page elements.

*Climate change issues brainstorm.*

In an extended brainstorm activity each class section began their brainstorm using the ideas and artifacts handed down from the previous section. The purpose of this activity was to synthesize students’ ideas of climate change issues into a set of salient climate change issues that would serve as the foundation for an upcoming collaborative inquiry activity.

The brainstorm activity progressed in three steps:

- **Step 1:** In the first session of each class section, after discussing the video, students gathered in desk groups of four to six and were asked to write down all climate change issue that they deemed important on post-it notes and attach them to a chart paper. Student groups in section 2, section 3, section 4, and section 5 were given one chart paper and one pad of post-it notes per group, and attached post-it notes with ideas written on them on a chart paper.
• Step 2: In session 3 of the unit, students in section 1 sat in groups and received a piece of chart paper. The teacher, then, instructed them to identify common themes among notes on the chart paper, select a name for each theme and place relevant notes under the identified themes in a new chart paper. Section 2 and section 3 students continued this process until all post-it notes were either placed under a category or were deemed irrelevant and discarded. In addition to categorizing ideas, students in section 2, section 3, and section 4 revised existing categories to rename categories or move post-its if necessary.

• Step 3: Composing brainstorm categories as issues in the brainstorm section of the Drupal site, was the final step of the brainstorm activity. My fellow researcher and I showed students how to make a new issue topic in the brainstorm section of the website. The teacher in section 5, Barbara, had already reviewed all issues categorized on chart papers. During section 5, she wrote the names of categories on blackboard, assigned one student to each topic and gave them a laptop, and had five students take the categorized post-it notes to the students who were responsible for creating brainstorm issues pages on Drupal. These students first created a brainstorm issue page named after a specific category. Then, they collated the contents of all notes in that category in a list.

Overall, 31 brainstorm issues pages were created in this sequence. Contents of a sample brainstorm issue page can be seen in Figure 13.
5.3.2 Phase 2: Co-constructing a community knowledge base.

Phase 2 consisted of a six-week collaborative inquiry project, five individual reflections, and a peer review activity.

**Collaborative inquiry to co-construct shared knowledge base.**

The central component of this phase was an six-week collaborative inquiry project where small groups were defined across the five class sections, each working on a climate change issue identified from the brainstorm activity. The students worked on their climate issue page periodically throughout the six weeks, adding ideas from scientific and social perspectives, as aligned with the progressing topics of the course.
This activity allowed students to co-construct the core knowledge base of their classroom community.

Based on the synthesized list of climate change issues from the brainstorm activity, the teachers composed a refined list of issues to guide students’ inquiry. Criteria for selecting topics were relevance to the scientific concepts covered in the unit, and availability of relevant resources so that students could conduct evidence-based explanation-rich inquiry projects. The initial list of 31 brainstormed issues was reduced, many being combined into broader encompassing issues, to 16, which provided the framework for the knowledge base.

In the “Issue page” activity, students were required to examine a given issue from the following perspectives: Scientific evidence including the greenhouse effect, thermal energy circulation, and carbon sinks and sources, models and scenarios, legislation, and existing remediation plans.

Informed by findings from iteration 1, a more explicit scaffold was used for this inquiry activity. A multi-section page was implemented in Drupal for each climate change issue (Figure 14) that consisted of the following sections with embedded hints and/or sentence openers that sought explanatory rather than fact-based responses (Hakkarainen, 2003):

- Description of issue: Students would provide an overview of what the issue was about, why it was significant, and what they learned about it. This section was made more explicit in iteration 2, as students in the first iteration neglected to conclude their collaborative inquiry project in phase two of the curriculum.
• The Sciences: By specifying three main scientific concepts covered in the unit, this section emphasizes science connections as relevant to the selected issue. In the template, shown shortly, a hint was provided for each of the three concepts to remind students of the purpose of these science sub-sections.
  o Greenhouse effect (Hint: Please give a detailed description of how the science of greenhouse effect causes or influences your issue.)
  o Thermal energy and circulation (Hint: Please give a detailed description of how the science of thermal energy and circulation causes or influences your issue.)
  o Carbon sinks and source (Hint: Please give a detailed description of how the science of carbon sinks and sources causes or influences your issue.)

• Models and Scenarios: during the course of this unit, students used two climate change models, TELS and Canadian models. In this section, they could use those models to investigate current state or predict future implications of their selected issue.

• Legislation: This section emphasized the social aspect of Climate change phenomenon. Students would inquire into and evaluate the effectiveness of existing legislations regarding to their selected issue. (Hint: Here are some current legislations that have been put in place to address this issue.)

• Remediation: Identifying remediation plans in place to ameliorate adverse impacts of climate change, prepared students for phase 3 of the
curriculum. With 16 issues, students would create a comprehensive account of existing plans, so that in the next phase they could propose modifications and improvements to these remediation plans. (Hint: Here are some current efforts that have targeted this issue in attempt to slow it down.)

- References: The reference section in Issues inquiry pages allowed students to search existing references. The design team assumed that by making shared knowledge base more accessible through search, students would gradually become accustomed to checking their existing knowledge base before adding new knowledge objects.

*Figure 14. An empty Climate Change Issue page.*
Before introducing the Issue Page activity in class, the three teachers divided their classes into small groups of three to four students. These groups were defined in Drupal and assigned a group name. The research team then created a Drupal page for each issue using the predesigned template. Next, the teachers in each of the five sections introduced the activity and emphasized that two groups of students from two different sections would collaborate to conduct inquiry on a selected issue. In each class section, the teacher listed the inquiry topics on the board, mentioning the ones that had already been assigned two groups of students, and asked student groups to select a topic for which there were not already two groups committed. The researchers then assigned student groups to their selected pages in Drupal. For this activity, student groups could edit the page that was assigned to them and could only view other Climate Change issues pages.

The co-design team intended to have at least two groups of students assigned to each issue. However, miscommunication between two teachers led to two issues being selected by only one group. I brought this issue to the attention of teachers but they decided that those two groups should continue working on their selected issues without collaborators from another section, as they had already started their inquiry.

Figure 15 shows a snapshot of a sample Issue page in edit mode. Each section of an Issue page could be edited in a rich-text editor that supported multimedia files. This way, students could add picture, sound files, and videos to enrich the representation of their inquiry project.

Issues pages also contained log messages and comments. A log message was an optional text area in the edit modes, where a student editing the page could enter a message for the rest of the team to explain what she did to the page in her edit sessions.
and/or request her group members to edit certain parts of the page. Log messages could be added by team members. Comments could be added by anyone in the five class sections to the end of an Issues page. In this curriculum, comments were used to implement peer review.

<table>
<thead>
<tr>
<th>Description:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web page addresses and e-mail addresses turn into links automatically.</td>
</tr>
<tr>
<td>Links and paragraphs break automatically.</td>
</tr>
</tbody>
</table>

**Figure 15.** A screenshot of a Climate Change Issue page in edit mode with multimedia supporting html editor.
**Group planning pages.**

To reinforce students’ metacognitive awareness of their group progress, a planning page was included as a scaffold so that students in their inquiry groups tease out their goals, identify needed tasks, plan for accomplishing their goals, and review the progress of their collaborative inquiry. For each Climate Change Issue, a planning page was designed in the form of a “to do list”. An empty to-do list with embedded scaffolds is shown in Figure 16.

![Sample To-Do List](image)

*Figure 16. An empty to-do list.*

The purpose of the to-do list was to weave concurrent planning and revision during collaborative inquiry so that students identify and manage logistical tasks they needed to address in order to complete their inquiry pages. To avoid a fully divide-and-
conquer situation in collaborative groups, the teacher explained that every member of the group was responsible for contributing to their inquiry page, regardless of the specific task(s) they had signed up for. Students whose names were listed under a specific task would oversee the quality and completeness of the work in progress. To-Do lists were private to a given group, the teachers, and the researchers.

The Issue page activity lasted from session 4 to session 18, with three reflection notes scheduled for session 5, 11, and 17 to capture the development of students’ understanding of their social and cognitive role during collaborative inquiry activities.

**Individual reflections.**

Reflection notes contained various types of questions, including open-ended responses, multiple choice, and likert scale, and were integrated with the Climate Change Issues inquiry activity. Reflections were private to the author of the note, the teachers, and the researchers. Items addressed in reflections fell into two broad categories of content knowledge and metacognitive knowledge. Three reflection notes were specifically designed to promote curricular goal of the KCI model that is establishing a knowledge community across classrooms, and required students to reflect on the quality and quantity of their contributions to the group; group dynamics; knowledge co-construction; implications of peer feedback; scientific depth of co-constructed knowledge; and opportunities for reusing and/or improving existing knowledge base. Reflections 4, 5, and 6 produced data for this study and are listed in appendices H, I, and J respectively.
Phase 2 of the curriculum supported students across the five class sections as they co-constructed a knowledge base that connected instructional material such as lectures, labs, and documents with scientific and social aspects of real-word climate change issues. Small groups of students worked collaboratively to develop a shared knowledge of their selected issue. The theoretical perspectives of KCI, and of the knowledge community perspective, propose collective ownership and responsibility towards shared knowledge.

In iteration 2, a peer review activity was designed to require students to review knowledge co-constructed in other groups and thereby promote a wider awareness of the collective knowledge base. In session 13, each student was assigned one Issues page to review. Barbara provided the following rubric for peer reviews:

- Be positive: Identify something that is good/strong. Say what is good about it.

- Provide constructive criticism:
  - Identify something that should be improved
  - Be very clear as to what you are talking about; why it should be improved
  - Give a good suggestion for making this improvement.

The three teachers approached the peer review activity somewhat differently. Mindy and Jerry asked their students to comment on the whole Issue page, while Barbara recommended that the students focus on one section of the page. The technology tool for peer reviews was the embedded comment section of the Issue pages. While this feature was mainly used for the peer review activity, students in the Issue group sometimes used
the comment space to communicate with each other about their group’s progress and collaboration.

5.3.3 Phase 3: Using co-constructed shared knowledge as a resource

In phase 3, curricular activities shifted to include opportunities to reuse knowledge objects from the shared knowledge base. Phase 3 consisted of a within-section small group inquiry activity to examine strengths and shortcomings of remediation plans, identified in phase 2, and to suggest improvements or propose new plans. This phase lasted for four class sessions.

Collaborative inquiry activity.

The Remediation plan activity was bound to single sections of classes, meaning that two groups from two different class sections could choose the same remediation plan topic, but each would conduct their inquiry independently. Students examined the effectiveness of their selected remediation plan with regard to any relevant issues, to suggest improvements to the plan, and to predict the implications of the modified plan in the future. Each group was provided with a Drupal page that included built-in scaffolds for the following sections:

- Title of the Remediation Plan
- Description of the Remediation plan (300-500 words)
- Three issues that are mostly impacted by this remediation plan
- Effectiveness of the remediation plan of two of the selected issues
- Overall Effectiveness of the plan
- Proposed improvements, extensions, or new alternatives to the Remediation plan
- Predication of Future Effectiveness of Modified Remediation
- References

Students were advised to use the scientific simulations and models that had been employed during the course unit, including two WISE models, and a Web-based simulation of Greenhouse Gases and Population/CO2 Emissions, to illustrate the implications of their modified remediation in the future and explain those in less than 300 words. Links to the WISE models were provided, and the prompt suggested that students run the model, adjust variables, and include a screen capture of the model in fifty years’ time their report. During the last session of the Climate Change unit, student groups in each of the five sections presented their page to the class.

The technological scaffolds for remediation pages allowed multiple students to simultaneously edit different sections of the same page. Every remediation page was implemented as a collection of sub-pages concatenated into one overarching page as shown in figure 17.

The viewing permission for remediation pages was restricted to being “within section”. Thus, students in one section of the M3 class could only see the remediation pages created by their peers in that section. This was to ensure that students working on the same remediation topic in two different sections were not tempted to peruse the contents of their peers in the other section, a restriction desired by teachers who were concerned with assessment issues.
It is important to describe a misunderstanding in its enactment, where teachers assumed an approach to selecting the Remediation plan topics that differed from the one assumed by researchers. In the course of the co-design meetings, it had been discussed that the remediation approaches identified by students on their Issue pages would provide a source of the topics, thereby supporting the KCI principle of enabling community voice to influence the inquiry. However, the teachers had forgotten this decision, and defined a set of common remediations, which they handed out to students, without checking with the researchers.

In an effort to make connection to the Issue pages, the teachers agreed that it would be a good idea to have the students review Issues pages and find Issues that were affected by their selected remediation.
5.4 Data Sources

5.4.1 Pre-unit & post-unit questionnaires.

For this iteration, the pre-post unit questionnaire was revised to measure changes in students’ knowledge of climate change and gain an understanding on their attitudes toward learning science and collaborative work with their peers. The test was divided into two sections: Knowledge of Climate Change, and Purposes and Ways of Learning Science at School. Each section consisted of multiple-choice, long-answer, short answer, and likert-scale questions (See Appendix G).

The Knowledge of Climate Change items were created by the lead teacher and further revised for clarity and ease of implementation by my research supervisor. The second section of the questionnaire, Purposes and Ways of Learning Science at School, asked students to reflect on what they referred to as credible sources of knowledge, application of their school knowledge in other situations, current level of interaction with peers, and current attitude toward collaboration. In composing these questions, I referred to existing literature on motivation for collaborative learning, epistemological commitments toward learning science, and collaborative knowledge construction (Chow & Law, 2005; Madhok, 2006), using my research objective as guide. I intended this section to provoke students thinking about working in collaborative groups within a larger context.

The post-unit questionnaire was identical to pre-unit questionnaire at the time of design. During implementation, however, some modifications were required for the post-test, for two of the class sections. Moreover, the response rate for pre and post-unit
questionnaires was 92% and 56%, respectively. In order to respond to overlap with her existing assessments, one of the teachers made changes to the formatting and content of the test. By the time these problems had been clarified, it was too late to make corrections, without compromising the teacher’s class time. A bulk of post-unit questionnaire data was lost to this enactment issue. The other two teachers asked their students to complete the post-unit questionnaire as a homework activity. However, the response rate for these three classes was low, with only 24 out of 63 students completing the post-unit questionnaire.

5.4.2 Drupal pages.

Of the sixteen Climate Change Issues pages, I considered all revisions of fourteen pages as one source of data. I discarded two of the Issues pages, as only one group of students worked on each. A goal of this research was to maximize non-collocated collaboration among students, and to understand how students would use technological scaffolds to co-construct and improve their knowledge. Multi-section groups were designed to provide more diverse patterns of engaging in collaborative knowledge construction. Consequently, the two single section groups, while providing a sufficiently rich learning experience for the students involved, were not representative of the KCI design and were omitted.

The contents of the final reversion of the Issues pages provided evidence for the level of knowledge integration and epistemic complexity of the pages. Revisions of the pages would reveal students’ participation patterns in co-constructing knowledge and the
growth of ideas contributed to the page from the time of entry to the final revision of the page.

5.4.3 Group planning pages.

Students’ use of the group planning pages could provide evidence about how individual students within a group took responsibility to create shared knowledge in their Issue page. The 14 planning pages, in addition to version logs, helped me to corroborate patterns of participation and to determine whether providing an explicit planning scaffold, would facilitate distributed participation in collaborative work and higher scientific quality of the Issue pages.

5.4.4 Reflection notes.

Considered along with revisions of issues pages, group planning pages, and peer comments, individual reflection notes would provide a more in-depth insight into students’ perceptions of their role in collaborative knowledge construction as opposed to the actual quality and quantity of their contributions to knowledge co-construction. The three reflection notes—Appendices H, I, and J—were considered in data corpus had 69, 69, and 67 responses apiece, out of a total possible 109 students. A reason for lower response rate was that teachers assigned them as non-assessed homework.

5.4.5 Remediation pages.

The Remediation pages would provide evidence of knowledge reuse from the Issues pages. I considered the final revision of Remediation pages as one source of data.
Students in five class sections created 29 Remediation pages. Remediation topics, and if more than one, the number of groups that selected those topics were as follows:

- Rising sea levels
- Architecture (2 groups)
- Carbon offset programs, emissions reductions, carbon taxes and credits (4 groups)
- Energy Star (2 groups)
- Government Rebates
- Individual Actions
- Transportation (2 groups)
- Recycling (2 groups)
- Reducing Electricity Use (3 groups)
- Low emission technologies
- Renewable Energy (5 groups)
- Tree planting (3 groups)
- Water management (2 groups)

Of these pages, I discarded Water Management, Rising Seal Levels, and Low Emission Technologies topics. The contents of the first topic, although from the list provided in the References section, were irrelevant to the theme of the unit. The two other topics were never mentioned in the Issues pages or in the References section of the Drupal website. After reading through Tree Planting Remediation pages, I decided to discard 2 of them from data corpus. Both pages belonged to students from Mindy’s class. In one, the students left the Effectiveness section of the Remediation page empty and in
the other, the students totally ignored issues pages and in the Effectiveness section, discussed topics from the list provided in the beginning of the unit for the Reference Annotation assignment. From the remaining Remediation topics, I considered those that were selected by more than one group of students, 18 Remediation pages in total:

- Carbon offset programs, emissions reductions, carbon taxes and credits (4 groups)
- Energy Star (2 groups)
- Transportation (2 groups)
- Recycling (2 groups)
- Reducing Electricity Use (3 groups)
- Renewable Energy (5 groups)

5.4.6 Classroom observation and field notes.

In the co-design meetings, I took personal notes of all decisions made, and contributed to a planning wiki page that was kept updated to reflect the latest design of curricular activities. I added my own interpretations of design decisions in my notes. I kept these notes, in chronological order.

For classroom observations, I used a simple template, which included the following entries:

- Date and time of the class meeting
- Name of teacher
- Curricular activities as specified in the planning document or, if existed, the lesson plan
• Preparations
• Questions to guide my observations
• Progression of curricular activities in class
• Questions that I would need to address before the next class

5.4.7 Supporting documents.

I retained all email communications among co-design group members during the design and implementation phases, as well as curricular documents and lesson plans. These documents provided a record of any revisions, modifications, and deletions applied to the designed curriculum, which might have influenced the enactment.

5.5 Data Analysis

5.5.1 Students learning gains.

In iteration 2, I elected to discard the second part of pre-unit and post-unit questionnaires, concerned with students’ beliefs about the nature of science, as they were not answered at post-test by a sufficient number of students. Also, as there were two versions of posttest, I prepared a list of shared items and only scored those. As in iteration 1, I trained a fellow Ph.D. student to score one third of pretest and posttest. We achieved an inter-rater reliability of 95. %.

5.5.2 Scientific quality of co-constructed knowledge.

I used the final versions of all Issues pages to examine the depth of students’ collective understanding of Climate Change science. The same Knowledge Integration
rubric that I used for iteration 1 was applicable to Issue pages in iteration 2. Table 7 shows this rubric.

Table 7

*Knowledge Integration rubric for Climate Change unit*

<table>
<thead>
<tr>
<th>Score</th>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Knowledge Integration</td>
<td>- Idea is not relevant to the scientific context of the inquiry task</td>
</tr>
<tr>
<td>1</td>
<td>Partial Knowledge</td>
<td>- Idea is personal experience or opinion.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Isolated facts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- One or more main concepts are recognized. No explanation provided</td>
</tr>
<tr>
<td>2</td>
<td>Limited Knowledge</td>
<td>- Possible connections between sub-concepts of a main concept is recognized but are either not elaborated or lack evidence. Content is relevant to inquiry topic</td>
</tr>
<tr>
<td>3</td>
<td>Complex Knowledge</td>
<td>- Elaborate account of connections between sub-concepts and main concept relevant to inquiry topic. Other main concept may have been mentioned. Evidence is provided.</td>
</tr>
</tbody>
</table>

I applied the rubric to contents of Issue pages under the following headings:

- Description of Issue
- Greenhouse Effect
• Thermal Energy and Circulation
• Carbon Sinks and Sources
• Models and Scenarios

Each heading would represent a coding segment and would be assigned the highest level of knowledge integration students achieved under that heading.

5.5.3 Distribution of participation in knowledge co-construction.

The purpose of this analysis was to investigate symmetry of participation among students during collaborative inquiry as manifested in their Issues pages. I used the revisions of Issues pages as the main source of data for this analysis. These pages were created during a long-term collaborative inquiry activity and would have maximized the chances for all group members to contribute to knowledge co-construction in their Issues group.

I approached this analysis differently than in iteration 1, in part because of the technological problem I faced with the page comparison functionality of Drupal. In this iteration, to examine the distribution of participation in creating Issues pages, I created group level measures, presented below, to identify groups that represented different patterns of participation in knowledge co-construction activities.

To understand the distribution of students’ participation in knowledge co-construction in Issues pages group, I first calculated the number of page edits and the number of regulatory messages for each group member in the eight weeks when they were working on Issues inquiry activity. Then, for each Issues page, I used revision log of Drupal to create a list in Excel containing the following fields for each edit session:
This list provided data on the number of times each student had edited an Issue page during collaborative inquiry and the number of log messages each student had authored. However, students also left regulatory messages within each group’s planning page. Thus, I counted each contribution to the group’s planning page towards the total count of regulatory messages.

I, then, calculated the mean and standard deviation values of each measure for all groups. Using the coefficient of variation, the normalized ratio of the standard deviation to the mean of individual scores, of both measures in each group, I could compare students’ participation in knowledge co-construction across all Issues groups. Subsequently, I chose two cases for in-depth content analysis.

5.5.4 Growth of ideas.

Students in this iteration used collaborative writing as a medium to co-construct their knowledge about climate change issues as they engaged in multi-session collaborative inquiry. An in-depth analysis of their collaboration, as manifested in revisions of their Drupal Issues pages, would reveal cognitive and social mechanisms of knowledge construction. Such an objective can be achieved through analyzing students’ discourse using the contents of their communications in a synchronous or asynchronous computer mediated communication tool (De Wever, Schellens, Valcke, & Van Keer,
Drupal pages, the way they were used here, did not capture student discourse.

The goal of this analysis was twofold: First, to gain insight into the changes in the level of epistemic complexity (Hakkarainen, 2003) in students’ contributions to Issues inquiry project in consecutive revisions of their Drupal pages. I wanted to show if students moved beyond sharing information to providing elaborate explanations and acknowledging relevant ideas that existed in the knowledge base. Second, to reveal students’ practices of regulating and monitoring their collaborative inquiry.

The issues pages selected as cases from the previous analysis were the main data sources for this analysis. Supplementary data for this analysis were students’ reflection pages, group planning pages, and peer review comments. For confidentiality purposes, I assigned pseudonyms to students who were members of selected groups.


I randomly selected one Issues page, not included in the final coding, to examine whether the coding schemes that I developed in iteration 1 would apply to Issues pages from iteration 2. I revised the coding schemes to arrive at the final ones used for analyzing the growth of ideas, Table 8, and edit actions, Table 9.
To ensure authenticity of content, I checked the contents of Issues pages selected for in-depth analysis with the “Copy/Scape” online application. I found one instance of plagiarism in one of the pages, and discarded that paragraph from analysis.

Table 8

*Coding scheme for evolution of ideas in Drupal discourse*

<table>
<thead>
<tr>
<th>Main code</th>
<th>Sub-codes &amp; features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content</td>
<td><strong>Partial (PL):</strong> A few words added to a sentence with no independent meaning.</td>
</tr>
<tr>
<td></td>
<td><strong>Unelaborated Fact (UF):</strong> A list of facts and figures without explanation or link to existing ideas.</td>
</tr>
<tr>
<td></td>
<td><strong>Elaborated Fact (EF):</strong> An organized and connected list of facts. Elaboration of terms or phenomena without providing explanation or mentioning causal relationships. Description of terms, phenomena, or scientific concept without elaboration.</td>
</tr>
<tr>
<td></td>
<td><strong>Unelaborated explanation (UE):</strong> These ideas go beyond introducing describing a phenomenon and attempt to provide reasons and identify relationships. Explanation is not elaborate. The student introduces new information, rephrases or summarizes information from various resources. The sources used for explanation might be listed.</td>
</tr>
<tr>
<td></td>
<td><strong>Elaborated explanation (EE):</strong> An elaborate account of relationships and reasons to explain phenomena under study. Goes beyond providing information and uses resources as evidence to back up and to advance</td>
</tr>
</tbody>
</table>
personal ideas and arguments. Sources are listed and cited in-text.

<table>
<thead>
<tr>
<th>Regulation</th>
<th>Planning (P): A contribution that proposes a plan of action for the group to accomplish the inquiry. It includes, reporting what a group member or group members have accomplished so far, suggesting division of responsibilities by naming and individual or individuals, suggesting a timeline, and suggesting resources.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring (M): A contribution that evaluates the quality of group’s collaborative inquiry report.</td>
<td></td>
</tr>
<tr>
<td>Persuading Collaboration (PC): A contribution in which students ask others to participate in adding content to a line of inquiry under a heading. A general call for the group to answer a question that the submitter needs help with</td>
<td></td>
</tr>
<tr>
<td>Dissuading Collaboration (DC): A contribution in which students ask others to refrain from editing a line of inquiry under a heading.</td>
<td></td>
</tr>
<tr>
<td>Collaborating (C): Taking action in response to a PC contribution. Acknowledging group member’s involvement when their name does not appear as a contributor.</td>
<td></td>
</tr>
</tbody>
</table>

To track the growth of ideas in selected Issues pages, I created an Excel list for each page. Every row contained information about revision number, transaction number, editor, epistemic complexity of the added content, resulting epistemic complexity of the subheading after each revision/transaction, number of words added, number of words deleted, and whether a log message accompanied the transaction. I decided to account for
planning notes, comments, and relevant reflection notes after I established a preliminary trajectory of ideas.

To code regulatory contributions in Issues pages, it was possible to assign multiple codes to one contribution, as it could serve various regulatory purposes.

Table 9

*Coding scheme for patterns of participation in editing Drupal pages*

<table>
<thead>
<tr>
<th>Category</th>
<th>Subcategory and defining features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiate</td>
<td><strong>Content (IC):</strong> Adding content under a heading (template or other) for the first time</td>
</tr>
<tr>
<td>Edit</td>
<td><strong>Edit Self (ES):</strong> Revising content that was added by self. Any revision counts (word, sentence, and paragraph level).</td>
</tr>
<tr>
<td>Add</td>
<td><strong>Adding Content (A):</strong> Each paragraph, text list, or table is coded as “add” when it is added under a heading that already has content.</td>
</tr>
</tbody>
</table>

5.5.5 Patterns of knowledge reuse.

The KCI model emphasizes that students become aware of their collective knowledge so it can be referred to and used in future inquiry activities. The Remediation plans activity in the third phase of the Climate Change curriculum was designed to target this awareness.
To investigate the students’ use of existing knowledge as a resource, I first identified knowledge objects in each Remediations page that would be relevant to the knowledge generated during the Issues pages inquiry activity. Then, I examined whether there were knowledge objects within any of the Issues pages that matched those knowledge objects identified on the Remediation pages. The unit of analysis was, thus, a knowledge object and its length could range from several sentences to multiple paragraphs.

For each Remediation page, I created one table with two columns. Working with the Effectiveness sections of the final version of each Remediation page, I located knowledge objects that could possibly have referenced one of the Issues, and recorded them in the rows of the table with Issue title bolded and placed before the knowledge object. These tables would provide me with information about referred and newly created Issue-related knowledge objects in the Remediation pages. As a number of Remediation topics were chosen in multiple class sections, I identified each table with Remediation title and class section.

Another source of data for this analysis was students’ response to one of the reflection questions, which asked: “How do you think you will use existing content created by all students in the "Issues" activity in the culminating activity?” Reflection 6 was scheduled to be completed before the Remediations inquiry activity. However, only 25 students submitted their response on time and the rest of reflections, 42, were submitted during or after Remediations inquiry activity.
5.6 Findings

5.6.1 Students’ knowledge gains.

A two-tailed dependent t-test showed significant content knowledge gain (p<0.001, t=15.69) from pre-unit to post-unit tests, for the science content portion of the test, with all cases of missing data removed from analysis. The mean value for the pretest was 7.07 out of a possible 22 with SD= 2.46. The mean value for posttest was 13.90 out of a possible 22 with SD= 2.72.

Considering that this research was conducted in a competitive school, students’ knowledge gains in the scientific concepts related to the Climate Change unit were expected. However, the significant knowledge gain does lend some support to this curriculum intervention, at least in the sense that it did not inhibit students’ learning, and indeed facilitated their understanding of Climate Change science topics that were represented on the pre-unit to post-unit tests.

5.6.2 Scientific quality of co-constructed knowledge.

Figure 18 shows an overview of the number of knowledge objects in each Issues group, color-coded for Knowledge Integration scores. With the exception of two groups, Individual Action and Overpopulation, students reached a fairly complex level of knowledge integration in their Issues pages.
To further investigate any improvement, I compared the percentage of knowledge objects in each Knowledge Integration score for both iterations. As evident from figure 19, the number of knowledge objects coded as Complex increased at least four times in
iteration 2. There is also a considerable decrease in the number of knowledge objects coded as Partial and No Knowledge Integration in iteration 2 compare to iteration 1 where No knowledge Integration code constitutes only 3.96% of all coded knowledge objects.

![Figure 19. Changes in the portion of knowledge objects coded for levels of Knowledge Integration from iteration 1 to iteration 2.](image)

This higher level of knowledge integration in the final version of Issue pages suggests that the revised template and the included guiding questions were more effective in promoting the development of scientifically rich content than those of iteration 1.
5.6.3 Students’ participation in co-authoring Issues pages.

In this section, I share baseline findings relevant to students’ contribution to their Issue page, as evident in their overall number of edits and control messages.

**Overview of the Issues pages.**

In groups of 6 to 8, students from five class sections created 14 Issues pages in Drupal. Table 10 shows the number of revisions, the number of group members, and the number of words in the final revision of each page for 14 Issues pages. Note that I did not count revisions done by research assistants or by the teachers. Those revisions constituted a small percentage of all revisions.

The range of authoring revisions was a minimum of 56, Glaciers Melting group, to a maximum of 208, Desertification group. The number of words in the Issue pages ranged from 1811, Glaciers Melting group, to 5333, Unusual/Extreme Weather group. Unlike iteration 1, students were not allowed to create subpages. I looked into the number of co-authors for each Issues page to determine the number of group members whose name was present as an author in the page’s revision history. As evident in figure15, Issues pages had between 6 to 8 authors. I checked these numbers with the number of group members for each Issue page and realized that 100% of group members had edited their issue page at least once.
Table 10

*Revisions and word count for Issue pages*

<table>
<thead>
<tr>
<th>Page</th>
<th># of revisions</th>
<th># of group members</th>
<th># of words</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alberta Tar Sand</td>
<td>56</td>
<td>7</td>
<td>3418</td>
</tr>
<tr>
<td>Deforestation</td>
<td>93</td>
<td>8</td>
<td>2829</td>
</tr>
<tr>
<td>Desertification</td>
<td>208</td>
<td>6</td>
<td>3133</td>
</tr>
<tr>
<td>Economy</td>
<td>85</td>
<td>7</td>
<td>4406</td>
</tr>
<tr>
<td>Glaciers melting</td>
<td>44</td>
<td>6</td>
<td>1811</td>
</tr>
<tr>
<td>Individual Actions</td>
<td>58</td>
<td>7</td>
<td>2830</td>
</tr>
<tr>
<td>Natural Disasters</td>
<td>99</td>
<td>8</td>
<td>4839</td>
</tr>
<tr>
<td>Ocean Warming and</td>
<td>77</td>
<td>6</td>
<td>2678</td>
</tr>
<tr>
<td>Thermohaline Circulation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polar Amplification</td>
<td>56</td>
<td>8</td>
<td>2208</td>
</tr>
<tr>
<td>Pollution &amp; Greenhouse Gases</td>
<td>78</td>
<td>6</td>
<td>3442</td>
</tr>
<tr>
<td>Rising of the sea level</td>
<td>79</td>
<td>7</td>
<td>3302</td>
</tr>
<tr>
<td>Tropospheric Ozone</td>
<td>89</td>
<td>6</td>
<td>4278</td>
</tr>
<tr>
<td>Unusual/Extreme Weather</td>
<td>164</td>
<td>7</td>
<td>5333</td>
</tr>
<tr>
<td>Wildlife</td>
<td>74</td>
<td>8</td>
<td>4621</td>
</tr>
</tbody>
</table>
Students’ contributions to Issues pages.

Students could contribute to Issues pages in two ways: Adding content; and adding regulatory entries. Content would apply to material contributed to the Issues pages that appeared in the page. Regulatory entries were either log messages that students entered along with their contribution to issues pages or entries that they made in their group planning pages.

The number of times each student edited an Issues page varied between 1 and 91 (Mean= 13.09, SD= 14.01). All students edited their Issues page at least once. The histogram in figure 20 illustrates the frequency of the number of edits in intervals of 10 edits. Most of the students edited their pages between 1 to 20 times. High numbers of edits were limited to a minority of students, 15 students. I discuss the distribution of participation within groups, in terms of equitable share for each student, shortly.

![Figure 20. Frequency of the number of times students edited Issues pages.](image-url)
To calculate the number of regulatory messages, I added the number of log messages students added to Issues pages and the number of times they edited their group’s planning page. Overall, students made between 0 and 38 regulatory messages (Mean=3.45, SD=5.24). Histogram in figure 21 shows that the more students added between 0 and 5 messages of this kind. Twenty two students, 22.68% of all students, did not add any regulatory message. This is a promising finding, as the majority of students apparently deemed regulatory scaffolds useful.

*Figure 21. Frequency of regulatory messages added by students.*

Next, I examine the distribution of page edits and regulatory messages among students in each Issues group to investigate the degree to which these contributions were quantitatively equitable.
Patterns of participation in collaborative Drupal editing.

To investigate whether the students were equitably participating in co-
constructing knowledge in their issues pages, I calculated the following measures for
each student in a regional group: Number of edit, and number of regulatory messages.
Mean and standard deviation of each measure for 14 Issues pages are listed in Table 11.
A preliminary observation from this table is that Desertification and Unusual/Extreme
weather groups showed greater variance in the number of times each group member
edited either of the two Issues pages. The number of regulatory messages students made
in Deforestation and Economy groups also varied more compared to other Issues groups.
In the following sections of this chapter, I use the term “high contributors” for those
students whose number of edits was higher than the group mean. “Low contributors” are
students whose number of edits was lower than the group mean.

The mean value of each measure varied widely across Issues groups, in
proportion with the varying overall length of the pages themselves. Thus, I calculated the
coefficient of variation (CV), the ratio of standard deviation to mean, as a dimensionless
measure, to serve as a basis for comparison across Issues groups. Higher values of CV
denoted greater dispersion in the distribution of participation measures. Table 12 contains
the CV values calculated for Issues groups.
Table 11.

*Mean and standard deviation value for three measures of distribution of participation in knowledge co-construction in 14 Issues groups.*

<table>
<thead>
<tr>
<th>Issues Page</th>
<th>Mean No. Edits (SD)</th>
<th>Mean No. Regulatory messages (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alberta tar sand</td>
<td>8 (8.14)</td>
<td>2.71 (2.50)</td>
</tr>
<tr>
<td>Deforestation</td>
<td>11.5 (13.93)</td>
<td>6.50 (12.8)</td>
</tr>
<tr>
<td>Desertification</td>
<td>34.83 (27.85)</td>
<td>3.50 (2.88)</td>
</tr>
<tr>
<td>Economy</td>
<td>12.86 (9.55)</td>
<td>10.00 (8.45)</td>
</tr>
<tr>
<td>Glaciers melting</td>
<td>7.33 (5.16)</td>
<td>2.17 (2.14)</td>
</tr>
<tr>
<td>Individual actions</td>
<td>8.86 (4.18)</td>
<td>4.86 (4.81)</td>
</tr>
<tr>
<td>Natural disasters</td>
<td>13.38 (8.30)</td>
<td>0.50 (1.07)</td>
</tr>
<tr>
<td>Polar amplification</td>
<td>7.13 (4.97)</td>
<td>1.50 (1.31)</td>
</tr>
<tr>
<td>Tropospheric ozone</td>
<td>14.83 (11.50)</td>
<td>4.00 (3.74)</td>
</tr>
<tr>
<td>Unusual/Extreme weather</td>
<td>23.43 (30.64)</td>
<td>2.71 (3.35)</td>
</tr>
<tr>
<td>Pollution &amp; GHG</td>
<td>13.00 (4.60)</td>
<td>3.00 (2.83)</td>
</tr>
<tr>
<td>Wildlife</td>
<td>9.25 (4.86)</td>
<td>1.00 (0.76)</td>
</tr>
<tr>
<td>Ocean warming</td>
<td>12.83 (4.92)</td>
<td>4.00 (2.37)</td>
</tr>
<tr>
<td>Rising of the sea level</td>
<td>11.29 (9.53)</td>
<td>2.43 (2.15)</td>
</tr>
</tbody>
</table>
Table 12

Dispersion in three measures of distribution of participation expressed as coefficient of variation.

<table>
<thead>
<tr>
<th>Issues Page</th>
<th>No. of Edits</th>
<th>No. of regulatory messages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alberta tar sand</td>
<td>1.02</td>
<td>0.92</td>
</tr>
<tr>
<td>Deforestation</td>
<td>1.21</td>
<td>1.97</td>
</tr>
<tr>
<td>Desertification</td>
<td>0.80</td>
<td>0.82</td>
</tr>
<tr>
<td>Economy</td>
<td>0.74</td>
<td>0.84</td>
</tr>
<tr>
<td>Glaciers melting</td>
<td>0.70</td>
<td>0.99</td>
</tr>
<tr>
<td>Individual Actions</td>
<td>0.47</td>
<td>0.99</td>
</tr>
<tr>
<td>Natural Disasters</td>
<td>0.67</td>
<td>2.14</td>
</tr>
<tr>
<td>Polar Amplification</td>
<td>0.70</td>
<td>0.87</td>
</tr>
<tr>
<td>Tropospheric Ozone</td>
<td>0.78</td>
<td>0.94</td>
</tr>
<tr>
<td>Unusual/Extreme Weather</td>
<td>1.31</td>
<td>1.24</td>
</tr>
<tr>
<td>Pollution &amp; GHG</td>
<td>0.35</td>
<td>0.94</td>
</tr>
<tr>
<td>Wildlife</td>
<td>0.53</td>
<td>0.76</td>
</tr>
<tr>
<td>Ocean Warming</td>
<td>0.38</td>
<td>0.59</td>
</tr>
<tr>
<td>Rising of the sea level</td>
<td>0.84</td>
<td>0.88</td>
</tr>
</tbody>
</table>

The KCI Climate Change curriculum promoted equitable participation in knowledge co-construction during collaborative inquiry activities. The two participation measures provide an approximation of how equitably students were engaged in creating content within each group and in regulating their collaborative inquiry. I plotted the CV
values of these two participation measures for all Issues pages groups in a scatter plot to understand where the Issue groups stood in relation to each other (Figure 22).

Figure 22. Distribution of participation in knowledge co-construction for 14 Issues groups.

Figure 22 shows that 11 Issues groups had low to mid levels of dispersion in number of page edits and in number of regulatory notes, suggesting that students in those groups participated in knowledge co-construction rather equitably. In three Issue groups, Deforestation, Natural Disasters, and Unusual/Extreme Weather, at least one of these measures was more dispersed compared to the other eleven groups. These initial findings indicated that log messages and group planning pages, the two regulatory scaffolds emphasized in iteration 2, helped students in their Issues groups contribute to knowledge co-construction more equitably.
To further understand the trends in the growth of ideas during Issues groups collaborative inquiry, I selected the following two Issues groups that represented different levels of participation on the part of students in terms of number of page edits and number of regulatory notes:

- **Deforestation**: This Issues group had high CV values both for the number of edits and for the number of regulatory notes.
- **Ocean Warming**: Contrary to the Deforestation group, the Ocean warming group had the lowest CV in its distribution of participation measures, suggesting that students in this group were equitably involved in their collective endeavor.

Next, I examine how the students in these two groups collaboratively developed their inquiry report by tracking the growth of their contributions in terms of epistemic complexity. The upcoming analysis investigated the nature of contributed ideas and students’ awareness of the state of their shared knowledge as manifested in their efforts to improve each others’ contributions or their own contributions.

### 5.6.4 Growth of ideas in the Issues pages.

This analysis provided further evidence on whether Issues group with lower variability in the share of group members editing the Issue page worked as a whole to co-construct their knowledge, or if there were individuals or subgroups whose contributions made up the bulk of the content. Also, I could understand the dynamics of knowledge co-construction among group members where the majority of edits were performed by some of the group members, e.g., Deforestation. Additionally, I was able to examine any
potential impact of log messages, peer comments, and reflections on the quality of contributions. Finally, the analysis also allowed me to see how students regulated their collaboration within the group, by leaving messages, assigning responsibilities, and evaluating the work in progress.

**Growth of epistemic complexity.**

Based on the findings of iteration 1, curriculum design in iteration 2 provided scaffolds to encourage students to pay attention to the quality of contributions made by themselves or by their peers. These scaffolds included planning pages, individual reflection, log messages, and peer review comments. In this section, in addition to examining the trends in the growth of ideas and presence or lack of collaboration, I probe any potential impact of the above-mentioned scaffolds on the quality of contributions.

First, I present the findings regarding the changes in the initial and the final epistemic complexity of ideas in the two selected Issues groups in 20 coded sections. In the Deforestation group, the contents of one of the coded sections were completely deleted in a revision. As a result, findings below apply to the 19 non-empty coded sections. Figure 23 presents the number of coded sections where the epistemic complexity of contents grew from the first to the last revision.
The rest of coded sections, 11 out of 19, did not show any change in the initial and the final level of epistemic complexity (Figure 24). Although fewer sections showed growth in ideas, 8 out of 19 sections contained explanatory content from the very first revision. In the remaining section, students managed to raise the epistemic complexity of 8 sections from factual to explanatory level. In the end, with only three sections remaining at an Elaborated Fact level, 84.21% of content in the coded sections contained explanations.
Absent in the final revision were knowledge objects coded as Unelaborated Fact or Elaborated Explanations. While absence of sections coded as Unelaborated Fact would indicate a success for Curriculum design iteration 2, lack of Elaborated Explanations is disconcerting. One criterion for coding a section as Elaborated Explanation was proper use of resources where the students would cite relevant references that supported their arguments and explanations. In the two selected groups, however, none of the 22 references added to the page was cited in-text. My notes from co-design meetings however, showed that the research team had inquired about students’ knowledge of proper referencing. Although, according to the teachers, students were familiar with at least one standard citation format, they did not follow it in their Issues pages. One reason for improper use of references could be lack of emphasis on the importance of this aspect.
of inquiry report. The handout describing the Issues Pages activity mentioned that “Groups are expected to use the resources in the REFERENCES page” but there was no requirement for following a standard citation format.

Next, I investigated if improvements in the level of epistemic complexity occurred as a result of students collaborating with each other and conducting peer edits. I also examined the role of scaffolds in increasing students’ awareness of the quality of their own and their peers’ contributions and acting accordingly to increase the sophistication of their progressive inquiry report.

Seventeen out of nineteen coded sections had a collaboration index of 2, meaning that students in both selected groups worked together collaboratively to co-construct knowledge in their Issues pages. This shows a considerable improvement with regards to distributed participation in knowledge co-construction comparing to iteration 1 where only 4 out of 39 coded sections were written collaboratively. What’s more, collaboration led to an increase in the level of epistemic complexity of 5 sections in the Ocean Warming Issue groups and 3 sections in the Deforestation Issue group.

I further examined if explanatory contributions in each transaction were added as standalone paragraphs or self-edit, or else, were added to the existing content in the form of peer edit. The Deforestation group had high dispersion in the amount of edits among its group members with four out of eight members contributing considerably more to knowledge co-construction. Students in the Ocean Warming group seemed to be more equitably engaged in collaborative inquiry. In the Deforestation group, of 18 explanatory contributions only 5 were peer edits and the rest were added as individual contributions. In contrast, Ocean Warming group had 17 collaborative explanatory contributions out of
a total of 31 explanatory contributions. The students in the Deforestation group appear to have functioned in a more individualistic manner.

**The effect of scaffolds on the quality of co-constructed knowledge**

Examining the reflection notes and log messages of students in the two Issues groups provided insight into their awareness of the quality of contributions and their willingness to improve the sophistication of existing content within their Issue page.

Three log messages, one in the Ocean Warming Issue group and two in the Deforestation Issue group, were concerned with the quality of page contents. For example, noticing that the existing contents of the page did not address inquiry prompts and questions, a student from the Ocean Warming group wrote the following log message:

Please read: The greenhouse effect section should be about how the increase of temp from the effect changes the salinity, temp and density of the oceans and how this changes the actual circulation. The thermal energy and circulation section should explain how the circulation actually effects the world around it. It should also thoroughly explain how it works.

After this log message, the GHG section of the Issue page was edited in seven revisions and the same student added a paragraph describing, not explaining, how global warming affects this circulation. Later, two other group members identified three existing explanatory knowledge objects in the Issues page that could be edited and moved under
examples of GHG heading. This log message had a positive impact on the quality of co-constructed knowledge and instigated peers’ contribution.

The two log messages in the Deforestation group did not lead to collaborative content improvement. What’s more, log messages in both groups were not used extensively to comment on the quality of the shared knowledge. Thus, I referred to reflection notes to further my understanding of students’ level of awareness of the quality of the shared knowledge, the quality of their contributions to the shared knowledge, and their awareness of their peers’ contributions.

The three teachers reminded their students to fill in personal reflections in several occasions. However, only three students from the Ocean Warming group and three students from the Deforestation group completed their reflection notes.

One reflection question specifically asked the students to comment on the scientific quality of knowledge objects they contributed to their Issue page. Although scientific quality of knowledge objects does not necessarily relate to their epistemic complexity, students’ responses allowed me to infer their self-identified criteria for quality contributions.

Using the number of words each group member contributed towards factual or explanatory content, I could identify members in both Issue groups whose quality of contributions were lower than their peers. Four of these students, two from each Issue group, answered the above reflection question and showed awareness of their lack of participation and lower quality of contributions. Consider the following responses from two of these students:
My group mates contributions to the issues page were better than mine because my contributions were mildly non-existant. (StudentD1, Reflection 6)

My group members did more than I did, so I would say that the scientific quality of what I submitted was not of that of the quality my group mates submitted. (StudentD2, Reflection 6)

On the other hand, a student whose share of contributed explanatory content exceeded group’s mean, provided specific these two reasons for why her contributions to Ocean Warming Issue page were high quality: Being supported by credible sources, Containing elaborate and detailed explanation that used fact for support. She also mentioned her paying attention to the quality of peers’ contributions and editing them when needed. Below, I discuss the second part of her reflection note in terms of encouraging group members to improve the quality of their contributions.

The iteration 2 curriculum intended to make students more aware of the quality of content contributed by their peers – one feature of distributed cognitive responsibility. Reflection notes showed that group members were aware of their level of participation and the quality of their contributions. In one reflection note that asked how students could help their group mates to be more productive, a low contributing student contended that: “Honestly, I'm the one who needs help getting involved and being productive.” Her group members used log messages to elicit everyone’s ideas and encourage them to participate.
Yet such public calls for participation did not persuade the abovementioned to become more active.

Communicating the need for improving contributions remained rather implicit and both Issues group students with higher quality contributions did not directly comment on the quality of knowledge object provided by peers. They would leave log messages asking for less active members to participate, but I did not find an indication that a peer who mostly contributed factual information was asked to make them more elaborate. A students’ response to a reflection question that asked how they could help their peers to be more involved indicated a need for clarifying in advance that students could keep their peers accountable for their contributions to the shared knowledge during collaborative inquiry:

I feel that if I give more direct suggestions to my group members in terms of what additions I think we should try and add to our page, how they might go about taking care of their own responsibilities, and maybe edit their work and giving them constructive criticism, it might help them become more involved and productive. The knowledge that I am willing to help, and readily give suggestions/ am available to help them (perhaps edit their work) might help in motivating them. (Student OW, Reflection 6)

Although reflection notes did not provide students with the means to boost the growth of ideas in collaborative inquiry, they did help some students explicitly express how they had contributed to knowledge co-construction. Perhaps requiring students to
take such specific action, based on their reflections, could facilitate collaborative growth of ideas in Issues pages.

Another scaffold that was put in place to promote community-wide responsibility towards collective knowledge was peer review. Requiring students to address areas of improvement identified by peers outside their small group would support the purpose of the Climate Change curriculum: Fostering a knowledge community across classrooms.

Peer review comments for the two Issues groups fell into two main categories: Content-related and style-related. Content-related comments evaluated the quality of content added to the page while style-related comments provided suggestions for the look of the page. Here, I focus on content-related peer review comments submitted to the Ocean Warming and the Deforestation groups. These comments requested group members to further explain certain headings, reduce the redundancy of content, explain added images and diagrams, and deleting irrelevant content. The students in these two groups addressed, even partially, the majority of peer-review comments, which suggest that feedback provided by peers outside group had a positive impact on the quality of Issues pages. As one student from the Ocean Warming group said in her reflection note:

It showed many specific places throughout the page where there were mistakes, and parts in our explanation of the topic which were not detailed enough (or too complicated). We would not have otherwise known, because it is different when someone else who does not have background information on a topic is reading something; we figured out places we needed more explanation, or where we made it too complex.
However, the effect of peer review comments were not always long-lasting as students would sometimes bounced back to their initial habits of knowledge co-construction. For example, one peer-review comment asked Ocean Warming group to describe or explain the images that were added to the Issue page. In response, two group members added a short description to an image that depicted the great ocean conveyor belt. The other existing image, a diagram depicting the observed and the expected level of Carbon Dioxide uptake by Carbon sinks remained unexplained. Later on students added more images and diagrams to their page. However, only one of those images, a snapshot of a model showing changes in the global annual temperature over a 100 year period, had accompanying explanation.

Peer review comments did not necessarily increase participation level of less active group members as they could pay little attention to the content of the comment. My argument is based on reflection notes of two low contributors from the Deforestation group. In response to a reflection question that inquired about the usefulness of peer review comments one of those students said:

I found that a lot of the feedback was suggestions as to how to improve or correct spelling or grammar in many parts of the issues page. Though this was very useful, remarks on the clarity or layout of the page would have been more so. (StudentDF3, Reflection 6)

The other student’s response was similar as he mentioned that the bulk of the comments asked for reducing excess information. However, at least two peer review comments clearly pointed out areas that needed either clarification or further explanation.
I suspect that not every peer-review comment were read carefully as my field notes showed that students were concerned about the sheer number of comments each Issue group had received.

Finally, as a formal response to peer feedback comments was not required, it is difficult to speculate whether all peer comments were deemed relevant and therefore worthy of being addressed.

In the next section, I examine how the two groups used log messages and planning pages to regulate their collaborative inquiry.

### 5.6.5 Regulating collaborative inquiry.

The Ocean Warming and the Deforestation Issue groups showed two types of group dynamics. Students in the Ocean Warming group were more equitably involved in co-constructing knowledge whereas in the Deforestation group, half of the members were responsible for the bulk of contributions to collaborative inquiry. Below, I compare the two groups’ use of regulatory notes to plan their inquiry, persuade participation in knowledge co-construction, and monitor the quality of their collective work.

**Planning.**

In the Ocean Warming group, 56 out of 76 regulatory note that students added in the form of log messages, comment, or entries in the group’s planning page were of planning type.

These students paid ample attention to assigning responsibilities—self-assign or peer-assign—and reporting what they had accomplished to the group. To examine if
students in the Ocean Warming group accomplished self-assigned or peer-assigned responsibilities, I tracked all messages within the planning page and matched notes to students’ contributions. Figure 25 provides a summary of the number of self or peer assigned planning notes and whether they were accomplished. The third column in the diagram, non-assigned contributions, indicates spontaneous contributions made by a group member. I exclusively considered textual contributions and did not count planning note-units regarding adding images.

![Figure 25](image)

*Figure 25.* The number of self or peer assigned planning note-units and number of accomplished assignments.

Except for one group member, all students in the Ocean Warming Issue group accomplished their assigned tasks. This is not to say that all students were involved in knowledge co-construction at the same level. The number of assigned/accomplished
planning note was not proportionate to group members’ contribution to knowledge co-construction as two group members contributed less content compared to their peers. Rather, these findings show that students held each other accountable for the assigned responsibilities. The example below illustrates students’ attention to planning notes.

On December 10th 2009, a student signed up to contribute to the Evidence section of the Ocean Warming issue Page. This self-assignment was accomplished after he added one hyperlink to the Evidence section. Noticing that this student had not provided an elaborate contribution to the Evidence section, on January 16 2010 another group member posted this message: “Could you please finish the evidence section?” This comment was not left unnoticed as the student returned to the Evidence section four days later and edited it, although minimally.

The group planning page was introduced to the students as the main scaffold for regulating collaborative inquiry during the Issues pages activity. Log messages and page comments were supplementary scaffolds. Thus, I expected to observe more planning note-units in the planning page rather than in log messages and comment. However, more than half of such notes were added outside the planning page. One group member even asked her group mates to leave a log message every time they edit the page. Log messages being immediately associated with the Issue page were apparently a more convenient planning tool.

In the Deforestation group, too, the majority of regulatory notes in the Deforestation groups were of planning type as well, 97 out of 139. This group, however, used two planning pages, one for each class section. The student who created the second planning page left this message for his group members in the other class section:
I would first like to apologise for the confusion to those working on other projects but of the same group. Me and my peers are also working as group 4 members, and I was unsure of whether to modify the previous to-do page, or make a new one, so I did the latter. If you want me to move this page into the other to-do page, please notify us. (StudentDF1, Planning page 2, 12/01/2009)

I did not find any indication that any of the students, from either class section, made an effort to combine the two planning pages. In fact, planning pages were barely used as intended. Beyond an initial task assignment to four group members, the original planning page was never updated again to reflect the status of the assigned responsibilities or to add new tasks. In this group, planning pages were not used as a common drawing board for identifying and constantly monitoring the progress in their collaborative inquiry. Rather, students individually took the initiative to complete various sections of their Issues page.
As evident in figure 26, the vast majority of the planning notes were of spontaneous type. One group member in particular was very meticulous with planning notes and left a detailed description of every contribution he made to the page. However, he did not encourage his group mates to do the same. A typical log message sent along his contribution would be similar to the following:

Edited Description section. Finished inserting orphaned information into the paragraphs. Edited displayed thumbnails. Moved some pictures around due to display problems. Inserted inactivated hyperlink in description section. Going to ask group and staff on whether or not the hyperlink should be there. For now it does not work, but only marks the place where I feel we should hyperlink. Also edited remediation. Saw
many defunct images, but am not sure whether to delete them or leave them as placeholders. I am leaving them in place, but will tell my group about the defunct pictures and inquire on what to do with them.

(StudentDF7, Log message, Version 57)

The other three high contributors in this group added fewer planning notes, but their notes served the same purpose. Overall, this group used planning notes as a reporting tool rather than a venue to identify elements of inquiry activity and to distribute responsibility among all group members. Missing from the planning notes are messages to peers to delegate or demand responsibility from less active peers.

Aside from poor use of planning pages, group members did not use log messages to remind their peers to contribute to knowledge co-construction. The number of regulatory messages per student had a high dispersion in the Deforestation group comparing to other Issues groups. The existing evidence indicated that this group, as a collective, did not benefit from planning scaffolds implemented to facilitate a more equitable distribution of cognitive responsibility towards knowledge co-construction. Note that, the students may have used their school-issued email to discuss their progress but that data source was inaccessible to me.

**Persuading Collaboration.**

In the Ocean Warming group six collaboration note-units contained messages to group members encouraging them to participate in knowledge co-construction. Three note-units were section-specific, where one group member would ask her peers to
contribute to a specific section within the Issue page. Remediation, being the last heading on in the Issue page was last to be completed and apparently no group member was self-assigned or peer-assigned to it. Towards the end of Issues inquiry activity two group members asked if all group members should contribute to this section, or if those who already had contributed less would become responsible for this section:

   For the remediation section do you guys all just want to collaborate?  
   (since we're all still busy working on different sections/editing.)  
   (StudentOW1, January 17 2010)

   Has anyone who hasn't done much want to do the remediation?  
   (StudentOW2, January 17 2010)

These note-units apparently did not get the attention of less active members to contribute to the Remediation section. While these notes may have not been effective, they show group members’ awareness about the participation level of peers in collaborative inquiry.

Non section-specific note-units were public calls to group members to sign up for completing the page or encourage them to keep on working. The three notes in this category were properly addressed.

In the Deforestation group 3 note-units elicited group members’ participation and input on the textual content of the Issue page. The other 12 notes dealt with the visual aspect of the inquiry report. Take the following sequence of notes as an example:
When wood burns, CO2 is produced. The chemical formula for this is
<Insert here>. (StudentDF2, Version 20)

There is no chemical formula for wood, but if there was the formula wood
look like this: Wood + O₂= CO₂ + H₂O, that is why I (Neil) removed the
part saying the chemical formula would look like this (StudentDF3,
Version 49)

The second note may not be scientifically accurate, as there exists a formula for
wood combustion. However, a general call for feedback from StudentDF2 apparently
encouraged him to contribute, even partially.

In this group, I observed more concern about the look and the placement of
images in comparison to the quality of the co-constructed content. Monitoring notes may
provide further evidence for this speculation.

**Monitoring.**

Students in the Ocean Warming group and in the Deforestation group used log
messages to monitor the quality of contents and looks of their issue page. Between the
two groups, more than 53% of monitoring messages addressed formatting problems in
the Issues pages.

In the Deforestation group, content-related monitoring messages suggested parts
of the content to be deleted or moved under a different heading, all of which were
addressed by group members. These messages did not comment on how the existing content could be further improved and elaborated.

The planning page asked the students to leave comment for each other on the quality of each heading and specify if a heading was completed. As the Ocean Warming Issue group used their planning page extensively for assigning responsibilities, I examined its content for monitoring type messages. However those fields in the planning page remained empty.

Issues pages inquiry activity engaged students in an eight-week long collaboration. Design elements in the form of scaffolds facilitated and promoted distributed cognitive responsibility, awareness of the state of shared knowledge, and attention to the quality contributed knowledge. The students, thus, could have developed competency in the three areas mentioned above and apply it in their next collaborative activity, Remediation Plans.

I considered the students’ responses to the reflection question: “What did you learn from working in collaborative groups that would help you become a more effective group member in the culminating activity?” to further my understanding of their experience during collaborative inquiry that would transfer to their future collaborative efforts.

An elaborate response from a member of the Ocean Warming group, showed this group’s collective awareness of and attention to the process and outcome of writing their progressive inquiry report. Note this student’s emphasis on the importance of planning and communication during collaborative work:
I learned that a high level of communication is necessary between group members, and that it is necessary to have an organized plan before tackling the topic, or else the work will not be completed fairly and effectively. [omitted] It was effective leaving messages to my fellow group members, as it gave a report as to what my opinion was, what work I had done, and what work needed to be fixed. As they did this to myself as well, every voice was heard and whenever something important needed to be said, it was heard by every group member. (StudentOW3, Reflection 6)

Her reflection considered along with low dispersion in group members’ participation in editing the Ocean Warming Issue page, suggested that the scaffolds designed to encourage equitable participation in knowledge co-construction, increase attention to the quality of collective knowledge, and elevate awareness of individual contributions may have a positive effect on the dynamics of collaborative work within this Issue group.

Responses from low contributors reflected the Issues activity entailed little learning experience that was transferable to the upcoming collaborative activities. One exception was a student from the Deforestation group with virtually no contribution to collaborative knowledge eco-construction. He pointed out the importance of being responsible for his own share in collaborative activity but did not provide any reason for his lack of contribution to the Deforestation Issue group:
What I learned was that nothing will get done for you. You will only receive, how much you put it in, so if you do not do anything, you will be stuck with nothing. I learned that you must always pull your own weight.

(StudentDF2, Reflection 6)

Even a well-designed collaborative inquiry activity may not lead to fostering characteristics of a knowledge community among students, if students do not deliberately engage in or are required to take part in knowledge co-construction activities.

Next, I examine how the knowledge that was co-constructed in Issues pages was used a resource for Remediations inquiry activity.

5.6.6 Reusing community knowledge as a resource.

Two class sessions were dedicated to the Remediation inquiry activity, with a third session (the final one for the unit) in which students presented the results of their inquiry in a 10 minute oral presentation. This culminating activity explicitly required students to address two specific Issues that would be “the most significantly affected” by their chosen remediation.

Table 13 provides an overview of the number of Issue-related knowledge objects, their status as to being referenced vs. being newly created in the Effectiveness section of chosen Remediation pages, and the percentage of group members who contributed knowledge objects.

All 66 students who responded to the reflection question “How do you think you will use existing content created by all M3 students in the "Issues" activity in the
culminating activity?” expressed their intention to review the contents of the Issues page and use relevant information in their Remediation inquiry activity. One student said:

    I think that it will be easier to find another group's issue page with a topic relevant to our culminating topic than to do our own research because all of the research and information will be there already. As well, we can use the information from the issue page to compare with our own research to make sure that our sources are accurate. (StudentW4, Reflection 6)

Willingness to use the existing content as a credible resource shows that the students understood the relation between the Issue inquiry activity and the Remediations activity. In practice, more than 61% of Remediation pages contained knowledge objects that referred to relevant content in the Issues pages. Another student’s response to the abovementioned reflection question provides insight into how the contents of the Issues pages were used:

    While creating our Remediations page, the Issues pages were very helpful because when we wanted to learn about a certain topic (that we hadn't worked on before), rather than researching the issue through multiple websites, we were able to collect accurate and reliable information from one of our classmates' pages. (StudentUW6, Reflection 6)
<table>
<thead>
<tr>
<th>Remediation (Class Section)</th>
<th># Referenced knowledge objects</th>
<th># Non-referenced knowledge objects</th>
<th>% Contributing members</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon taxing</td>
<td>1</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td>Energy star</td>
<td>1</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Recycling</td>
<td>1</td>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>2</td>
<td>33.33</td>
</tr>
<tr>
<td>Reducing electricity use</td>
<td>1</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1</td>
<td>33.33</td>
</tr>
<tr>
<td>Renewable Energies</td>
<td>1</td>
<td>2</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>Transportation</td>
<td>2</td>
<td>1</td>
<td>66.66</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>2</td>
<td>50</td>
</tr>
</tbody>
</table>
In her Remediation page, Renewable Energies (Section 5), her group referred to the existing content in the Pollution and GHG and the Individual Actions issues pages.

Of 36 issue-related knowledge objects in the Effectiveness section of these Remediation pages, 23 were newly-created, and thus non-referenced, and 13 were referenced. Similar to iteration 1, students in iteration 2 did not explicitly cite Issues pages in their Remediation pages. Again, finding Issue-related knowledge objects that were used in Remediation pages would call for my careful reading of the contents of these pages.

Overall, 6 out of 14 Issues were identified as being more heavily influential of these Remediations. The number of times each of these 6 Issues were discussed in the “Effectiveness” section of Remediation pages and whether they were referenced or non-referenced is shown in Figure 27.

![Figure 27. Number of Issue-related knowledge objects in Remediation pages.](image-url)
Economy, Pollution and Greenhouse Gases, and Individual Actions Issues, were each discussed at least twice more than other Issues. As Pollution and GHG would be impacted by any of the remediation plans, its recurrence was expected. The same can be said about Individual Actions and economy, as remediation plans had either direct or indirect implications for citizens and also for various sectors of the economy. Apparently, students favored general Issues rather than specific ones. Note that, the guidelines for the Remediation inquiry activity did not require the students to justify their two choices either.

One improvement in the culminating activity in iteration 2 (Remediations) compared to the culminating activity in iteration 1 (Specialist group) was students’ participation in knowledge co-construction. The percentage of group members who contributed to the Effectiveness section of Remediation pages ranged from 33.33% to 100%. Only two groups had a participation rate below 50%, meaning that in the remaining 16 groups at least half of group members edited the Effectiveness section. Compared to iteration 1 where 3 out of 6 groups had a participation rate over 50%, students in iteration 2 seemingly assumed higher level of shared cognitive responsibility. However, it must be remembered that there were enactment issues in the iteration 1 culminating activity that would have impacted the level of collaboration.

5.7 Discussion and Implications

The co-design and the implementation of iteration 2 of this study proceeded smoothly, which was a great improvement compared to iteration 1. During the co-design meetings, the research team and the participating teachers worked together to address the
shortcomings that were experienced during the enactment of iteration 2. This collaboration resulted in the design of a well-scaffolded KCI-curriculum and a reliable technology platform. Curriculum implementation proceeded according to the planned timeline and students in all five sections of the class accomplished all inquiry activities designed for the three phases of the KCI model. Also, as one of the students mentioned, the inquiry activities led to the co-construction of transferable knowledge:

I can browse their issue page and possibly get valuable information from it. Not only for the UTS scientific projects, but later if I need some information on climate change, I can go back to these issue pages and get a lot of valuable information. (StudentGM5, Reflection 6)

Curriculum design for iteration 2 had two major design considerations:

- Reinforcing the notion of a knowledge community amongst students with regards to distributed cognitive responsibility, attention to the quality of shared knowledge, and awareness of the shared knowledge.
- Redesigning the jigsaw activity to foster more scientific connections and to increase the potential of reusing the knowledge that were co-constructed during collaborative inquiry activities in the upcoming inquiry activities.

Three main scaffolds were devised to facilitate these objectives: Group planning pages and log messages; individual reflections; and peer-review comments. One desired technology tool, a tagging mechanism that applied to sections of a page rather than a whole page, was designed, but was not implemented in the Drupal platform due to technical considerations.
The sections below discuss the findings presented in this chapter. In order to examine how the designed activities and scaffolds facilitated the goals of KCI in iteration 2, I discuss the findings according to four main themes: Distribution of participation, quality of co-constructed knowledge, attendance to quality of contributions, and knowledge reuse.

5.7.1 Distribution of participation.

Students’ participation in knowledge co-construction was more equitably distributed, both in the Issue inquiry activity and in the Remediation inquiry activity. In this iteration, technological shortcoming prevented me from applying the Edit Action codes to all Issues pages. I compared the Issues groups based on the dispersion in the number of edits and the number of log messages submitted by the students. With the majority of the Issues groups, 11 out of 14, showing relatively low dispersion in both measures, it appears that group members were more uniformly participating in knowledge co-construction. What’s more, none of the Issues groups were dominated by an individual member.

Log messages and planning pages also appeared to scaffold students in communicating their concerns regarding group members’ participation in knowledge co-construction. Students used these two scaffolds to invite less active members to contribute to content creation in sections of Issues pages. Reflection notes, too, revealed that students with lower participation rate showed awareness of and acknowledge their lack of involvement in collaborative inquiry.
In the two Issue groups that were studied in detail, such awareness did not lead to increased participation. In future developments, perhaps the technological platform could provide the teacher with a report of students’ participation patterns along with the reflection notes, log messages, and knowledge objects submitted by low contributing students. The teacher, then, could help guide interventions, as necessary.

In the case of a group with a dominant subgroup of students, group members did not utilize their planning page to distribute the responsibility of knowledge co-construction. Instead, high contributors added content spontaneously. One minor problem that students had in using planning pages throughout the collaborative inquiry was immediate access to their group’s planning page. To open the planning page, the students had to leave the Issue page. An integrated planning tool that it attached to each section, or heading, of the page would alleviate this problem and would also prevent students from creating multiple planning pages.

Another scaffold for future development that could promote more equitable participation in collaborative inquiry, is to present a visualization tool that depicts the amount of participation of each group member. Successful use of such a tool is reported in CSCL research (Janssen, Erkens, Kanselaar, & Jaspers, 2007).

The remediation pages, as explained earlier in this chapter, were broken down into several independently editable subpages. The research team was concerned that introducing subpages would lead to single authorship and a lack of collaboration. Students’ participation in knowledge co-construction, as reflected in the percentage of co-authors of the Effectiveness section in Remediation pages, suggests that overall, the designed curriculum had a positive effect in encouraging equitable participation. The two
Remediation groups with lower co-authorship rates were composed of students whose page edits in the Issue pages was close to the group mean. Perhaps an alternate group composition, with one high contributor in each group, could improve this situation.

5.7.2 Quality of co-constructed knowledge.

I examined the quality of co-constructed knowledge in the Issues pages from two perspectives: The level of knowledge integration and the epistemic complexity.

To foster more scientific connections in the progressive inquiry report of the Issues groups, the template explicitly asked the students to explain how the science of climate change would relate to their selected Issue. Compared to iteration 1, the contents of Issue pages showed a considerable growth in the amount of co-constructed content coded as Complex and Limited knowledge integration. Constructing that making deep science connections in a collaborative inquiry is at the heart of the KCI model, curriculum co-design in the second iteration appeared to have been successful.

The change in the theme of the jigsaw inquiry appeared to have a positive impact on the growth of the scientific connections within Issues pages. Instead of highlighting industrial and social implications of the Issues, the students were asked to mainly focus on the scientific aspects of their Issue. The social and political aspects of the Issues were not forgotten, though, as the page asked for the students to explore legislations that were put in place to alleviate their Issue of interest. Compared to iteration 1, the design of the jigsaw was improved in that regard.

From an epistemic complexity point of view, there was a 10% increase in the amount of explanatory content within the inquiry products, in comparison to iteration 1.
While promising, this improvement is based only on the content analysis of two out of 14 Issues group. Due to the limited number of groups selected for this analysis in iteration 1 and even fewer in iteration 2, this conclusion should be taken with some reservation.

The appropriate citation of resources, external or within the co-constructed knowledge, remained an under-solved issue. Although the students added a list of references to their issues pages, they did not acknowledge the resource in-text. This problem extended from the Issues pages to the Remediation pages where the students would not cite the Issue page to which they made reference.

During the co-design meetings, the teachers expressed that the students were familiar with using resources and citing them in their writing. Curricular activities designed for iteration 2 successfully engaged students in finding relevant resources. Although the students did use external resources, I did not find an instance where they critiqued the content of a resource or compare it with contradicting evidence. As the teachers never showed concern about improper use of resources, I suspect that curricular expectations regarding this issue either did not exist or was underemphasized. The research group had a clear emphasis on use of credible resources in inquiry activities. Yet I did not find any indication on the part of participating teachers as to clarifying their expectations in this regards in the co-design meetings or later during curriculum implementation. For students to move beyond summarizing and paraphrasing available resources, and instead using them to back up their argument, they seem to need explicit scaffolds.
5.7.3 Attendance to the quality of contributions.

In the two Issues groups selected for in-depth content analysis, students collaboratively constructed knowledge in more than 89% of coded section which is a significant improvement over its 10% counterpart in iteration 1. What’s more, the collaboration actually led to a growth in the epistemic complexity of the content. Contents of selected Regional pages in iteration 1 contained no instance of improvement due to collaboration.

Although some of the group members did still contribute more explanatory content, they also used log messages to caution the group about areas that needed improvement, which, in some case, led to low contributors edit shared content.

Planning pages, log messages, peer review comment, and individual reflections were not left underused during the Issue pages collaborative inquiry. Peer review comments, in the two Issue pages that were analyzed, were deemed useful as most of them were addressed and acted upon. Students’ paying attention to their peer’s comments about the quality of their Issue page shows that the scaffold was effective in instilling a collective ownership over the shared knowledge. This scaffold, however, could be further enhanced. Students in Issues groups were not required to leave a response for the peer review comment they received. As a result, judging the relevance of the peer comments was not feasible. It would be an improvement if the students could rate the usefulness of these comments on a sliding scale regarding the effect they could have on the quality of the co-constructed knowledge. This would encourage peers to focus on the content rather than the format and style of the pages.
The remaining scaffolds were not extensively used to monitor the quality of co-constructed knowledge. Planning pages and log messages were mostly used to plan the Issues inquiry and to encourage group members to participate in knowledge co-construction. These two scaffolds were less frequently used to comment on the quality of contributions. Moreover, log messages were not directed to individual group members. Rather, in most of the log messages the whole group was asked to edit a specific portion of the Issue page. An integrated planning tool that was attached to each section, or heading, of the page would alleviate this problem, especially in the later phases of the inquiry activity when students need to monitor and reflect on the quality of their co-constructed knowledge.

Enabling the students to monitor the quality of their co-constructed knowledge would have likely required additional scaffolding. This simple scaffold could take the form of a list of criteria for scientifically sound and epistemically complex contributions. Such guidelines were described in the handouts given to students. However, they would have been more effective had they been integrated in the planning pages or been included as a side bar next to the Issues pages.

Reflection notes designed in iteration 2 targeted, in part, students’ awareness of the quality of their own and their peers’ contributions. Reflection notes of low contributing students revealed that they were aware of the low quality of their contributions to the Issues pages. However, such awareness did not result in them contributing more epistemically complex content.

I speculate that one reason for this problem was that such question was posed later in the Inquiry activity and was not further followed up. Had such reflection question been
posed midway through the inquiry, it was possible that the students would be enticed to contribute higher quality content. A follow up reflection towards the end of the Issues activity asking for an example of a high quality contribution could further clarify KCI curricular expectation of collective responsibility towards the co-constructed knowledge.

Also, the response rate for reflections was rather low, and even decreased from reflection 4 to reflection 6. The three reflection notes contained four questions each. Of the 12 questions 9 were open-ended with no word limit. As these reflection notes were not a mandatory assignment in the Climate Change curriculum, it is possible that the students found them time consuming and thus skipped them. I propose that future KCI curricula use more focused reflection notes that progressively address two specific issues, the quality of self contributions and the quality of shared knowledge.

4.7.4 Knowledge reuse.

Based on the findings of iteration 1, the jigsaw activity for the second iteration was thematically re-designed. The second inquiry activity, Remediations, would build on one of the dimensions of the Issues pages. The research team assumed that the contents of the Issues pages would have a high potential to be used as a main resource for the Remediations inquiry activity. A miscommunication between the research team and the participating teachers, however, compromised this activity and led to the majority of Issues-related knowledge objects in the Remediation pages to be of non-referenced type.

Considering this design flaw, students would not be able to readily identify relevant knowledge objects. Also, the tagging functionality in Drupal platform could not be customized so that tags were applied to page headings, which made locating relevant
knowledge objects even more difficult. While students expressed their willingness to use their shared knowledge base a resource in the Remediations inquiry activity, the two problems mentioned here probably prevented them from building on existing knowledge.

In the next, and final, chapter of this thesis, I address the research questions.
CHAPTER 6: DISCUSSION AND CONCLUSIONS

This research investigated a new pedagogical model called Knowledge Community and Inquiry, which has been advanced by a small community of scholars to make the knowledge community approach more accessible to secondary science, as well as to integrate such learning and instruction with powerful technological scaffolds. My work builds upon a previous doctoral project reported by Peters (2010), which itself offered the first empirical support for KCI. In this research, I responded to some of the major discussion points offered by Peters (2010), adding an increased level of collaborative design to the inquiry activities, and reinforcing the treatment of collective epistemology. KCI was specified at an increased level of detail, in the form of several mutually dependent principles, which were employed by a co-design team to help create two iterations of a substantive curriculum in global climate change. The two iterations were conducted as a design study to examine: (1) if the designed curriculum adhered to the KCI model; (2) if the enacted curriculum was faithful to that which was designed; and (3) the outcomes in terms of student learning, knowledge co-construction, collaboration, and epistemological commitments.

The topic of global climate change was chosen because it was new to the 10th grade Ontario science expectations, and was taught in 9th grade science courses at my participating school. Climate change was seen as being well suited to KCI, because it includes a wealth of relevant science content, that could serve as the topic for collaborative knowledge community, and involves many social issues that would be personally relevant to students for purposes of inquiry learning. The length of the co-designed curriculum unit was the same in both design iterations: Eight weeks in total.
Although the curriculum design and implementation were both compromised in iteration 1, the two participating class sections did complete all activities, and students did show some indication of learning, as well as some level of engagement in collaborative inquiry. Building on the lessons learned from the first iteration a team of researchers, teachers and technologists created a second version that responded to some of the key challenges and findings. Iteration 2 of this study was successfully implemented, and engaged 5 different class sections in collaborative inquiry within a knowledge community approach.

In this chapter, the four research questions that were posed in Chapter 1 are reviewed, in the light of the findings and discussion presented above. The implications for KCI are discussed are also discussed and comments regarding future research on the knowledge community approach to learning and instruction are offered. Finally, a review of the basic methodological paradigm is presented, showing how it succeeded in interpreting the two iterations.

6.1 Pedagogical Aspects of KCI Curricula

Research question 1 addressed the pedagogical features of curriculum for knowledge community development: “What pedagogical features support the development of a knowledge community in secondary science classrooms?”

The present research emphasized three pedagogical aspects of the KCI curriculum. First, the knowledge construction and inquiry activities should be integrated throughout the duration of the broader curriculum unit in order to support the development of a knowledge community. Second, the design of collaborative activity structures should be carefully scripted to ensure that topics are addressed
comprehensively, and that community knowledge serves as a resource for collaborative inquiry activities. Third, collaborative groups should be enabled in monitoring their own progress and collaborative processes. These three elements responded to challenges cited by Peters (2010) and guided the design of activities and pedagogical scaffolds used within the two iterations of this study. Another goal of carefully specifying all collaborations was to avoid an implementation where the classroom teacher focused only on superficial interpretations of the activity structures, or else abandoned the designed curriculum (Sherin, Mendez, & Louis, 2004; Withcomb, 2004).

The design of iteration 1 supported these pedagogical elements, except for the group process monitoring, which was only weakly enabled by wiki page comments. The enactment of iteration 1 was a different story, as two major issues impeded the adherence to design: the use of sub-pages in the Regional groups activity, which fundamentally limited the degree of collaboration, and the lack of time and support allocated to the Specialist activity, which meant that students could not meaningfully collaborate, no engage with the content of the knowledge base.

In iteration 2, the two-stage design from iteration 1 was redesigned to further emphasize scientific connections to the curricular expectations in both steps. Moreover, in addition to whole class discussion about classroom-based knowledge communities, further epistemological treatments were also spread throughout the unit in the form of individual reflection questions. An increase in the amount of collaborative knowledge construction and considerable decrease in the number of groups with dominant individuals suggest that students benefited from the increased level of support for the knowledge community practices. Reflection notes were designed as scaffold that helped
students to understand their individual responsibilities within a collective context and to become more attentive to the quality of their collective knowledge. In their study of the effectiveness of knowledge building portfolio notes in grade-9 geography classes, Lee, Chan, and van Aalst (2006) recommend incorporating principles that drive curriculum design, knowledge building in this case, to facilitate students’ understanding of desired collaboration style and knowledge quality. The implication for KCI curricula would be to translate underlying design into implications for students’ roles and responsibilities during collaborative inquiry and knowledge co-construction. Such set of principles, reiterated through reflection notes would make the concept of KCI knowledge community more accessible to students.

6.2 Supporting Distributed Cognitive Responsibility

The second research question addressed an important characteristic of distributed cognitive responsibility: “What forms of collaborative knowledge construction activities support the distribution of responsibility among students?”

The two iterations examined three dimensions of this characteristic: Distributed participation, on the part of students, in planning, implementing, and monitoring their collective inquiry; distributed participation in contributing high quality knowledge objects to a shared knowledge base; and, distributed participation in the improvement of the knowledge base, including resolution of inconsistencies in knowledge objects that were contributed by themselves or their peers.

Collaborative activities in Iteration 1 provided minimal technological and pedagogical support for these dimensions. It is safe to say that the co-design team
assumed that the students would automatically develop the implicit knowledge of taking on the responsibility of planning for and monitoring an extended knowledge co-construction effort. However, none of the Regional groups showed an equitable participation on the part of group members on these three dimensions, although there were noted enactment confounds.

In iteration 2, several scaffolds were added to support such collaborative work—planning pages, log messages, reflection questions, and peer feedback. Out of 14 Issues group, only 3 showed high dispersion in group members’ participation in planning, enacting, and monitoring knowledge co-construction. Still, collaborative activities in iteration 2 could potentially be improved. One could infer from students’ participation patterns (i.e., in editing their Issues pages) that they did not fully grasp the implication of distributed cognitive responsibility. While aware of the low quality of their contributions, as evident in their reflection notes, some of the students still did not show any attempt in becoming more active in knowledge co-construction. Reminders from group-mates would not generally lead to more participation from these students.

The design of collaborative inquiry could include group-bound evaluations where members of one group evaluate the quality of contributions made by other group members half way through the inquiry. Less active members would, then, have a chance to improve their participation habits.

Technological and pedagogical scaffolds can be designed and integrated in curriculum to facilitate self assessment (van Aalst & Chan, 2007) of collective regulation, knowledge co-constructions, and knowledge improvement. More importantly, such collective responsibility needs to be weaved into the learning philosophy of classrooms
and practiced by both students and teachers. For example, Zhang et al. (2009) studied three different collaborative group structures to examine the emergence of collective cognitive responsibility among grade-4 classrooms. The findings of their study favored opportunistic collaboration model over fixed and interactive small groups. While the technological platform they used, Knowledge Forum, provides detailed information on what individuals contribute to the collective and thus facilitates access to the quality of peer’s work automatically, the teacher had a key role in reminding the students of their responsibility towards collective knowledge.

Considering that the technology fell short to provide teachers with real time and easy to access logs of students’ activity level, future KCI studies need to include such feature in their technological platform.

6.3 Supporting Scientific and Epistemic Quality of the Shared Knowledge

An important design requirement of the KCI model is the responsiveness of the designed curriculum to the requirements of conventional assessment. Deep connections between curricular content and the content that is co-constructed in collaborative activities is, thus, a concern for the KCI model. The third research question attended to this issue: “3. How does the design of collaborative inquiry activities influence the scientific depth of knowledge objects co-constructed by the students?”

Given the level of content that needed to be covered in a climate change curriculum unit, the time allocated to collaborative inquiry was actually quite limited. Thus, it is important to carefully design opportunities for students to integrate each new scientific concept as it is introduced throughout the duration of the curriculum. In the
first iteration of this research, the Regional groups activity was disconnected from the actual presentation and discussion of science topics, and was presented to students as an inquiry activity where they would try to apply the concepts they had learned, but also to consider non-scientific or social aspects of climate change.

The more elaborated design of the Issue pages activity required students to attend to the scientific connections between their issue and the content covered in class (including search for relevant external resources). Also, hints given at the beginning of each section reminded the students to explain the connections instead of providing a descriptive account of the phenomenon under study. The result was more scientific co-constructed knowledge resource that became somewhat explanatory in nature.

Scientific inquiry in KCI curriculum, as implemented in the two iterations of this research, presents a rather open definition of inquiry. Rather than following inquiry steps, or cycles, students have the question they are not required to collect data or perform experiments. What is important in inquiry for KCI is that the students can make deep connection to the science content that is presented in class. To emphasize desired scientific quality of knowledge co-constructed, pedagogical scaffolds, such as assessment rubrics given to the students, and technological scaffolds, such as page templates and reflection notes, focused on content rather than process of inquiry. In case future KCI curricula aims to target inquiry cycles as well, appropriate scaffolds need to be designed.

6.4 Supporting Knowledge Reuse

Lastly, consistent with other theoretical frameworks of knowledge community (Brown & Campione, 1996; Scardamalia & Bereiter, 2003), the KCI model promotes the
active use of existing knowledge objects as resources in inquiry activities. This subsequent inquiry can, in turn, make contributions to the knowledge base (including organization or expansion). The fourth, and last, research question addressed this issue: “What features of collaborative inquiry activities promote active engagement with a community constructed knowledge base?”

The design of KCI curriculum in both iterations continued to employ a jigsaw approach to sequencing collaborative activities. This question is interested in the use of shared knowledge that is co-constructed in earlier collaborative activities as a resource for subsequent collaborative inquiry.

One shortcoming of iteration 1 was that it did not finalize the design of the entire activity sequence before the start of the unit, which led to challenges in the later activities, especially as time began to run out in the teacher’s schedule. In contrast, the curriculum design in iteration 2 was fairly well specified, and simplified, compared with its predecessor. The knowledge constructs within the iteration were also better specified, leading to more structured inquiry activity in the regional pages: describing the issue with respect each science topic, as well as several other subheaders. This resulted in better structure for the overall knowledge base, making it easier to connect the following inquiry activities directly to relevant science content.

One enactment problem occurred within the Remediation activity in iteration 2. Because it was designed with the same name as a major subsection of the Issue pages, the design had assumed that students would gather their ideas about remediation from the Issue pages, conduct a brainstorm of interesting options, and thereby connect their inquiry to the knowledge base. However, in presenting this activity to students, teachers
provided students with a list of Remediation options to choose from. This was a real-time change by the teachers, based on a previous lesson, and a miscommunications the source of the Remediation topics. This led to lower amounts of knowledge reuse, compared to what was originally expected. This aspect of the KCI model still remained underachieved.

Assuming a two-step design for the collaborative inquiry activities in KCI curricula, an alternative design for the second inquiry activity could be that students take on the work of another group, focus on one aspect of their progressive inquiry report and improve it.

6.5 A Methodological Framework

Building on the approach of Peters (2010), a methodological framework is emerging to help guide KCI research. First, it is important to examine the designed curriculum, evaluating it against the specifications of KCI, in order to determine whether it captures the essential principles. Next, it is important to evaluate whether the curriculum was enacted according to its design. While real time adjustments will always be a reality in the classroom, these must be carefully documented, so that the researcher understands exactly what processes and interactions occurred.

In order to capture the enactment, I developed a set of analyses that would explore the various processes within the curriculum, and applied them to the iteration 1 and, subsequently, iteration 2 data.

The first enactment analysis was concerned with determining whether and to what extent students had collaboratively developed a knowledge base. If students had not
conducted the collaborative inquiry, as designed, then the benefits predicted by KCI model would not be expected.

The next analysis, which offered a deeper insight into the collaboration, was concerned with the growth of ideas collaborative groups. Performing this analysis on a few selected groups could reveal interesting characteristics of the groups regarding co-construction of explanatory knowledge while constantly monitoring the progress of the group.

A final enactment analysis was the reuse of ideas. The design of the second inquiry activity requested students to use the knowledge from their first inquiry activity as a resource. This analysis examined the knowledge content of the second inquiry activity and looked for direct mappings back to the knowledge objects in the first inquiry activity reports.

Taken together, the evaluation of the design, fidelity to KCI, the analysis of the enactment, fidelity to the design, and the analysis of knowledge co-construction processes provide a framework for the research of KCI curriculum. This notion of research framework is of great relevance to the philosophy of science, and is important in the development of a new theoretical perspective like KCI. Certainly, the other major knowledge community approaches, such as knowledge building (Scardamalia & Bereiter, 2000) have developed their own frameworks for research over the years, or are still confronting this challenge.
6.6 Contribution of the Study

In this study, I examined the emergence of characteristics of knowledge communities in secondary school science classrooms where curriculum design and enactment was guided by Knowledge Community and Inquiry model. I conducted the study in two design iterations in grade-9 science classes.

This study contributed to KCI research in three ways. First, as an implication of Iteration 1, KCI model moved beyond a predetermined set of participant structure and the emphasis of the model shifted to supporting practices of knowledge communities in secondary school science classrooms. Second, at the start of this research, classroom-based knowledge community fostered by KCI was generically described. Through this research, I provided theory-informed specification of practices of such knowledge communities, referred to as characteristics of knowledge communities. Third, I proposed scaffolding structures that were designed to facilitate the emergence of the desired characteristics of knowledge communities in KCI science curricula.

Overall, the findings of this research show that KCI science curricula can supports knowledge co-construction within the limited timeline of a curriculum unit and can increase students’ awareness of their role as knowledge community members. This model, thus, can provide teachers with a scaffolded means to fostering practices of knowledge communities in their classrooms.
REFERENCES


Lave, J. (1997). The culture of acquisition and the practice of understanding. In D. Kirshner & J.A. Whitson (Eds.), Situated cognition: Social, semiotic, and


Scardamalia, M. (2000). Can schools enter a Knowledge Society? In M. Selinger & J. Wynn (Eds.), *Educational technology and the impact on teaching and learning* (pp. 6-10). Abingdon, RM.


APPENDIX A: SCHOOL PRINCIPAL CONSENT FORM

To: 
From: Dr. James D. Slotta, Associate Professor, OISE/University of Toronto
Subject: Letter of Consent to Participate in University of Toronto Study

I am interested in conducting a research project in your school entitled: Technology-Enhanced Activities and Interactions in the Science Classroom: Pedagogical Scripts for Knowledge Communities. This project will investigate how science teachers employ technology in their classrooms to enhance students’ understanding of challenging science topics. Specifically, science teachers from your school will design inquiry oriented activities that enable students to collaborate in various ways such as small groups or whole class cooperative learning. A variety of technologies will be used in such designs, depending on teacher’s comfort level, and the requirements of their pedagogical designs. My research team, including myself and two doctoral students (Hedieh Najafi and Naxin Zhao), will enable teachers to succeed with the technology, providing design assistance and technical support. Technologies will likely include wikis, online discussion forums, Web-based learning environments, and java-based learning tools such as simulations of science concepts. The information that this study generates will be valuable to our research community, in terms of our understanding of how teachers develop inquiry curriculum, and how students learn from such curriculum. It will also be of value to your school administration, in terms of promoting innovative teaching practices and deep reflections on the part of science teachers.

Most research activities will involve only normal teaching practices, such as curriculum design and enactment. We will analyze the teachers’ curriculum designs, observe the enactment during class, and consult with teachers about their assessments of student work. Occasionally we will seek interviews with students to provide a deeper understanding of their experience of the curriculum, as well as their understanding of the relevant science topics. In these cases, we will request permission from selected students’ parents, using the Interview Permission Letter attached below. In addition, we may also wish to videotape some selected class periods, in which event we would also secure video permission from every student’s parent, using the Video Permission Letter, also attached below.

Because these inquiry science lessons will be conducted as part of the normally occurring instructional practices within your school science department, we do not expect any additional effort or negative impact on your students. Every attempt will be made to ensure that this research in no way impedes the regular course of instruction and only serves to enhance the students’ and teachers’ experiences. Some possible student activities will include: learning about and using new technologies, having discussions about science with their classmates; and participating in brief interviews with myself or my doctoral students. Students may also be asked to complete a short questionnaire about
their ideas concerning science topics at the beginning of the term, to help us assess their
developing understanding. Only myself, the teachers, and my doctoral students, who will
be identified well in advance, will have access to any of the data collected for the study.
At no time will students’ names, teachers’ names, or the name of your school be
identified in published documents. All information that is collected will be kept in locked
files and will be destroyed upon completion of the research. There are no risks associated
with participation in this study and teachers will be free to withdraw from the research at
any time.

Procedures will be taken to ensure the identities of participating and non-participating
students remain confidential during all phases of the study. Most of the information used
in this study will be from the computer-based data logs. This information will only be
accessed only from a secure database within my research laboratory. If a student is asked
for an interview, they will be asked either before or after class, or when their teacher is
not in the room. Interviews will take place either during lunch hour or after school. At no
time will teachers know whether or not a student has elected to participate in an
interview.

A copy of this consent form will be given to you for your reference. If you have any
the study please feel free to contact me by phone: 416-978-0121 or through email:
jslotta@oise.utoronto.ca. Any questions about teachers’ or students’ rights as participants
can be directed to the University of Toronto Ethics Review Office at:
ethics.review@utoronto.ca or 416-946-3273. Research results will be made available
upon request.

Sincerely,

James D. Slotta
Associate Professor, Department of Curriculum, Teaching and Learning, OISE/UT
Canada Research Chair in Education and Technology

I give my permission for Dr. James D. Slotta to conduct the research project outlined
above.

__________________________  ______________________________
Signature                     Date

Published study results will be made available for students and/or parents who are
interested. Please feel free to contact the principal investigator with any questions or
concerns: James D. Slotta, Associate Processor, OISE/UT, 252 Bloor Street West,
Toronto, ON M5S 1V6. Phone: (416) 978-0121, Email: jslotta@oise.utoronto.ca
APPENDIX B: TEACHERS CONSENT FORM

To: Dr. James D. Slotta, Associate Professor, OISE/University of Toronto
From: [Teacher’s Name]

Subject: Letter of Consent to Participate in University of Toronto Study

I am interested in conducting a research project in your class this year entitled:
Technology-Enhanced Activities and Interactions in the Science Classroom: Pedagogical Scripts for Knowledge Communities. As part of a research project, I am interested in how teachers can use technology in their classrooms to help students’ understanding of science. Specifically, students would be participating in an activity that we co-design that involves them collaborating with their classmates. The information that this study generates will aid in finding new and perhaps better ways for teachers to help students develop deep understandings about science.

This study provides a unique opportunity for students in your class to experience an innovative science lesson that utilizes technology and aligns with new curriculum standards. Consenting students in your science class will be participating in the study. The students would be participating in the study during regularly scheduled class time. Every attempt will be made to ensure that the study does not impede any of the regular course instruction and will enrich the students’ learning experiences. Occasionally, myself or two of my doctoral students (Hedieh Najafi and Naxin Zhao) might need to interview students after school or during their regular lunch hour. As a participating teacher, you may also be asked to participate in an interview before, during, or after the study. It is important that you know that participation in this activity is strictly voluntary and you and/or your students may withdraw from the study at any time, for any reason, and without penalty.

Some of the things the students would do during the study are: learning about and using new technologies, having discussions about science with their classmates; and participating in brief interviews with one of my doctoral students or myself. Students may also be asked to complete a short questionnaire about science at the beginning and end of the study so that any changes in their level of understanding can be measured. All information collected during the study will be used for the purposes of data analysis. Only my doctoral students and myself will have access to any of the data that is collected for the study. At no time will students’ names, your name, or the name of your school be identified in published documents. All information that is collected will be kept in locked files and will be destroyed after the research is completed. There are no risks associated with participation in this study and students’ grades will not be affected by choosing to participate.

Procedures will be taken to ensure the identities of participating and non-participating students remain confidential during all phases of the study. Most of the information used in this study will be from the computer-based data logs. This information will only be
accessed from my or my doctoral students’ own private computer. You will not know which students have decided to participate in the study by reviewing any of the students’ work. Information will be reviewed only from those students who are participating in the study. Any written data (e.g. quizzes) will be collected from the entire class. In private, a photocopy will be made only of the work completed by participating students. If a student is asked for an interview, they will be asked either before or after class, or when their teacher is not in the room. Interviews will take place either during lunch hour or after school. At no time will you know whether or not a student has decided to participate in the study.

A copy of this consent form will be given to you for your reference. If you have any questions about the study please feel free to contact me by phone: 416-978-0121 or through email: jslotta@oise.utoronto.ca. Questions about students’ rights as participants can be directed to the University of Toronto Ethics Review Office at: ethics.review@utoronto.ca or 416-946-3273. Research results will be made available upon request.

Sincerely,

James D. Slotta
Associate Professor, Department of Curriculum, Teaching and Learning, OISE/UT
Canada Research Chair in Education and Technology

I give my permission for Dr. James D. Slotta to conduct the research project outlined above.

________________________________  ____________________________________
Signature                              Date

Published study results will be made available for students and/or parents who are interested. Please feel free to contact the principal investigator with any questions or concerns: James D. Slotta, Associate Processor, OISE/UT, 252 Bloor Street West, Toronto, ON M5S 1V6. Phone: (416) 923-6641 Ext. 2446, Email: jslotta@oise.utoronto.ca
APPENDIX C: STUDENTS CONSENT FORM

To: Students in grade 9 science class
From: Prof. James D. Slotta
Subject: UTS teachers’ participation in a curriculum planning study at University of Toronto.

I am interested in conducting a research project in your school entitled: Technology-Enhanced Activities and Interactions in the Science Classroom: Pedagogical Scripts for Knowledge Communities. This project will investigate how science teachers use technology in their classrooms to help students learn science. Your science teacher will design activities that allow you to collaborate with your classmates in small groups or take part in whole class cooperative learning. Different technologies will be used depending on the topic and type of activity. My research team, including myself and two doctoral students (Hedieh Najafi and Naxin Zhao), will help your teacher use the technology by providing design assistance and technical support. Example technologies are wikis, online discussion forums, Web-based learning environments, and simulations. The information provided from this study will be valuable to our research community to understand how teachers develop inquiry curriculum, and how students learn from this curriculum. It will also be of value to your school administration, in terms of promoting innovative teaching practices for your science teachers.

It is important that you know that both your science teacher and the school principal have approved of this study. Most research activities will involve only normal teaching practices. We will analyze the teachers’ curriculum designs, observe their teaching, and ask them about their assessments of student work. Occasionally we will ask students for an interview to gain a deeper understanding of their experience of the curriculum, as well as their understanding of the science topic. If you are asked to participate in an interview, we will give you and your parents a separate Interview Consent Form. We may also want to videotape certain class periods, in which event we would give a separate Video Permission Letter to all students in the class and their parents.

Because these inquiry science lessons will be part of your regularly schedule science class, we do not require any additional effort on your part. Efforts will be made to make sure this research does not interfere with your regular learning and only improves you and your teachers’ experiences. Some possible activities you may participate in include: learning about and using new technologies, having discussions about science with your classmates; and participating in brief interviews with myself or my doctoral students. You may also be asked to complete a short questionnaire about a science topic at the beginning of the term so we can assess your developing understanding. Only myself and my doctoral students will have access to any of the information collected for the study. At no time will your names, your teacher’s names, or the name of your school be identified in published documents. All information that is collected will be kept in locked files and will be destroyed upon completion of the research. There are no risks associated with
participation in this study and you and your teacher will be free to withdraw from the research at any time.

Every effort will be taken to make sure your identity is kept confidential. Most of the information used in this research project will be from the computer-based materials used within your science lesson. Your identity will be visible to your classmates and your teacher, but will not be available to anyone from outside the school. Our research team will work with your materials, but will never include your name or any identifying information in any of our analyses, reports, or materials. For our own internal reference to your information, we will replace your name with a random ID number (not your student number). Any information will only be accessed from a secure database within my research laboratory. If you are asked for an interview, we will do so either before or after class, or when your teacher is not in the room. All interviews will be conducted in a private room during your lunch hour or after school.

If either you or your parents/guardians have any questions about the study please feel free to contact me by phone: 416-978-0121 or through email: jslotta@oise.utoronto.ca. Any questions about your rights as a participant can be directed to the University of Toronto Ethics Review Office at: ethics.review@utoronto.ca or 416-946-3273.

Sincerely,

James D. Slotta
Associate Professor, Department of Curriculum, Teaching and Learning, OISE/UT Canada Research Chair in Education and Technology

Please complete and return the consent form below to your child’s science teacher at UTS.

I have carefully read and understood the details of the study outlined in this letter.

____________________________
Name of Student (please print)

____________________________
Student’s Signature

____________________________
Name of Parent/Guardian (please print)

____________________________
Parent/Guardian’s Signature

____________________________
Date

Published study results will be made available for students and/or parents who are interested. Please feel free to contact the principal investigator with any questions or concerns: James D. Slotta, Associate Processor, OISE/UT, 252 Bloor Street West, Toronto, ON M5S 1V6. Phone: (416) 978-0121, Email: jslotta@oise.utoronto.ca
# APPENDIX D: CLIMATE CHANGE CURRICULUM OUTLINE, ITERATION 1

*Climate Change unit curriculum outline 2008-2009*

<table>
<thead>
<tr>
<th>Session</th>
<th>Date</th>
<th>Lesson</th>
<th>Wiki and homework</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nov. 13</td>
<td>Introduction to climate change</td>
<td>Wiki:</td>
</tr>
<tr>
<td>2</td>
<td>Nov. 19</td>
<td>Climate change in Canada: Jigsaw with posters from across Canada</td>
<td>- Complete pre-test</td>
</tr>
<tr>
<td>3</td>
<td>Nov. 20</td>
<td>Energy Savings (SEEDS) and GHG Impact</td>
<td>Homework: Either of these</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>- Personal home energy audit</td>
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<td></td>
<td></td>
<td></td>
<td>Home Energy Audit</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>- Vehicle fuel efficiency</td>
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<tr>
<td>4</td>
<td>Nov. 24</td>
<td>Library for Project: research climate change for your region</td>
<td>Wiki:</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>- Adding annotated references</td>
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<tr>
<td>5</td>
<td>Nov. 27</td>
<td>TELS center activity:</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Global climate change: virtual earth</td>
<td></td>
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<tr>
<td>6</td>
<td>Dec. 1</td>
<td>Energy flow: carbon sinks and sources</td>
<td></td>
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<tr>
<td>7</td>
<td>Dec. 3</td>
<td>GHG 1</td>
<td></td>
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<tr>
<td>8</td>
<td>Dec. 4</td>
<td>Paleoclimatology</td>
<td></td>
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<td>9</td>
<td>Dec. 8</td>
<td>Ozone &amp; CFC's; Paleoclimatology (intro)</td>
<td>Wiki:</td>
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<tr>
<td>10</td>
<td>Dec. 10</td>
<td>Paleoclimatology: Ice cores lab</td>
<td>- Brainstorm activity</td>
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<td>Dec. 11</td>
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<td>Dec. 18</td>
<td>Factors that affect climate - ocean currents - The Gulf Stream; Great Pacific Garbage Patch</td>
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<tr>
<td>13</td>
<td>Jan. 5</td>
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<td>Read article &amp; write individual reflection</td>
<td>Each group member (both classes) post an important issue for your region on to wiki (total = 6 issues)</td>
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<td>Identify 3 main issues for region</td>
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<td>As a specialist develop each of your issues on the wiki (~500 words/page/issue/specialist)</td>
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<td>- Become familiar with current models and their complexity</td>
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<td>- Use models to predict future changes for region</td>
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<td>- Identify key issues that you need to bring to your Industry specialist groups (list on wiki pages)</td>
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<td>- 5 min: group organization</td>
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<td>- 7 x 5 min presentations</td>
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<td>- 30 min facilitated discussion</td>
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<td>- Complete Post-Test if necessary</td>
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APPENDIX E: PRETEST AND POSTTEST QUESTIONNAIRE, ITERATION 1

Knowledge of Climate Change

• What is global warming?
• What is greenhouse effect?
• Look at the list below and select all of the factors that you think have an effect on global warming. You can select more than one.
  ○ Acid rain
  ○ Water Vapor
  ○ Greenhouse Gases
  ○ Clouds
  ○ Carbon Dioxide
  ○ The Ozone Layer
  ○ Solar Energy
  ○ Infrared Energy
• What is the role of clouds in The Greenhouse Effect?
• What is the role of greenhouse gases in Global Warming? Be sure to be as detailed as possible when explain your answer. You can draw a picture to help explain your thoughts.

Students Epistemological Beliefs

• How do you think your out-of-school activities could be related to what you learn in science class?
• Who is more responsible for your learning in science class: The teacher, or you? Please explain.
• How do you know when you have really learned something? Describe an example.
• From the list below, which methods of learning new science material would you most prefer?
  ○ being told what is correct by a teacher
  ○ Doing experiments by myself or with other students.
  ○ Make observations and try to figure things out.
  ○ Use what I already know to understand new material.
  ○ Read the right answers in the textbook.
  ○ Figure out the new material before relating it to what I know.
  ○ Explain your choice: __________
• How can working collaboratively with a group of your peers help you to learn science topics more deeply?
• How are students’ ideas (your own and those of your peers) important for learning in science class? Please explain.
• How can the science teacher help students to develop their own ideas about science topics?
• How do you prefer to participate in class discussions (you can choose more than one)
  ○ Start your own new topics
• Which best describes scientific knowledge: (check one and give an example that helps explain your answer)
  o Science knowledge is constantly changing because different scientists have different opinions
  o Science knowledge does not change. Scientists do experiments to confirm existing results.
  o Science knowledge is constantly expanding because scientists use the results from experiments to replace or improve current ideas.
APPENDIX F: BASELINE DATA ON REGIONAL GROUPS, ITERATION 1

1- Atlantic Provinces
   **Group Members:** Tatiana and Chad from Section A; Rebecca, Angela, Pat, and Amy from Section B.

   **Wiki Space**

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2- BC
   **Group Members:** Elena, Vanessa, and Greg from Section A; Ben, Kathy, and Rita from Section B.

   **Wiki Space**

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3- Nunavut

**Group Members:** Stan, Laura, and Adriana from Section A; and David, Roy, and Brian from Section B.

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4- Ontario

**Group Members**
Sara and Mike from Section A; Cara, Sam, Cheryl, and Chris from Section B.

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Ontario Carbon Sinks (Mike)
Ontario Climate Change Issues (Mike & Sara) *
Great Lakes Water Level Changes (Sam) *
Ontario Greenhouse Gases (Sara)
Ontario Invasive Species
Ontario Weather Patterns (Stephanie)
Paleoclimateology in Ontario (Cara)

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| Prairies        | Main          | 51              | Five group members plus Kate from Quebec group |
| Carbon sinks resources- other assignment | Sub | 1  | Martha |
| Carbon sources  | Sub           | 6               | Kate, Michelle, Tim |
| Desertification | Sub           | 1               | Tim |
| Environmental impact against economic benefits of the tar sands | Sub | 1 | Tim |
| Green house gases | Sub         | 9               | Tim, Martha, Michelle |
| Main industry   | Sub           | 5               | Tim, Martha, Michelle |
| Primary Industry in the Prairies (Farming) | Sub | 4 | Tim |
| Weather patterns and anomalies | Sub | 6 | Michelle, Dan |

6-Quebec

Group Members: Steve, Kate, and Frank from section A; Joshua, Jake, and Janice from section B.

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| Page title      | Page level    | Revisions       | Author or co-authors |
| Quebec          | Main          | 72              | 6 group members |

5- Prairies

Group Members: Tim and Michelle from Section A; Dan and Martha from Section B. The group originally had five members but one of them was absent for the most of the group work. I disregarded her contributions.
7-Yukon and Northwest Territories

Group Members: Pauline, Nathan, Anthony from Section A; Jason, Tamara, Justin, and Robert from Section B.

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APPENDIX G: PRE AND POST-UNIT QUESTIONNAIRE, ITERATION 2

Please enter your first and last name: *
Gender: *
Female
Male

Section 1: Knowledge of Climate Change
In This section you will answer questions about your current knowledge of Climate Change science.

The term "Albedo" refers to: *
A source of CO2.
The reflection of incoming solar energy.
The impact of the moon's reflection on the solar energy absorbed.
An increase in white coats in Boreal animals
A person in the Xenosaga Universe

Human caused changes are referred to as: *
Anthrophotogenic
Anthroclimatic
Anthropological
Anthropogenic
Anthropic

Which of the followings are greenhouse gases: *
CO2, N2, H2O NO2, CH4(methane)

Which of the following relationships are important to models of climate change: *

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<td>Increased CO2 in the air leads to warmer global temperatures</td>
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<td>Light coloured surfaces (e.g. ice, snow) reduce the amount of heat trapped by the earth</td>
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<td>Human population density and ambient air temperature</td>
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<tr>
<td>Prevailing wind patterns are governed by thermal convection cells</td>
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<tr>
<td>Percent of land cover by forest</td>
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| Approximately what percent of the earth's total Carbon is stored in the soil: *
| 10%, 30%, 50%, 70%, 90% |
| Thermal energy is transferred through the atmosphere and the oceans by the process of...: *
| Three indicators of climate change are: *
| Trees can act both as carbon sinks and carbon sources: *
| True, False |
| What is the greenhouse effect: *
| How does the greenhouse effect occur: *
| Briefly describe the effect of climate change on humans: * |
Briefly describe the effect of climate change on natural ecosystems: *
Name and briefly explain an initiative that currently exists to reduce climate change: *
Briefly explain why you think this initiative does/does not work: *

Section 2: Purposes and ways of learning science at school
In this section you will answer questions regarding your beliefs about purposes and ways of learning science at school. Answer these questions to the best of your knowledge. Remember, you are not being assessed.

How would you rate your performance in high school science classes you have taken: *
Poor, Average, Good, Excellent

How would you rate your performance so far in M3 science class: *
Poor, Average, Good, Excellent

How do you know when you understand something? How can you tell: *
"Overall, the science I learn in school has little or nothing to do with my life outside of school." Do you "Agree" or "Disagree"? Please explain.: *

When learning new science material I prefer to: *

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<th>Most of the times</th>
<th>Sometmes</th>
<th>Rarely</th>
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<td>Be told what is correct by a teacher.</td>
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</tr>
<tr>
<td>Read the right answers in the textbook.</td>
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<tr>
<td>Have an expert explain the right answer to me.</td>
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<tr>
<td>Do experiments by myself or with other students.</td>
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<tr>
<td>Make observations and try to figure things out.</td>
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<tr>
<td>Use what I already know to understand new material.</td>
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<tr>
<td>Use an example to help me understand new ideas.</td>
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</tr>
</tbody>
</table>

Describe a situation where learning science was enjoyable and effective for you: *
In M3 science class: *

<table>
<thead>
<tr>
<th>Most of the times</th>
<th>Sometmes</th>
<th>Rarely</th>
</tr>
</thead>
<tbody>
<tr>
<td>I get the chance to talk to other students.</td>
<td></td>
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<tr>
<td>I talk with other students about how to solve problems.</td>
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<tr>
<td>I explain my ideas to other students.</td>
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<td></td>
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<tr>
<td>I ask other students to explain their ideas.</td>
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<tr>
<td>Other students listen carefully to my ideas.</td>
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</tbody>
</table>

How do the following describe your opinion of working collaboratively in groups: *

<table>
<thead>
<tr>
<th>Most of the times</th>
<th>Sometmes</th>
<th>Rarely</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>Neutral</td>
<td>Disagree</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
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<td>----------</td>
</tr>
<tr>
<td>I enjoy working in groups.</td>
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<td></td>
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<tr>
<td>Working in groups (compared with working individually) allow me to</td>
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<tr>
<td>tackle more complex project topics.</td>
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<tr>
<td>Working in groups to do projects can help me to learn the subject-</td>
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<tr>
<td>related knowledge.</td>
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<tr>
<td>Working in groups provides many chances for discussion and sharing</td>
<td></td>
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<tr>
<td>of ideas.</td>
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<tr>
<td>I learn more effectively by working with peers on a project than by</td>
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<tr>
<td>doing homework.</td>
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<tr>
<td>When working in groups, I have more courage to take the initiative</td>
<td></td>
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<tr>
<td>to investigate more complex topics.</td>
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<tr>
<td>If I don’t participate in group work, my reputation among my</td>
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<tr>
<td>classmates will be affected badly.</td>
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<tr>
<td>Working in groups is great for some topics, but not for difficult</td>
<td></td>
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<tr>
<td>topics like science.</td>
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</tbody>
</table>
APPENDIX H: REFLECTION NOTE 4

What is something you learned about an important climate change issue during the brainstorm activity: *
Something I learned was...

Which of the following describes your contribution to the brainstorm: *
I contributed one or more good ideas.
I added something to someone else's idea.
I listened to my peers and thought about what they said.
I did not feel that my ideas were recognized.

Which of the following describes the brainstorm process of your group: *

<table>
<thead>
<tr>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agree</td>
<td>Neutral</td>
<td>Disagree</td>
</tr>
</tbody>
</table>

Our group worked effectively and everyone got a chance to contribute.
Our group was disorganized and confused.
One or two people tended to dominate the discussion.
Working together, our group was more productive than if we had all worked separately.

How did the group brainstorm process help you develop a deeper understanding of climate change issues: *
APPENDIX I: REFLECTION NOTE 5

How do greenhouse gases relate to your issue: *

How did you contribute to your group's effort: *
Adding content to your issues page.
Signing up for a section on your group page.
Completing the section for which you had signed up.
Editing content added by other group members.
Leaving comment for group members on the quality of their work.
Leaving comment for group members pointing out things that need to be done.
How have other members of your group helped you understand this topic of greenhouse gas and how it relates to your issue?: *

How do you feel that you can help your group mates get more involved and be more productive: *
APPENDIX J: REFLECTION NOTE 6

How do you evaluate the scientific quality of your contributions to the issues pages in comparison to your group mates' contributions?: *

How do you think you will use existing content created by all M3 students in the "issues" activity in the culminating activity?: *

How useful was the peer feedback you received on your issues pages? Briefly explain why?: *

What did you learn from working in collaborative groups that would help you become a more effective group member in the culminating activity?: *