KNOWLEDGE COMMUNITY AND INQUIRY IN SECONDARY SCHOOL SCIENCE

by

Vanessa Lynn Peters

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Abstract

This design-based study was the first empirical investigation of a new model of learning and instruction called Knowledge Community and Inquiry (KCI). In KCI, students are engaged as a learning community as they work on scaffolded inquiry activities that target specific science learning objectives. Although community-oriented approaches have been successful at the elementary level, there has been relatively little uptake of such methods at the secondary school level – particularly in science. The pedagogical framework of KCI addresses the challenges of community models by blending established inquiry based approaches with community-oriented pedagogy. This dissertation tested the validity of KCI by designing, implementing, and empirically evaluating a curriculum based on the KCI model. This was achieved through curriculum trials involving two separate cohorts of grade-ten biology students ($n = 102; n = 112$).

The first implementation consisted of a two-week physiology lesson that engaged students in co-authoring wiki artifacts about human system diseases, which students then used as a resource for solving medical case studies. The second implementation, an eight-week lesson on Canada’s biodiversity, was a deeper application of the model, and focused on students’ collaborative processes during the construction of their wiki-based knowledge repository. In both cases, the curriculum was evaluated according to its design, enactment, and learning outputs, as evidenced by students’ knowledge artifacts.
and performance on the final exam. Technology scaffolds ensured that students focused on the physiology and biodiversity science curriculum expectations. Analyses of the data revealed that KCI engaged students in collaborative learning processes that were characteristic of a knowledge community. Additionally, final exam scores demonstrated increased learning performance when compared to those from previous years where students did not participate in KCI.

The findings from this research provide the first empirical support for KCI, and demonstrate its potential for engaging secondary science students in the kinds of collaborative inquiry processes of authentic knowledge communities. This dissertation provides insight into the conditions necessary for such engagement, and contributes design recommendations for blending knowledge community and inquiry in secondary school science curriculum.
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CHAPTER 1: INTRODUCTION

1.1 Chapter Overview

This dissertation describes a research study that investigated a new model of learning and instruction for secondary school science. It is concerned with the design, implementation and evaluation of a pedagogical model that aims to engage students in inquiry activities within the context of a knowledge community, and while making use of scaffolded inquiry activities that guide students to achieve curriculum content expectations. This chapter begins with a discussion of the motivation for the study, including the research goals and questions. It then provides a brief introduction to the pedagogical model that was the focus of this study, and concludes with a description of the organization of the dissertation.

1.2 Motivation for the Study

Over the last decade, there has been tremendous growth in the development of technology in every sector of society. With the ubiquity of personal computers and mobile devices, people are increasingly looking to the Internet as a source of information and a primary channel for communication. The societal impacts of these new technologies are particularly visible in the business and economic sectors. Across the globe, industries have been largely restructured due to the improved quality and decreased prices of hardware and software, as well as the flexible access to information afforded by networked computing (Pohjola, 2002).

Advanced technologies have changed the ways in which humans collaborate and create knowledge, to the extent that technology and knowledge advancement are now inextricably related (Karmarkar & Apte, 2007). As a result of these changes, most
occupations now require new kinds of literacies such as searching for and using relevant information, communicating and collaborating in digital environments, and using initiative and self-direction to solve complex problems (Warschauer & Matuchniak, 2010). The skills typically associated with these “literacies” – computer literacy, digital literacy and information literacy – have collectively come to be known as “21st century knowledge skills” (Lemke, Coughlin, & Reifsneider, 2009).

The new workplace literacies have been said to reflect the growth of a “Knowledge Age”, in which society has come to rely on processes of knowledge creation and advancement over those of labour, industry or mechanical production (Bereiter, 2002; Bereiter & Scardamalia, 1996). Half a century ago, Drucker (1959) described a citizenship where, “the man who works exclusively or primarily with his hands is the one who is increasingly unproductive. Productive work... is work that applies vision, knowledge and concepts – work that is based on the mind rather than on the hand.” (p. 120).

Technology plays a central role in the knowledge age. Jobs requiring manual or routine tasks are increasingly being done by computers, and replaced with jobs where computers are used to enhance the complex thinking and knowledge work of humans (Warschauer & Matuchniak, 2010). In the 21st century workforce, productive knowledge work is associated with the processing and distribution of information, decentralized decision-making, and collaborations within and between organizations and industries (Karmarkar & Apte, 2007). From the perspective of education, it is becoming widely accepted that competencies in these abilities are essential if citizens are to be constructive
contributors to the “knowledge economy” (Scardamalia & Bereiter, 2003; Zuboff & Maxmin, 2002).

Given the rapid development of computer and information technologies, it would follow that today’s schools are helping students develop the skills they will require to succeed in tomorrow’s workplace. But leading researchers argue that this is not the case. Collins and Halverson (2009) hold that there are deep incompatibilities between technology and schooling, and that classrooms that use computers do so in mostly superficial ways. In contrast with the developments occurring within most domains, the education sector remains largely unchanged, with classrooms closely resembling those of the mid-20th century (Becker, 1999). As diSessa (2000) observes, “Few can or should claim that computers have influenced the cultural practices of school the way they have other aspects of society, such as science or business. Just look at texts, tests and assignments from core subjects. They really have changed little so far.” (p. 3). In the educational literature, a general consensus has developed regarding the necessity of reconciling school-based technologies with those of the outside world.

This is not to suggest, of course, that there is no technology currently utilized within schools. Indeed, word processing software and the Internet are standard tools for most students’ projects and essays. In addition, many teachers use the Internet for supplemental activities such as searching for and evaluating resources (Becker, 1999). The problem lies in that technology is not being used to help students develop the critical thinking, reasoning and teamwork skills that are necessary for contributing to a knowledge society (Collins & Halverson, 2009).

Lemke et al. (2009) contend that educators have largely miscalculated the depth
of change required to infuse technology into the curriculum in meaningful ways. These include the impact of technology on staff time, school budgets, professional development programs and curricula design. Such underestimation can result in what Maddux and Cummings (2004) refer to as educational “fads”. They point out that technology innovations (e.g., smart boards) are vulnerable to becoming short-lived trends that are met with initial enthusiasm and adopted before best practices can be established (Maddux & Cummings, 2004). Maddux, Liu, and Johnson (2008) remind us that every innovation will have drawbacks, and that only through extensive research involving curriculum innovations can we avoid early dismissal of educational technologies. Such research will require sensitivity to school culture, curriculum standards, and teachers’ current classroom practices (Lemke, Coughlin, & Reifsneider, 2009).

There are already a number of research initiatives investigating 21st century learning. Some of the earliest work has been done by the Partnerships for 21st Century Skills (P21), a joint initiative between American businesses, government and education leaders that provides resources to schools for their efforts in developing student readiness for the 21st century workforce (Partnership for 21st Century Skills, 2009). The International Society for Technology in Education (ISTE, 2010) advances similar ideas by espousing the use of innovative technologies for developing students’ information and digital literacy skills in the context of disciplinary subjects (see www.iste.org). More recent initiatives include the Assessment and Teaching of 21st Century Skills (ATCS), an international project that seeks to operationalize and assess 21st century skills by identifying barriers – both technological and methodological – that impede educational reform. The ATCS have articulated a core set of 21st century skills that are crucial for K-
Central to these initiatives is the underlying goal of engaging students in activities and tasks that resemble those of real knowledge workers. In such a classroom, students would learn to become strategic, goal-directed and resourceful, with the aim of becoming “expert learners” (Bereiter & Scardamalia, 1993; Brown, Ellery, & Campione, 1998).

Curricula designs that make use of emerging technologies – such as those associated with Web 2.0 – are needed to link formal learning with the kind of persistent informal learning that occurs outside the classroom (Barth, 2009; Lemke, Coughlin, & Reifsneider, 2009).

Thus, the predominate form of classroom instruction – which usually consists of lectures and homework – are not desirable models for 21st century learning (Collins & Halverson, 2009). To prepare students for the knowledge age, we must challenge them to think critically about scientific concepts so that they can develop critical thinking, inquiry and collaboration skills (Linn, Kali, Davis, & Horwitz, 2008).

The domain of science provides an ideal context for the instruction and practice of such skills, however, science remains one of the most entrenched disciplines in terms of rote learning of mandated curriculum expectations (Slotta & Linn, 2009). This is especially the case in secondary school science, which typically covers more topics than any other subject, resulting in textbooks that have been described as being “a mile wide and an inch deep” (Schmidt, McKnight, & Raizen, 1997, p. 62). Not surprisingly, the responsibility placed on secondary teachers for teaching specific content matter makes it difficult for them to design learning activities where students can pursue a deep understanding of science topics (Slotta & Linn, 2009). All science lessons must fit within a tight schedule of content coverage, leaving teachers little or no time to ask students the
“big picture” questions.

Developing curricula that moves towards 21st century knowledge skills will require extensive research. Although there is already a wealth of research on technology-enhanced learning, many of these studies fail to report the fidelity of their interventions with respect to design, curricular fit and teacher enactment (Lemke, Coughlin, & Reifsneider, 2009). Many K-12 educators are aware of the importance of teaching students 21st century skills, but their efforts are hampered by a lack of clear guidelines from researchers of how to teach them in the classroom. Some students may develop these skills incidentally, but without operationalizing them in a curriculum, it will prove challenging, if not impossible, to involve all students in 21st century learning (Barth, 2009).

1.2.1 Knowledge Communities

The educational community has made advancements towards the development of instructional models that support 21st century skills. A great deal of this effort has focused on investigating scientific inquiry, in response to calls from organizations such as the National Research Council (NRC, 2010) and the National Science Education Standards (National Academy Press, 1996). Education scholars have developed a number of programs that have demonstrated success in supporting students’ scientific inquiry skills. Included among them are the Web-Based Inquiry Science Environment (WISE) (Slotta & Linn, 2009), BioKIDS (Songer, 2006), Inquiry Island (White & Frederiksren, 1998) and the Biology Guided Inquiry Learning Environment (BGuILE) (Sandoval & Reiser, 2004). These programs, while highly successful, focus on carefully crafted “scaffolded” activities designed for learning specific science concepts. Students work
closely in pairs or small groups, but are generally unaware of the accomplishments and challenges faced by classmates in other groups. More often than not, these activities are included as adjuncts to existing curricula, and are generally not well integrated into an overall approach to learning and instruction (Peters & Slotta, 2010).

To engage students in authentic scientific inquiry – reminiscent of the activities of scientists and other knowledge workers – a number of scholars have called for a change in the very culture of schooling, a change that involves the transformation of classrooms into “knowledge communities” (e.g., Brown & Campione, 1996; Scardamalia & Bereiter, 2003). Knowledge communities can be characterized by the emphasis on collective knowledge over individual knowledge, the improvement of ideas over the accretion of facts, and by the pursuit of understanding problems that are of interest to all members of the community (Scardamalia & Bereiter, 2006). Other knowledge community models have focused on the acquisition of deep disciplinary knowledge, topic specialization within the community, and the widespread sharing of peer-created resources (Brown & Campione, 1996).

While the knowledge community model is perhaps more compelling in terms of preparing students for 21st century knowledge work, it has received comparatively little attention from educational researchers. This is perhaps due to the profound changes that are required to transform classrooms into knowledge communities – changes that require significant alterations to curricula and teachers’ current instructional practice (Peters & Slotta, 2010). To advance the research in this important area, we require new approaches that make the knowledge community model more accessible for teachers of content dense
subjects like science – subjects that already have a history of successful research with scaffolded forms of inquiry.

### 1.2.2 A new pedagogical model

A new model of learning and instruction promises to engage secondary science students in the kind of technology-enhanced knowledge work that is necessary for the 21st century workplace. Developed by Slotta (2007), the Knowledge Community and Inquiry model (KCI) combines collaborative knowledge construction and scaffolded inquiry activities that target specific learning objectives in secondary school science. The model begins with an activity that engages students in collaboratively creating knowledge artifacts that aggregate to form a community knowledge base. This knowledge base then serves as the primary resource for subsequent inquiry activities that require students to make extensive use of the knowledge artifacts created by their peers. To make the knowledge base more relevant for students, and to ensure that specific science content is addressed, the KCI model employs technology supports that guide students during their knowledge construction and inquiry tasks. The theoretical goals underlying the KCI model, which are discussed in Chapter 2, are reflected in the design and sequencing of the activities that contribute to a KCI-based curriculum. By involving teachers in all phases of the design process, the KCI model guides the development of curriculum materials that have a high degree of ecological validity in the classroom.

### 1.3 Research Goals

This dissertation study is the first scientific investigation of the KCI model, including the first design of a KCI curriculum, the first implementation effort, and the
first analysis of a curriculum based on the KCI model (in terms of its effectiveness for student learning). The research draws on the prior work of Slotta and his colleagues (Slotta, 2002, 2004; Slotta & Linn, 2009), as well as the wider literature concerned with inquiry and community-based learning. By instantiating the KCI model within a secondary science curriculum, this study investigated the efficacy of the model, and offers design-based recommendations for its improvement based on the outcomes of two classroom interventions.

### 1.3.1 Research questions

Before it was enacted as a curriculum in a classroom, the KCI model could only be understood in the abstract – as a complex pedagogical approach for developing curriculum units that engaged the classroom as a whole while guiding students in inquiry activities that target specific learning goals. But without specification of the essential elements of such a model and how they work together, any learning model risks becoming both superficial and proceduralized (Brown & Campione, 1996). To move toward a set of design principles that embody the theoretical commitments of KCI, the model requires cycles of design, enactment and evaluation within the context of classroom trials. The following research questions provide the focus for the first effort in such a design-based study:

1. What design elements are important for a secondary science curriculum that is consistent with the theoretical commitments of the KCI model?

2. What forms of student collaboration and inquiry can be supported by a KCI-based curriculum?
3. How does KCI support students in meeting the content learning expectations, as well as developing knowledge skills?

1.4 Researcher Background

With an undergraduate degree in Applied Linguistics, I was drawn to educational research through my experiences as a student and ESL teacher in both Ontario and abroad. My interests in technology emerged while I was pursuing a master’s degree in computer applications at OISE/UT. This interest was deepened through my undergraduate teaching experiences at Brock University, where I was involved in designing and teaching Brock’s first series of online credit courses.

For my dissertation research, I was interested in working with secondary school students and teachers, and learning about the dynamics of a K-12 classroom. In particular, I was very interested in the notion of co-design (see Penuel, Roschelle, & Shechtman, 2007). Co-design is a process where teachers are brought deeply into the process and development of research materials. Although the curriculum design in my study was a combined effort between the teachers and researchers, the teachers’ position on certain aspects of the curriculum – for example, the length of the activities or the weighting of assessments – were not challenged unless they compromised the theoretical commitments of the KCI model. The goal of this design process is to achieve a curriculum design that the teachers feel is their own – that is, the researcher does not even need to be in the classroom for it to be enacted faithfully to its design. During the study, I was mindful that the classroom was very much the teachers’ domain, and avoided becoming unnecessarily involved during the enactment stages of the KCI curriculum.
1.5 Organization of the Thesis

There are six chapters in this dissertation. In Chapter 2, I review the literature and previous research that are relevant to this work, and elaborate on the components and theoretical commitments of KCI. In Chapter 3, I discuss the methodology used in this study, including a description of the research setting and study participants. Chapters 4 and 5 provide details about the methods, analysis and findings of two design research iterations. The first iteration was a careful test of the capacity of students, teachers and technologies to achieve some of the basic elements of KCI. The second iteration built on lessons learned from the first to achieve a full implementation of KCI. Chapter 6 is a general discussion pertaining to both design cycles and the study as a whole, and presents some conclusions about the research.
CHAPTER 2: LITERATURE REVIEW

2.1 Chapter Overview

This chapter reviews the relevant prior research, drawing on literature from cognitive science, educational psychology and design-oriented research. The review is organized in four sections: (i) Theoretical Foundations, (ii) Knowledge Communities, (iii) Inquiry-Based Learning, and (iv) Emergent Technologies. The chapter concludes with a more detailed description of the KCI model, including the design and sequencing of activities in a curriculum designed according to the model.

2.2 Theoretical Foundations

This dissertation research, including the KCI model, has a theoretical perspective of social constructivism that is common to the learning sciences research on inquiry (e.g., Quintana, Zhang, & Krajcik, 2005; Slotta & Linn, 2009), collaboration (e.g., Rochelle, 1992) and knowledge communities (e.g., Bielaczyc, 2004; Bielaczyc & Collins, 1999; Scardamalia & Bereiter, 2006). It is important to start at the beginning with respect to these theoretical foundations, as they provide the scientific basis for the kinds of learning and instruction advocated by KCI, and have influenced the research into the learning processes of students in K-12 classrooms (Bransford, Brown, & Cocking, 2000; Palincsar, 1998).

2.2.1 Cognitive constructivism

Research in the learning sciences is based primarily on constructivist learning theory (Sawyer, 2006). This perspective contrasts with the earlier “transmission model” that assumes knowledge is transferred directly to students through instructional content
such as textbooks or lectures (Miller & Seller, 1990; Reddy, 1979). In essence, constructivism holds that learning is a process whereby individuals transform information into knowledge through a process of interpretation (Murphy, 2003), and that regardless of the subject domain, there may be any number of individual interpretations that are considered equally valid (Dalgarno, 2001; Driscoll, 1994). Jonassen, Davidson, Collins, Campbell and Bannan-Haag (1995) summarize the constructivist perspective as follows: “The important epistemological assumption of constructivism is that knowledge is a function of how the individual creates meaning from his or her experiences; it is not a function of what someone else says is true” (p. 11).

At the heart of constructivist theory is the work of psychologist Jean Piaget (1896–1980), whose theories of cognitive development shaped a great deal of research into the learning processes of both children and adults. Piaget’s main assertion was that children progress through four stages of cognitive development, and that these stages can account for why children think differently from adults (Bransford, Brown, & Cocking, 2000). This idea came to be known as “stage theory”, and resulted in much criticism of Piaget’s work. Researchers have criticized Piaget’s theory on the grounds of underestimating children’s competence (Donaldson, 1978; White, 1993), undermining the role of social factors in cognitive development (Broughton, 1981; Winegar & Valsiner, 1992) and for disregarding cognitive development past the late adolescent stage (Alexander & Langer, 1990; Basseches, 1984).

Piaget articulated a number of internal processes that account for learning within the developmental stages. Two important mechanisms, assimilation and accommodation, explain how learners push the boundaries of their understanding (Montangero &
Maurice-Naville, 1997). According to Piaget, assimilation occurs when learners process new information so that it will make sense in terms of their existing knowledge. Accommodation, on the other hand, occurs when learners reconsider their existing knowledge in order to make sense of the new information. Piaget held that individuals experience disequilibrium when there is conflict between new information and what they already know. The result of disequilibrium, argues Piaget (1985), “forces the subject to go beyond his current state and strike out in new directions” (p. 10).

The productive disequilibrium advocated by Piaget is most likely to occur in a social context, where there are higher levels of interaction between peers (Palincsar, 1998). This notion of “sociocognitive conflict” is of central importance to many collaborative and peer-directed learning models, which assume that learning takes place during the exchanges which occur between learners (King, 1992; Palincsar, 1998). When students interact with one another, they are often confronted by perspectives and views that are different from their own. Students reconcile these differences through explaining and justifying their position to their classmates, eventually arriving at a negotiated understanding of the question or problem (King, 2002; Webb & Mastergeorge, 2003). Learning models that promote this type of interaction include peer tutoring (Topping, 1988; Walker, Rummel, & Koedinger, 2009), small-group problem solving (Yackel, Cobb, & Wood, 1991), productive peer-helping (Webb, Farivar, & Mastergeorge, 2002) and, more recently, scripted forms of collaboration (Dillenbourg, 2002; Fischer, Kollar, Haake, & Mandl, 2007).
2.2.2 Social constructivism

Although social interaction has a role in Piaget’s theory, it is more directly associated with the theoretical contributions of Vygotsky (1978) who, like Piaget, believed that children construct new knowledge based on prior experiences and beliefs. Vygotsky focused on the social, cultural and historic factors that influenced learning (Robbins, 2005), rejecting Piaget’s stage theory under the argument that learning is a lifelong process where knowledge is constructed through the use of language (Driver, Asoko, Leach, Mortimer, & Scott, 1994). Vygotsky focused on social development, maintaining that learning should be conceived as a process of assimilation into an established community of practice (Duffy & Cunningham, 1996).

The social focus of Vygotsky’s theory provides the context for what is probably his most recognized contribution: the Zone of Proximal Development (ZPD). In Vygotsky’s words, the ZPD refers to “the distance between the actual development 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 ZPD represents specific circumstances where a student, by interacting with a more knowledgeable individual, can complete a task that they would otherwise have not been able to achieve.

Although Vygotsky conceptualized the ZPD as a support provided by the teacher or a more knowledgeable peer, in practice any mechanism that supports students could have the effect of situating them within their ZPD. These supports could be in the form of curriculum materials, or features and supports that are integrated into the learning environment (Palinscar, 1998). In the educational literature, mechanisms that provide
support are referred to as “scaffolds”. Scaffolds have been specifically designed to support a number of pedagogical approaches, including knowledge integration (Slotta & Linn, 2009), collaborative argumentation (Jeong & Joung, 2007), complex reasoning (Reiser, 2004) and metacognitive awareness (Quintana, Zhang, & Krajcik, 2005).

Constructivism – particularly social constructivism – could be described as the zeitgeist of contemporary educational theory (Applefield, Huber, & Moallem, 2000). But within the constructivist view there is considerable room for interpretation. Many teachers, for example, believe that any activity involving group work qualifies as constructivist teaching (Brooks & Brooks, 1993). However, there is general consensus that constructivist practice aims to encourage deep thinking and understanding in students, along with the ability to transfer and use new knowledge within real world contexts (Applefield, Huber, & Moallem, 2000).

With respect to the challenge of helping students develop 21st century knowledge skills, a reasonable approach is to emulate contexts where knowledge creation occurs naturally, such as in scientific or scholarly communities. In such a community, all participants benefit from the advancement of the community’s overall knowledge about specific topics, ideas or practices (Scardamalia & Bereiter, 2003). Within the educational literature, however, the notion of a community-oriented classroom is underrepresented when compared with other forms of learning and instruction (Hakkarainen, 2009). In the following section, I discuss some of the literature on learning within knowledge communities, including classroom studies that have specifically adopted a community-based approach.
2.3 Knowledge Communities

The notion of a knowledge community (also referred to as a learning community) is nebulous within the research literature (Bakardjieva, 2004; Gardner, 2004). Etzioni (2004) describes community as a social milieu in which individuals are involved in affective relationships. To be in a community, members must share both a history and an identity, which is expressed through their commitment to the values and norms of their social environment (Kling & Courtright, 2003). Rheingold (1996) echoes the belief that community is comprised of shared interests and goals, but emphasizes that individuals must be highly interpersonal to feel connected to a community. Once a sense of community becomes established, individuals experience a sense of security and satisfaction with respect to their community membership (Wellman & Guila, 1999).

As a framework for learning, the community model has been applied to disciplines where groups of individuals regularly interact to produce collective knowledge (Kling & Courtright, 2003; Preece, 2000). Community models have been advanced in a number of fields, including business, politics, law and medicine (Noddings, 1996). In education, researchers have developed models that emphasize knowledge advancement and collective understanding in classrooms. Among the most prominent knowledge community models are Knowledge Building (Scardamalia & Bereiter, 2003), Fostering a Community of Learners (Brown & Campione, 1996), Communities of Practice (Wenger, 1998) and Progressive Inquiry (Hakkarainen, 2003).

When applied to the classroom, these models have similarities and differences on a number of levels, including the structuring and sequencing of activities, the distribution of student expertise, and the type and degree of cognitive and social scaffolding. The
models share a common purpose, however, in that students work together to construct knowledge that belongs to the entire community (Bielaczyc, 2006). In a knowledge community classroom, the teacher is considered a learning partner and facilitator, not an expert who is the principal source of knowledge. Instead, students develop expertise by asking questions, offering solutions, and negotiating understanding through their own lines of inquiry (Bielaczyc & Collins, 2002).

Although desirable from the perspectives of social constructivism and the need to develop 21st century knowledge skills, cultivating a knowledge community in a classroom is a challenging endeavour. As Kling and Courtright (2003) observe, “developing a group into a community is a major accomplishment that requires special processes and practices, and the experience is often both frustrating and satisfying for many of the participants” (p. 221). A sense of community develops when individuals, though their social interactions, attempt to satisfy their desire for a common purpose or goal (Preece, 2000; Rovai, 2002). The behaviour of community members is guided by accepted social protocols and implicit codes of behaviour that form the norms of a group (Preece, 2000). It has been suggested that to advance community-oriented approaches in education, researchers must take a deeper look at the social transformation that is required for turning classrooms into learning communities (Hakkarainen, 2009).

There are, however, pragmatic challenges to cultivating a knowledge community in the classroom. The changes that are required – both pedagogical and social – must be deeply embedded within a teacher’s curriculum, and reflected within the teacher’s own practice (Brown, 1997). To transform a classroom into a knowledge community, researchers must first develop a clear, achievable approach or model, and then help
students and teachers in achieving that model (Gardner, 2004). Many researchers have articulated pedagogical designs that reflect the learning principles and learning goals of a community-oriented learning approach, however, what has received little attention is how to increase the uptake of such approaches in secondary school science. In the following section, I describe some of the features and challenges of community-oriented models, referring to specific knowledge community models for purposes of illustration and discussion.

### 2.3.1 Shared community knowledge base

Just like members of a scientific community, students in a knowledge community create and use their own knowledge repository. In the Fostering a Community of Learners model (FCL), Brown and Campione (1996) developed a systematic activity structure based on cycles of “research, share and perform”. In the first cycle (research), students participate in activities that require them to read, write or listen as they select relevant materials for their topic. Research activities can take a number forms, such as reciprocal teaching, guided writing, and peer and cross-age teaching. Some of these activities, reciprocal teaching in particular, are powerful learning mechanisms in their own right. Developed by Palincsar and Brown (1984), the reciprocal teaching program was widely successful in helping students improve their text comprehension. In this learning approach, students take turns asking questions, summarizing and making predictions of a text, and leading the discussion (Palinscar & Brown, 1989).

Other activities in the FCL research cycle emphasize writing. For example, in an activity called guided writing (Brown & Campione, 1996), students are responsible for producing their own learning texts. The composition process in this activity gives
students practice in communicating their thoughts and ideas to their peers, and for making decisions about what kind of content is relevant. Regardless of the type of activity employed, the goal of the research phase in FCL is to generate resources that students can use in the subsequent cycles of sharing and performing, and to disperse disciplinary expertise among students. The resources students create focus on topics of disciplinary content that are carefully chosen for their suitability to support the instructional goals (Brown & Campione, 1994, 1996).

Not all knowledge communities impose the same level of structure as FCL. In Scardamalia and Bereiter’s knowledge building model, ideas take the place of disciplinary knowledge resources (Scardamalia & Bereiter, 1996, 2003). Rather than topic-based artifacts that focus on content, knowledge building advances conceptual artifacts that are used for epistemic purposes such as explaining, predicting or theorizing (Bereiter, 2002; Hakkarainen, 2009). Such artifacts are not part of students’ individual knowledge, rather, they are part of the cultural knowledge in what Popper (1972) describes as “World 3” – a world occupied by abstracts such as scientific theory, stories and art. Hakkarainen (2003) describes a similar notion in his Progressive Inquiry model, where the cognitive conflicts that students experience are referred to as “cognitive resources” (p. 1074). Thus, for all community models, a shared resource base is seen as an important common reference that fosters a feeling of membership amongst participants, captures their diverse perspectives and contributions, and offers a source of knowledge and information for the activities of the community. Important from a Vygotskian perspective, the shared knowledge base is fashioned at a conceptual level that is likely to be set within the ZPD of most community members.
2.3.2 Establishing the big ideas

One of the main objectives of a knowledge community approach is to find and focus on the “big ideas” of the disciplinary topic, and then impart those big ideas to students (Gardner, 2004; Rico & Shulman, 2004). In a study involving two school high school biology classes, Rico and Shulman (2004) investigated how teachers went about identifying the formative big ideas of an invertebrates and circulatory unit, and how those ideas were subsequently sized down into jigsaw-type activities. One of the biggest challenges, they note, was designing activities that focused on conceptual understanding. Although the teachers were enthusiastic about teaching for deep understanding, their activity designs still reflected the treatment of “science-as-facts” (Gardner, 2004).

2.3.3 Supporting the development of disciplinary knowledge

The domain of science is well suited for a knowledge community approach. The FCL framework by Brown and Campione (1996) was originally developed for the biological sciences for grade 6 students. Much of the subsequent research on FCL focused on science disciplines, which afforded the jigsaw-type activities that are central to the FCL model (Shulman & Sherin, 2004). Other subjects, such as mathematics, do not lend themselves as readily to this model (Sherin, Mendez, & Louis, 2004). Learning math usually entails a progressive understanding, and breaking math concepts into subtopics for different groups of students to explore is not consistent with most math teachers’ instructional practices (Sherin, Mendez, & Louis, 2004). Consequently, implementing an innovative pedagogical approach in the math classroom would require reconceptualizing math to involve not only facts and formulas, but also conversations about processes and intellectual reasoning (Sowder, Sowder, & Nickerson, 2009).
In the sciences, researchers have focused on teaching conceptual topics in areas such as biology, physics or earth science, which are suitable for activities where students pursue questions that are meaningful to them, and where they can share those findings with their peers (Brown & Campione, 1996; Smithenry, 2009). The use of science as a topic for instruction also allows students to engage in collaborative inquiry tasks with their classmates. For these reasons, knowledge community researchers have typically focused on science as a domain of inquiry within their research studies.

2.3.4 Implementation challenges

Even when carefully designed, a community-based learning approach can be challenging to implement (Gardner, 2004). For example, in a study involving three secondary school English classrooms, Whitcomb (2004) describes a crisis where teachers proclaimed a “state of emergency” during their implementation of an FCL curriculum. Although the FCL unit had been designed the previous summer, the planning did not include a delineation of the finer details of the activities. Whitcomb recounts how teachers, just prior to beginning the unit, abandoned the original plan after deciding it was not appropriate for their classrooms. Instead, they redesigned the unit to include a single FCL jigsaw activity that would also serve as a culminating project. The teachers explained that enacting the original unit was too risky in terms of covering the required material, and therefore felt it necessary to revert back to the previous year’s curriculum. Whitcomb (2004) further observed that, rather than trying to achieve holistic change within their classrooms (i.e., adopting the knowledge community perspective), the teachers had a tendency to subordinate FCL activities to simple additions or supplements within their traditional curriculum unit. This observation is consistent with Tyack and
Cuban’s (1995) assertion that research innovations rarely change teachers’ classroom practices. Rather, teachers tend to change the innovation so that it fits with their existing instructional approach.

In general, implementing a knowledge community is a big commitment for any teacher. It is not the kind of research-based innovation that can be developed by researchers, and then passed off to teachers for enactment. In their study of a biology classroom, Rico and Shulman (2004) explain how the teachers’ understanding of the FCL principles and its connection to science became “corrupted” as soon as the teachers put their understanding to practice. Both of the teachers were initially very excited about the possibilities of FCL for pushing students towards real understandings of science. Yet when the time came to enact the curriculum, both teachers pulled back from the highly collaborative activity structure and reverted to familiar and traditional teaching methods. Mintrop (2004) describes a similar concern in his study of an FCL implementation in four secondary school social studies classes, where he describes what he refers to as the “activity default” (p. 149). In his study, Mintrop observed that veteran teachers approached FCL as an opportunity for restructuring older units used in previous years into something more “constructivist”. Van Aalst and Chan (2007) report a study of the Knowledge Building model, where the instructor borrowed selectively from the principles underlying the pedagogical model, and only implemented a small portion of the curricular activities.

Other researchers have likewise described the challenges of engaging teachers as a knowledge community. According to Shulman and Shulman (2004), challenges can arise due to differences in teachers’ acceptance and application of a learning innovation.
Shulman and Shulman (2004) articulated a theory for explaining the distinction between teacher readiness and adeptness when enacting new pedagogical approaches. This led to the development of their “teacher learning communities” model, which is designed to support teachers in their adoption of curriculum that is theory-driven and open-ended, yet guided by disciplinary content (p. 259). Their model is based on five characteristics of teacher development: (i) readiness – the teacher can envision the innovation; (ii) willingness – the teacher is motivated, (iii) ability – the teacher understands the principles that underlie the innovation, and can enact complex pedagogies; (iv) reflective – the teacher can learn from experience; and (v) communal – the teacher is part of a teaching community. Their model is positioned as a method for preparing teachers to enact complex pedagogies across a variety of different disciplines and contexts.

2.4 Inquiry-Based Learning

Many constructivist approaches, notably in science education, strongly emphasize the process of inquiry (e.g., Krajcik, Slotta, McNeil, & Reiser, 2008; Linn & Eylon, 2006; Lunetta, 1997; Quintana et al., 2005; Roth, 1995). Inquiry learning theory was introduced in the late 19th century, largely by the reform work of philosopher John Dewey (1902, 1916). Dewey strongly advocated for schooling that was experience-based, where the curriculum was organized around practical problems rather than disciplinable topics (Schutz, 1991). According to Dewey, these problems should be real ones that students faced in the social context of their school community, and should be of immediate interest to the child.

Dewey’s philosophy of inquiry is perhaps best exemplified by his work in the Dewey School at the University of Chicago (1896-1903). Dewey believed that students
could only engage in real inquiry if their activities were situated within a broader social context. It was not enough to simply tell students how things were connected, they had to experience those connections for themselves (Schutz, 1991). Constructing individual knowledge could therefore not be disassociated from the external social world to which that knowledge is applied. In the Dewey School, inquiry was deeply embedded within occupational activities, which ranged from sewing, cooking, wood working and, depending on the child’s age, constructing an entire clubhouse. Knowledge about physics and mathematics would be learned because students would require skills in these areas to carry out their activities. Students would learn skills like reading and calculating divisions, Dewey argued, when they recognized that they needed this knowledge to continue with their work. Having students define their own problems in terms of what they need to know, and when, was central to Dewey’s theory of inquiry (Prospects, 1993).

Dewey’s perspective of inquiry has been problematized in a number of ways. For example, Bereiter (1992) points out that learning will likely be transient if children find solutions for only practical and everyday problems. Students in the Dewey School might be challenged to subdivide a small farm, and thus apply themselves to learn fractions in order to do so. But once the farm has been sectioned off, and the problem is solved, the inquiry process ends. Without incentives to explore the problem further, what remains in students’ memory are referents of the problem: ruler, sections, farm, measurements – what Bereiter refers to as “referent-centered” knowledge. The challenge for educators, according to Bereiter, is to present students with the kinds of persistent
high-level problems from which students can construct a deep and coherent understanding.

While problem-driven inquiry remains central to science education, most inquiry models involve neither the practical problems suggested by Dewey, nor the persistent high-level problems advocated by Bereiter. More often, problems are focused on curricular learning goals that are linked to disciplinary knowledge. Designing inquiry supports that guide students in reaching their learning goals has been the topic of much educational research. In the following section, I discuss some of the research on scaffolded inquiry in science education.

### 2.4.1 Scaffolded inquiry

A good deal of literature on inquiry learning has focused on the use of scaffolds to support students during inquiry-based activities. The notion of scaffolding as an instructional aid was first introduced by Wood, Bruner and Ross (1976) in a paper that explores the role of tutoring in problem solving. In their article, they describe scaffolding as a process where adults “control” parts of a task that are too difficult for children to achieve on their own, thus enabling them to focus on other aspects in which they are capable of performing (Wood, Bruner, Ross, 1976, p. 90).

Pea (2004) identifies two dimensions on which he believes scaffolds have made theoretical contributions in education: social and technological. The social parameter of scaffolding is related to the interactions that take place between individuals, while the technological describes the artifacts that evolve as a result of the scaffolding process. Both of these aspects will vary considerably depending on the context and discipline the scaffold is used in, as well as the purpose for which it is used (Davis & Miyake, 2004;
Stone, 1998). Reiser (2004) proffers two additional parameters of scaffolding: structuring, which involves simplifying the task at hand, and problematizing, a mechanism for drawing students’ attention to a part of the learning task that they might otherwise overlook.

In the learning sciences, more attention has been given to scaffolded inquiry than to knowledge communities (Slotta, 2007), perhaps because it is relatively straightforward to design and enact a well-controlled investigation involving scaffolded forms of inquiry. Many such investigations use scaffolding technologies to guide students through the curriculum sequence, prompt them for reflections, and provide rich multi-media materials. Several scaffolding environments have been developed over the past decades for science inquiry, notably BGuILE (Reiser et al., 2001), SimQuest (van Joolingen & de Jong, 2003), Inquiry Island (White et al., 2002) and WISE (Slotta, 2004). Each of these environments were designed to scaffold students and teachers to engage more easily in complex forms of inquiry by leveraging the pedagogical benefits afforded by technology (Roschelle et al., 2010).

Such work has given rise to several general frameworks for scaffolded inquiry. The scaffolding design framework of Quintana and his colleagues (Quintana et al., 2004) specifies design principles and guidelines for creating productive scaffolding tools. Linn and colleagues (e.g., Linn & Eylon, 2006; Linn & Hsi, 2000; Slotta & Linn, 2009) have developed the Knowledge Integration framework for fostering integrated and coherent understandings of science among students. And finally, Songer’s (2006) Learning Progressions model guides the development and evaluation of curricular materials
through the systematic sequencing of activities that encompass both scientific content and scientific practice (see also Songer, Kelcey, & Gotwals, 2009).

Typically, inquiry-oriented instruction involves problem-based activities where students are presented with interactive materials or simulations where they can collect data for their own investigations. The inquiry curriculum is carefully designed so that students are confronted with reflective opportunities in the face of “pivotal cases” (Linn & Eylon, 2006) that challenge their existing ideas and encourage revision and reconstruction of understandings. Methods of scaffolded inquiry have been employed to investigate activities such as modeling (White, 1993), anchored instruction (Cognition & Technology Group at Vanderbilt, 1993), argumentation (Bell, Davis & Linn, 1995; Linn & Hsi, 2000), scientific visualizations (Edelson, Gordin, & Pea, 1999; Pea & Gomez, 1992), argumentation (Bell, Davis & Linn, 1995; Linn & Hsi, 2000) and many other aspects of learning and reasoning.

Still, despite the relative success of such approaches, they have yet to pervade regular classroom settings (Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000; Borko & Putnam, 1995; Cuban, 2001). While inquiry activities may be easier to enact than a knowledge community approach, scaffolded inquiry methods are still quite challenging for teachers to adopt (Slotta & Linn, 2009). They generally demand a deeper treatment of topics, and thus more curriculum time for any given unit than most teachers are allowed – particularly in secondary science. In general, new models of collaboration and inquiry are challenging for teachers, who must tailor their course curriculum to provide room for covering certain topics with sufficient depth. This tailoring process requires teachers to fully understand the nuances of the innovative materials (including
any scaffolding technologies) to ensure that they are properly enacted. However, because it is generally researchers who develop these materials, teachers may not find them straightforward to interpret or adopt.

Another form of support that is similar to scaffolds – and relevant to the KCI model – is the process of “scripting”. The purpose of a script is to structure student interaction through inducing and sequencing activities between two or more peers (Kollar, Fischer, & Hesse, 2006). A script specifies certain aspects of collaboration, such as task distribution, work phases, sequencing and deliverables. A script can be communicated through initial instructions by the teacher, or be integrated into the learning environment (Dillenbourg & Jermann, 2007). Many researchers believe that without adequate support, students will not engage in productive collaborations on their own (Dillenbourg & Tchounikine, 2007). Scripts are used in a number of learning approaches such as reciprocal teaching (Palinscar & Brown, 1984), peer tutoring (Chi, Siler, & Jeong, 2004) collaborative reasoning (Anderson et al., 2001), and distributed monitoring (Wecker & Fischer, 2007). When embedded within a technology, scripts can facilitate complex interaction and groupings within the classroom (Kollar, Fischer, & Slotta, 2007; Slotta & Linn, 2009).

Scripts can be used for different purposes. Ayala (2007) distinguishes between two kinds of scripts: macro and micro. Macro scripts are used to specify the structure and organization of activities, such as group size and task assignment, while micro scripts detail students’ work processes (e.g., specifying and then guiding specific steps within an inquiry project). Scripts can be designed so they either impose or induce collaboration. Imposed scripts are instructions that determine the order in which students carry out
activities; the degree of compliance required by these instructions is referred to as the “cohesion degree” (Dillenbourg, 2002). Induced scripts provide learners with more flexibility with respect to their interactions. Both macro and micro scripts, which are embedded within the learning environment, assume that learners are already familiar with the process and purpose of collaboration (Ayala, 2007).

The widespread success of scaffolded inquiry methods is due in part to the fact that they are readily available to researchers. Because of the range of possible approaches and inquiry models, learning scientists can easily embed theoretical ideas within a scaffolded inquiry framework. Research materials can be developed in advance of any classroom study by researchers who work in partnership with teachers. The resulting curriculum and assessment materials are generally not overly complicated to enact, with student responses providing ample data to serve as measures in the study (Slotta, 2007; Slotta & Linn, 2009). Thus, the broad domain of scaffolded inquiry has been scientifically productive because it is so accessible to the research community.

Researchers can share their materials and technology environments, such as when several research labs adapted the WISE technology environment and curriculum materials for their own purposes (e.g., Jorde & Mork, 2007; Kollar & Fischer, 2004; Kollar, Fischer, & Slotta, 2007).

2.5 Emergent Technologies: New Opportunities for Research

Recently, researchers have investigated how emerging “Web 2.0” technologies can be used for scaffolded inquiry (Ullrich, Borau, Luo, Tan, Shen, & Shen, 2008). The moniker Web 2.0 was first coined in 2003 (O’Reilly, 2005) to refer to a collection of Internet applications where users both consume and produce web content. Whereas web
1.0 applications emphasized individual production and mass consumption (e.g., an individual creates a web site that is read by many), Web 2.0 emphasizes both mass production and mass consumption (e.g., Wikipedia articles, where many individuals both produce and consume).

Web 2.0 technologies encompass a wide range of applications, of which most citizens are already familiar. These applications present new opportunities for research on scaffolded forms on inquiry. Social software, for example, provides learners with a public space for sharing ideas, negotiating content, and constructing community artifacts. Such technologies have pushed the boundaries of how we think about collaboration and communication, by extending community membership and increasing collective capital knowledge (Surowiecki, 2004).

Many researchers have already explored how Web 2.0 can be productively used for learning and instruction (e.g., Greenhow, Robelia, & Hughes, 2009). Wikis, for example, provide a collaborative structure that enables students to learn from both their individual and collaborative efforts. The process of co-authoring a document offers a new form of scaffold for peer collaboration (Aguiton & Cardon, 2007). Students working in a wiki cannot predict how their contributions will be received, nor can they predict how the co-authored document will evolve. Co-authoring a collaborative document can foster student learning by exposing them to a wider range of perspectives and ideas (Palincsar, 1998; Webb & Palincsar, 1996). Bryant, Forte, and Bruckman (2005) demonstrated that participants adopt new goals as they become more involved in the authoring process, shifting their focus from one of personal contribution to one of growing concern for the shared artifact. Thus, wikis have the potential for being a valuable tool for learning, and
illustrate how technology can afford new epistemological perspectives and practices within the classroom (Papert, 2000).

The studies mentioned above are just the beginning of what is likely to become a growing trend within the research literature. Just as students and teachers can benefit from the opportunities provided by collaborative technologies, researchers can also gain new opportunities to support complex models of learning and instruction. There is still much to learn about how emerging technologies can be leveraged in ways that are compatible with theories of learning. In response to society’s increasing dependence on knowledge and technical innovation, educational researchers can help develop effective pedagogical approaches to support the development of critical 21st century knowledge skills.

2.6 The Knowledge Community and Inquiry (KCI) Model

Despite the advances made by researchers in promoting both the knowledge community and scaffolded inquiry approaches, there has been little adoption of these innovations by regular K-12 teachers (see Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000; Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991; Borko & Putnam, 1995; Cuban, 2001). This is particularly true in secondary school science, due in part to the scope of content expectations that teachers must address within the mandated curriculum. Scaffolded inquiry demands a much deeper treatment of topics, and considerably greater amount of curriculum time for teaching for deep understanding (Linn & Eylon, 2006). However, committing to such a depth of coverage would challenge teachers’ ability to cover the required breadth of domain content (Slotta & Linn, 2009). Teachers would find it an even greater challenge to adopt any kind of
community-oriented approach, which would require substantial professional
development and years of trial and refinement (Mintrop, 2004; Rico & Shulman, 2004;
Sherin, Mendez, & Louis, 2004).

In an effort to make headway on these problems, Slotta (2007) developed the
Knowledge Community and Inquiry (KCI) model that combines collaborative knowledge
collection with scripted inquiry activities to target specific curriculum learning
objectives in science. In KCI, students take part in collaborative knowledge construction
activities where they develop a shared knowledge base, and then engage in scaffolded
inquiry activities where students make use of knowledge artifacts from their community
knowledge base. KCI also includes a focus on the specific learning goals that are
required within the topic domain, and all inquiry activities are developed so they
explicitly target those goals.

The flow diagram in Figure 1 outlines the general sequencing of activities in a
KCI curriculum. This dissertation is concerned with three aspects of the model: First, it is
cconcerned with the essential design features of KCI, and the challenges involved in
instantiating those features into a curriculum. Second, it seeks to identify the forms of
inquiry and collaboration that students engage in when participating in KCI activities.
Thirdly, it is concerned with the effectiveness of KCI with respect to addressing
curriculum standards and content expectations. The principles underlying KCI are
described in more detail in the following sections.
2.6.1 Creating a community knowledge base

A KCI curriculum begins with a collaborative knowledge construction activity where students explore and research a topic of interest by adding to a collective knowledge base. The purpose of this activity is to generate knowledge artifacts that contribute to an aggregated resource for use by the wider classroom community (which can involve multiple classrooms), and to develop content specialists within the group. The knowledge artifacts created by students can take many forms – a question repository, bibliographic reports, web pages – that are mediated by a technology environment. The topic of the knowledge artifacts created by any given student would reflect their own interests within a broader subject area. For example, a student might choose to create a resource page about a species they were interested in, within the broader topic of food.
webs. The community knowledge base is dynamic, as students continuously update and reorganize their knowledge artifacts based on their learning progression and knowledge gained from subsequent activities.

2.6.2 Connecting inquiry and community knowledge

Students working in a knowledge community come to rely on each other as they pursue a shared understanding of a common problem or issue (Scardamalia & Bereiter, 1996). In KCI, students rely on the knowledge artifacts created by their peers, drawing on the resource base as they collaborate on an inquiry task. The integration of inquiry tasks is an important addition made by KCI to the knowledge community approach. It is through their participation in structured inquiry that students achieve the content learning goals that are essential to secondary science. If students are left to their own devices in the kind of open-ended approach that is characteristic of most knowledge community models, it is unlikely that they would make their way through the full content expectations required of a secondary science unit. By engaging students in a series of inquiry projects that intersect with their collaboratively constructed knowledge base, we can guide and focus students’ inquiry, scaffold specific processes or collaborations, and help assure that they attain the desired learning goals. Including such specificity is essential for getting the buy-in of secondary science instructors such as those who participated in this study.

When designing directed inquiry activities that connect to a knowledge community, it is important to craft a learning situation where students are interdependent, and where collaboration is necessary and not simply favorable (Brown, 1997). Similar to Brown and Campione’s (1996) consequential task, the inquiry activity in KCI is based on
motivated sharing. Students share information in order to perform the activity, and there is a sense of accountability from knowing that their work will be taken seriously by their peers. For this to be possible, any inquiry activity must be deeply connected to the community knowledge base so students have occasion to make productive use of their knowledge artifacts. As with the community knowledge base, any inquiry activities are guided by the teachers’ curricular learning goals for the class.

2.6.3 Integrating community interests and themes

An important aspect of most community-oriented approaches is that learning activities (such as inquiry-type investigations) are guided by the community through the knowledge construction process (Scardamalia & Bereiter, 1996). Common themes, ideas or interests should emerge, reflecting the “voice” of the community. It is challenging to design activities that reflect community interests while still addressing content expectations, as there is no way of knowing what those interests are beforehand. To allow the voice of the knowledge community to be reflected in the inquiry tasks, the inquiry activities cannot be completely designed in advance, thus, final design updates can only occur later after the community knowledge base has been established. Once completed, students then work independently or collaboratively on these activities, drawing on knowledge elements from the community knowledge base, producing new contributions to that knowledge base, and engaging in inquiry tasks that are connected to assessable learning outcomes.
2.6.4 Targeting curriculum expectations

KCI activities are designed to address specific learning goals, which are identified by the teacher and based on official curriculum documents, and articulated in design meetings. The process typically begins in a workshop with the school’s science department, where all teachers have the opportunity to explore potential research collaborations. Once a research partnership has formed, possible topics are considered that might be suitable for KCI – topics that afford classroom-wide or multi-classroom knowledge construction activities and targeted inquiry activities. After a suitable topic has been decided upon, subsequent design meetings address the development of the different stages in the model. Researchers and teachers are equal participants in these meetings, with each taking responsibility to ensure that their goals are addressed by the emerging design.

2.7 Summary

This chapter reviewed the literature relevant to this study, emphasizing the research on knowledge communities and inquiry learning. It then presented a new pedagogical model – the KCI model – that seeks to combine the two traditions. This model provides the theoretical foundation for a new approach to learning and instruction that engages secondary science students as a knowledge community while remaining sensitive to curriculum content expectations. As educators are increasingly recognizing the need to help students develop 21st century knowledge skills, there is a need for learning approaches that scaffold students and teachers in knowledge work practices. The following chapters present two iterations of a KCI curriculum that was implemented in secondary school science.
CHAPTER 3: METHODOLOGY

3.1 Chapter Overview

This chapter discusses the methodology used in this dissertation. It begins with an overview of the design-based research approach that guided the design and implementation of two KCI-based curricula. It then discusses the co-design method that was employed in both design cycles. This chapter also includes a description of the study participants, materials, and research setting, which vary slightly between the two iterations of the study. The specific procedure and analytic methods employed within each of the design cycles are detailed in Chapters 4 and 5, as some of those details are specific to the context of the particular curriculum implementation.

3.2 Design-Based Research

To investigate the KCI model, it was first necessary to operationalize the model in the form of a curriculum. Since designing and evaluating a theory-based curriculum will require repeated attempts, a research approach was needed that would support multiple design cycles for testing and evaluating the different elements of KCI. This approach would allow an evaluation of the effectiveness of a curriculum based on KCI in terms of student learning and enactment.

An increasingly popular methodological approach, called “design research” or “design experiments”, supports the kind of progressive refinements necessary for advancing the KCI model. Design research was proposed by Brown (1992) and Collins (1992) in recognition of the need for studying learning interventions in the context for which they were designed – the classroom. Many educational researchers have relied on
traditional comparison studies favoured by psychologists (Levin & O’Donnell, 1999). While such methods allow for a reliable evaluation of treatment effects, the rigidity needed to control conditions is not typically feasible in regular classrooms. Brown (1992) recounts how her own research trajectory was strongly based in controlled experimentation, and how her training in scientific methods were not readily transferable to her later work in inner-city classrooms. Brown (1992) stresses that to fully appreciate the complexities of learning, researchers must study the classroom in a more holistic manner than is permitted in a controlled experiment. Curriculum development, assessment and the role of the teacher are deeply interconnected, and cannot be examined independently without disturbing the synergy that is part of the classroom (Bielaczyc & Collins, 2006). Consequently, progress toward a learning theory that informs everyday practice can only be achieved if the innovation can be enacted in a regular classroom setting (Brown, 1992). Because of this distinction, design experiments have been described as “fill[ing] a niche in the array of experimental methods that is needed to improve educational practices” (Collins, Joseph, & Bielaczyc, 2004, p. 21).

In the past 10 years, a number of researchers have explored the methodologies of design-based research (Sandoval & Bell, 2004) or design-oriented research (Hoadley, 2004). For example, a special issue of the Journal of the Learning Sciences in 2004 was dedicated to the methodological implications of design research. In discussing the articles within that special issue, Kelly (2004) offered the following observation:

One way to classify design studies is by characterizing their ‘outcomes’ or ‘products.’ Some design studies wish to inform us about a model of practice, others about learning, still others about the design and use of a new piece of software or ‘learning environments’… In my opinion, design studies should produce an artifact that outlasts the study and can be adopted, adapted, and used by others. (p. 116)
Although design experiments provide researchers with increased flexibility for studying learning, there are a number of challenges that come hand in hand with this flexibility (Collins et al., 2004). First, unlike experimental studies that are conducted in a controlled setting to isolate the dependent variable, design experiments are conducted in the unpredictable and chaotic conditions of classrooms, where many dependent and independent variables may interact with one another. The role of the researcher presents another challenge. In experimental studies, the researcher usually makes all the decisions regarding the research design and analysis. Design experiments, however, entail close collaborations between the researcher and the various stakeholder groups that are involved, including teachers, students and school administrators. Dede (2004) notes that design studies can also be “over-methodologized”, resulting in voluminous datasets that are typically collected from both qualitative and quantitative sources (p. 107). Still, when well-conceptualized, design-based experiments can be conducted with empirical rigor, resulting in research with strong, evidence-based claims (Edelson, 2002; Hoadley, 2004).

3.3 Co-Design

The teachers who participated in this study were heavily involved in the design of the curricular materials. The standpoint of involving teachers when designing educational innovations has long been recognized as an important one. Drucker (1959) writes: “Education differs from most other investments in that all its ‘critical factors’ are human beings, their ability, their competence, their dedication. Above all, it is the teacher who makes education happen” (p. 130). The desirability for teacher involvement is only heightened when the innovation utilizes a new technology. Teachers’ participation becomes essential to reduce the risk of what Brown and Campione (1996) describe as
“lethal mutation”, where a teacher’s enactment or modifications of a design diminish its underlying principles (p. 292). Yet despite teachers’ central role in the classroom, they are often not consulted about educational interventions, even though it is generally their responsibility for ensuring its success in the classroom (Cuban, 2001).

Most research-based innovations already involve some level of collaboration between researchers and teachers, however, establishing and maintaining a productive partnership between the two can be challenging. Many of these challenges can be attributed to differences in the norms and expectations of the workplace, which can tax the working relationship between stakeholders. As Huber and Williams (2009) observe, “the worlds of public school, higher education, nonprofits, and business are all so profoundly disparate that one can almost hear an audible sigh of relief when grants run their course or programs are terminated” (p. 30).

So how can researchers deeply involve teachers in the design of innovations that serve their scientific investigations? Roschelle, Penuel and Shechtman (2006) have advocated a new design-oriented method called “co-design” that was used for a study that explored how handheld computers could improve classroom assessment in middle school science. They describe co-design as “a highly facilitated, team-based process in which teachers, researchers and developers work together in defined roles to design an educational innovation, realize the design in one or more prototypes, and evaluate each prototype’s significance for addressing a concrete educational need” (p. 606). What makes co-design unique from other approaches are the formalisms of its characteristic features. These include: (i) taking on a tangible innovation challenge, (ii) beginning the study with a close observation of current classroom practices, (iii) maintaining a flexible
curricular target, and (iv) following a schedule that fits with the regular school cycle. Co-design also has commonalities with other user-oriented design methods, such as participatory design and user-centered design. Both of these approaches emphasize the importance of input from end users, however, co-design involves a higher degree of negotiations and trade-offs before any final design decisions can be made. The flexibility of this approach makes co-design highly compatible with design-based research.

While it provides a helpful specification of the collaborative process, co-design does not escape the challenges of working in close partnership with teachers. Rochelle et al. (2006) discuss a number of tensions that are typical of a co-design approach. For example, the process of delineating a new curriculum brings to light an individual’s assumptions and expectations not only about their role in the design process, but also those of other team members. Each stakeholder group, including teachers, researchers, and software developers, often use their own language to describe their intentions for the design of the innovation. The unfamiliarity a group member may have with the challenges and obstacles faced by another stakeholder can make them appear insensitive or unappreciative of their efforts. For example, a teacher who is unaware of the logistics behind software development may appear demanding and unrealistic when requesting a particular technology feature from a programmer. Cross-pollination between such disparate working groups is relatively uncommon, and the perspectives of each group must be continuously kept in check to ensure a productive workflow (Penuel, Roschelle, & Shechtman, 2007).

It should be noted that co-design is not likely to achieve increased efficiency or even to produce higher-quality innovations. As Roschelle et al. (2006) point out, the
negotiations between researchers and teachers can be both intensive and time-consuming. For this reason, they stress the importance of communicating to teachers how slow and frustrating the early stages of the design process can be, and recommend that researchers clearly map out the expectations for each phase of the design process. Further, because innovations are negotiated amongst the various stakeholder groups, there is a possibility that the outcome of design efforts will compromise the values of both researchers (i.e., an innovation that does not adequately address research questions) and teachers (i.e., an innovation that does not address specific educational requirements). Although it is difficult and not always achievable, the result of a co-design process can be an innovation that is embraced by teachers, supports research, and has the potential for longevity in the classroom.

3.4 Participants

This section describes the participants involved in the study, including the co-design team, teachers and student cohorts.

3.4.1 Co-design team

The co-design team consisted of three secondary school biology teachers and two researchers: a senior researcher (Ph.D. supervisor) and myself. Two technology developers were also part of the team. The developers’ participation was limited to initial meetings about the design of the technology environment used in the study, as well as other meetings where they collaborated with the researchers about the design. The participation of the technology developers was thus somewhat indirect, and in future
implementations of this method, it may be of interest to engage the technology team more deeply in the co-design process.

The school principal and vice-principal also attended a small number of co-design meetings, particularly in the early stages of the study. The purpose of these meetings was to strengthen the working relationship between the school and the research group, and to establish administrative support for the research project. In these meetings we discussed the mission and interests of the wider school community, and how this research study might contribute towards those objectives.

Since designing a new curriculum places extra demands on teachers’ time, one might question the teachers’ motivations for participating in the research project. During a summer workshop, the teachers had expressed their interest and enthusiasm in creating more engaging and innovative science curricula, however, they also felt that developing the materials would require access to resources that was beyond what was currently available to them. They believed this research project could provide the materials and means for designing a technology-enhanced science curriculum, and might also provide some momentum for jump-starting their efforts. Although the teachers were aware that our collaborations were part of a research investigation, their primary interest in this project was the development of a curriculum for use in their classrooms.

The teachers’ involvement in co-design presents a unique dynamic in that they assumed the role of both research collaborator and participant. In this study, the teachers were not observed for their behavior and interactions during the co-design meetings. Rather, they participated as equal contributors in the discussions and negotiations concerning the design of the curriculum, providing valuable insight into the disciplinary
content requirements and classroom suitability of the innovation. Although positioned as collaborators more so than research participants, I nevertheless felt it was important to interview the teachers concerning their perspectives about the co-design process and the resulting KCI-based curriculum. As a result, the teachers were interviewed in the middle and end of both design iterations.

3.4.2 Teachers

Two teachers, Erin and Rebecca, were involved in both design cycles (all participant names in this study have been replaced with pseudonyms). A third teacher, Daniel, participated only in the second design cycle. Erin and Rebecca each taught two classes of biology in the first design cycle. In the second design cycle, Erin taught two classes, and Rebecca and Daniel each taught one. The teachers were varied in their level of experience. Erin had 19 years experience and had used technology in her classrooms for nine of those years. Rebecca and Daniel had been teaching for 5 and 3.5 years, respectively, and had always used technology in their classrooms. All three teachers had graduate degrees in biology.

I first met all three teachers in a summer workshop, when the science department of the site school met with the senior researcher to discuss a potential research collaboration. It was at this workshop that the participating teachers agreed to co-design a biology curriculum for the following academic year. Early in the study, the co-design meetings were held in the senior researcher’s laboratory, and lasted approximately one hour. The meetings were very informal, and typically involved food and other refreshments. As the school term progressed, and teachers got busier, the meetings were generally held at the school site – usually in the staff room and during the lunch break.
Finding a time that worked for all team members was challenging, and small pockets of time (e.g., free periods between classes) became increasingly valuable for planning purposes.

### 3.4.3 Students

This study involved two separate cohorts of grade-ten biology students: 102 students participated in the first design cycle, and 112 students participated in the second. In both design cycles, the students were divided into four class sections of a secondary school biology course. Students were placed in their classes via Trillium™, a computer-based student management system used by school administrators. The Trillium program works by generating a random class list for each course, factoring in only timetable conflicts, and balancing the enrollment numbers between sections. Birthdates, gender, or alphabetizations of first or last names are not taken into account when class lists are generated.

### 3.5 Materials

The students in this study used a wiki technology to create the knowledge artifacts for their community resource base. A wiki provided the ideal functionality for this activity for a number of reasons: it allowed students to easily access and edit each other’s contributions, to reorganize their evolving knowledge repository, and to link resource pages to establish connections between related themes or ideas. In addition, wikis allow a relatively quick start-up time, as students do not require any special training. The simple interface meant that students could intuitively navigate the wiki the same way they would
any other web site. For all materials in this study, an Atlassian wiki was employed (see http://www.atlassian.com/software/confluence/).

An important feature of the wiki technology was its use of customized page templates that helped scaffold students to address specific science content (e.g., using pre-designed page headers and sub-headers). Although it was important to preserve the open collaborative editing that characterizes wikis, it was also important to have a simple and structured way for students to begin creating their wiki pages, and to make sure that those pages addressed the specific learning objectives of the curriculum design. While the Atlassian wiki system did support the use of templates, the process of getting students to start a new page and make sure they chose the right template was somewhat complicated. We thus developed an additional technology component, using the Ruby on Rails programming language, to facilitate the process of creating wiki pages from templates.

The result of this effort was an embedded web form that was presented to students as a web link that was called, in the first iteration, “Create a New Disease or Disorder Page,” and in the second iteration, “Create a New Ecozone Page”. When students clicked on the link, they were presented with a web form with text fields and radio buttons that asked for information about their new page (see Figure 2). After students clicked the “Submit” button on the web form, a new wiki page was generated that automatically had a page title and section headers with instructional prompts for including specific science content (see Figure 3). Students could then continue editing their new wiki page using the normal wiki editing function.
In both design cycles, students were provided with laptops for use during class time. The senior researcher’s grant-funded project was able to provide the class with Apple Macbook computers, however, students could also opt to use their school’s PC laptops. During class time, the students worked in a room with a wireless Internet...
connection, which enabled them to circulate around the room and interact with classmates or the teacher. Students typically worked individually or in pairs when working on the computers in school. They also performed some wiki editing at home, particularly in the second iteration, which involved more substantive content than the first.

3.6 Methods and Analyses

Both qualitative and quantitative methods were used in this study. The advantages of using mixed methods are well documented, the main tenet being that using both approaches provides a more comprehensive view of a research problem (Creswell, 2007). The use of mixed methods in this research resembles that of an expansion or parallel design, as described by Greene, Caracelli and Graham (1989). An advantage of this approach is the flexibility in design options it affords when mixing the various methods (Green, Caracelli, & Graham, 1989). In an expansion study, qualitative and quantitative methods are used independently for investigating different phenomena. The phenomena of interest in this research include students’ construction of a shared knowledge base, their collaborative interactions when working in the wiki, and their perspectives of the KCI activities. The different research findings that result from mixing methods can highlight aspects of the research phenomena that may otherwise have gone unexplored (Erzberger & Kelle, 2003).

This dissertation employed both confirmatory and exploratory data analysis techniques, as outlined by Onwuegbuzie and Teddlie (2003). When reporting students’ efforts at knowledge construction and inquiry, I used exploratory measures (e.g., descriptive statistics, a posterior content analysis) to describe the outcome and
effectiveness of the KCI activities, as well as students’ collaborative practices in the wiki. Confirmatory measures (e.g., ANOVA, correlation analysis) were used to report the effect of the KCI curriculum on students’ exam performance, and the extent to which the science content expectations were addressed. When appropriately combined, qualitative and quantitative data analysis techniques can be used to complement and support the overall research findings (Kelle, 2001).

3.6.1 Data Sources

Data for this study were drawn from several sources: the wiki revision history, computer web logs of students’ online activity, student and teacher interviews and field notes. The first and second design cycles emphasized different data sources, which are described in more detail in their respective chapters.

3.6.2 Analytic approach

While detailed analyses and coding schemes will be provided in Chapters 4 and 5 (according to the two iterations of the study), the same basic approach will be used for each design cycle. To investigate the effectiveness of the KCI model, it is first necessary to create a curriculum based on the model, and then proceed with an enactment of the curriculum. Two analyses must therefore be performed. First, it is necessary to analyze the designed curriculum to see if it adheres to the KCI model – for if the curriculum does not fit the model, then there is little reason to investigate its effectiveness. Second, assuming the designed curriculum is a valid instantiation of the model, it is also necessary to analyze its enactment. Were the curriculum activities performed as designed? Again, if a valid curriculum was designed, but it was not enacted
appropriately, then any consideration about its effectiveness will be invalid with respect to conclusions about the underlying pedagogical model.

After determining if the curriculum was designed and enacted according to the model, we must then analyze the impact of the curriculum on student learning. This analysis must address the different features of KCI, including collaborative knowledge construction and the inquiry tasks. KCI is driven by achievement of specific learning goals, and must be held accountable to those goals and expectations. Accordingly, an analysis of student achievement on formal exams will be performed, including a content analysis on specific items.

For each of the design iterations (Chapters 4 and 5), I have conducted this same basic sequence: first, presenting the designed curriculum and analyzing its fidelity to KCI; second, describing and evaluating the enactment of the KCI curriculum; and third, evaluating student achievement as a measure of the efficacy of the model. In each design cycle, the goal is to provide an evaluation of KCI, as well as to make recommendations for future design efforts. Because KCI is a new model, it will require several more cycles of research to revise and improve the model, and to understand the nuances of implementation. An important contribution of the analysis, therefore, will be to leave recommendations for future studies investigating the KCI model.

3.7 Research Setting

The setting for this research was a unique secondary school located in downtown Toronto. Founded in 1910, this private co-educational school provides specialized curriculum for high-achieving students in grades 7 through 12. The school population is ethnically diverse, with the majority of students coming from middle-class homes. The
school has a strong commitment to the liberal arts and sciences curriculum, and students are expected to fully engage in their academic program. Assessment is ongoing throughout the school year and consists of formal progress reports and performance improvement plans.

The school also has a strong emphasis on community, and students take an active role in contributing to their school atmosphere through activities and creative pursuits. It is very much the students’ space – artwork and projects can be seen on every floor, and stairwells and lockers are painted in creative murals ranging from an underwater aquatic scene to a decoratively designed table of the elements. Students leave their mark – all artwork is signed and dated by the artists.
CHAPTER 4: DESIGN CYCLE 1: PHYSIOLOGY OF HUMAN DISEASES

4.1 Chapter Overview

In this chapter I discuss the first iteration of designing and enacting a KCI-based curriculum. I begin by describing the methods and analyses employed, then describe the activities that resulted from the co-design efforts, including the details and sequencing of the activities. Next, I discuss the outcome of the enacted KCI curriculum: students’ production of a shared knowledge base, their engagement in the inquiry activity, and the targeting of content expectations. The two sections that report the designed and enacted curriculum are organized according to the four elements of KCI: (i) creating a community knowledge base, (ii) connecting inquiry and community knowledge, (iii) integrating community interests and themes, and (iv) targeting content expectations. Finally, the chapter concludes with a section describing the lessons learned from the first design cycle, which informed the second iteration of the co-design process.

4.2 Methods and Analyses

In this first implementation, I was primarily interested in the basic viability of the KCI model: Did we successfully design a curriculum unit in which students collaboratively created a knowledge base and then used that knowledge base for subsequent inquiry activities? Did students learn the required science content? Analyses were designed to address these questions and focused on students’ production of shared knowledge artifacts, their participation in the inquiry activity, and their performance on the final biology exam.
4.2.1 Participants

Participants were two teachers (Eric and Rebecca) and 102 grade ten biology students from our partner secondary school. The students were distributed into four classes; each teacher taught two of these classes.

4.2.2 Data sources

Data sources for the first design cycle included all student-generated wiki artifacts (i.e., students’ resource pages in the community knowledge base), wiki revision logs, field notes and students’ final exam scores. Teachers and students were also interviewed after the curriculum unit was completed. Table 1 outlines how the data sources in the first design cycle were used to inform the research questions:

Table 1

Data Sources Used in Design Cycle 1

<table>
<thead>
<tr>
<th>Analysis Question</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did the co-design team design a curriculum that aligned with the objectives of the KCI model? (RQ1)</td>
<td>• Co-designed curriculum materials, student artifacts</td>
</tr>
<tr>
<td>Did students collaborate when constructing their community knowledge base? (RQ2)</td>
<td>• Archive of wiki revisions, student artifacts</td>
</tr>
<tr>
<td>Did students use each other’s knowledge artifacts while working on their inquiry activity? (RQ2)</td>
<td>• Field notes/classroom observations, student interviews</td>
</tr>
<tr>
<td>Did students learn the content expectations with the KCI-based curriculum? (RQ3)</td>
<td>• Student artifacts, final exam scores, teacher interviews</td>
</tr>
</tbody>
</table>

4.2.3 Analysis

For this first iteration, the wiki pages in the knowledge base were analyzed collectively, that is, with no distinctions made between the individual and group contributions to the wiki pages. The inquiry activity was analyzed for its effectiveness in
requiring students to make connections between the ideas that were contained within the knowledge base. Final biology exams were examined to determine the effects of the KCI curriculum on student learning, including students’ treatment of the curriculum content expectations. I relied on field notes and interviews to assess students’ use of the community knowledge base, and to learn about their perspectives of the KCI activities. The analyses proceeded according to the basic approach outlined in Chapter 3, which distinguishes between the “designed curriculum” that sought to address the objectives of KCI, and the “enacted curriculum” that comprised the actual actions of students and teachers, as well as curriculum artifacts.

4.3 Co-Designing the KCI Curriculum

Planning for the first design cycle began four months prior to scheduled implementation. During these four months, the co-design team met 11 times to discuss the design, delivery and content of the KCI unit. During these meetings, we used our own wiki space to record meeting notes and document the evolving curriculum. Since this was our first attempt at co-designing KCI activities, the teachers thought it was best if we limited the intervention to a one or two-week unit. The teachers decided that the Human Systems and Regulations unit would be an ideal fit for such a time frame, in particular the section covering the diseases and disorders of the circulatory, respiratory and digestive systems.

4.3.1 Creating a community knowledge base

With the topic decided, our first design challenge was to consider the kind of knowledge base that would be well suited to the physiology of human diseases, and could
serve as a resource for a subsequent inquiry activity within that topic area. After much
discussion, we decided on an activity where students would collaboratively create wiki
artifacts about the specific diseases and disorders of the three body systems, including
their causes, symptoms, and possible treatments. The four class sections would be
responsible for co-editing these pages, which together would constitute a shared
knowledge base for use by all students in the course. The team decided that all
curriculum activities should be introduced in the same manner in each of the four classes.

The teacher of the first class would begin the lesson by placing students into one
of the three human system groups – circulatory, respiratory or digestive. Working in
small groups, students would have the task of creating a “Disease Page” about a disease
or disorder of one of the three body systems. Students were free to specialize in any
disease or disorder that interested them. Using wireless laptops, students would be able to
log onto the wiki and use a customized “Create a New Disease or Disorder Page” web
form to create their resource page.

The second, third and forth classes would begin creating their resource pages in
the same fashion; however, if students from one of these later classes wanted to
specialize in a disease or disorder that had already been added to the wiki, they would be
instructed to continue working on the established page, rather than start a new one. This
avoided redundant entries in the wiki, resulting in a single community knowledge base
that would be used by all four sections of grade-ten biology. Each class would be given
two full periods to work on their disease pages; any unfinished pages would be assigned
as homework.
4.3.2 Integrating community interests and themes

An important dimension of KCI is that the voice of the community be taken into account when designing inquiry projects. This is accomplished by incorporating emergent themes and interests that can only be determined after the curriculum has gotten underway. In the physiology unit, however, it was challenging to create activities that were connected to the emerging interests within the knowledge base. Human body systems and diseases are a well-defined domain, making it difficult for students to be creative and pursue personal interests when constructing their disease pages. Thus, this iteration of KCI was limited in that the knowledge base would not leave much room for community interests to be revealed. Still, in allowing students to determine the topic of their pages, and work on them collaboratively across four class sections, we could be confident that there would at least be a sense of ownership and familiarity with the knowledge base. The co-design team set out to design an inquiry activity where students would need to use this knowledge base in a meaningful way.

4.3.3 Connecting inquiry and community knowledge

The next step was to design an inquiry activity that required students to make use of the artifacts they created for their community knowledge base. In accordance with the KCI model, it was important that students synthesize the material and make connections between the human diseases in the resource pages. Since students would have specialized in a disease from only one body system (i.e., the system for which they had created a disease page), they would not be familiar with diseases and disorders from the other two body systems. We needed to design the activity in a way that required students to make
connections between the anatomical and physiological properties of the respiratory, circulatory and digestive systems.

This activity ultimately took the form of a “Challenge Case”. The challenge case activity involved creating a fictitious case study of a patient who presents a number of symptoms to their physician for a diagnosis. Students would be asked to review the diseases and disorders within their body system (circulatory, respiratory or digestive), then create one or more challenge cases that their peers would have to “solve” (i.e., determine the disease the patient was suffering from) with the help of the knowledge base. Students could use creativity and humor when establishing the context for their case study, provided that the signs and symptoms of the disease were physically and scientifically viable. To support the creation of challenge cases, we used a customized web form (Figure 4) to generate a wiki page with headers that included instructions for including specific content (see Figure 5 for generated web form).

![Figure 4. Customized “Create a new Challenge Case” web form.](image-url)
Figure 5. Challenge Case page generated from web form.

In creating their challenge case, students were also asked to create a link to a “Hints Page” (Figure 6) for their case study. The hints page was intended to provide case solvers with clues that would point them in the right direction when determining a diagnosis. The hints could be in the form of a comment or a question, but were not to be too obvious as to give away the answer. Each challenge case also included instructions for the case solvers (Figure 7).

Figure 6. Hints page for a respiratory disease challenge case.

Figure 7. Instructions for solving challenge cases.
Once students finished creating their cases studies, they would be asked to solve one challenge case from each of the two body systems that were not in their area of specialization. Thus, if a student created a wiki page about a respiratory disease, he or she had to solve a challenge case that involved the circulatory and digestive systems. The purpose of this design was to engage students with the content of the entire knowledge base. To solve a challenge case involving another body system, the student would need to survey all of the disease pages from that system to determine the best diagnosis for their case study. We felt the design of this activity would provide students with the opportunity to use their peers’ knowledge artifacts in an authentic and purposeful way, while engaging them in an inquiry activity about the three human body systems. Once a student felt that he or she had solved the challenge case, they would be asked to email their responses to the authors of the challenge case, with a copy sent to both the teacher and the researcher.

The co-design team decided that solving the challenge cases would be an in-class activity. In pairs, students would present their case studies to the rest of the class. This short presentation took the form of a role-play, with one student performing the role of the patient, and the other performing the role of the physician.

4.3.4 Addressing curriculum content expectations

When designing the knowledge construction and inquiry activities, the teachers stressed that there was specific curriculum content that needed to be covered. We reviewed these requirements as a team, and noted the expectations for Human Systems and Regulations, as noted in the Ontario Science Curriculum documents (1999, 2008) for Grades 9/10 (see Table 2 on the following page):
Table 2

Ministry of Ontario Curriculum Standards for Physiology

<table>
<thead>
<tr>
<th>Curriculum Content Expectations for Human Systems and Regulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Students should be able to describe and explain the major processes, mechanisms, and systems – including the respiratory, circulatory and digestive systems, by which mammalians maintain their internal environment;</td>
</tr>
<tr>
<td>• Students should be able to report on the causes, symptoms and cures for three or more disorders related to the respiratory, circulatory and digestive systems (e.g., diabetes, appendicitis, gall bladder malfunction, gallstones, malnutrition, bulimia, emphysema, bronchitis, stroke, hypertension);</td>
</tr>
<tr>
<td>• Students should know how to select and integrate information from various sources, including electronic and print resources, community resources, and personally collected data to answer relevant questions (e.g., investigate the effects of carcinogens, water pollution, toxins);</td>
</tr>
<tr>
<td>• Students should use appropriately scientific terminology related to mammalian anatomy, including, but not limited to: systolic, diastolic, diffusion gradient, inhalation, exhalation, ulcers, etc.</td>
</tr>
<tr>
<td>• Students should be able to describe how general living conditions and lifestyle contribute to the functioning and maintenance of human body systems by referring to diet, physical exercise, environmental pollutants and epidemiological trends (e.g., SARS, West Nile virus, etc.)</td>
</tr>
</tbody>
</table>

An important requirement of KCI is that the overall curriculum should target the required learning goals or expectations. To ensure that students were addressing the required science content when working on their disease pages, we made use of the customized page template that was described earlier. The template, once completed, automatically generated a wiki page that included an appropriate page title and subheaders. The headers organized the resource page into the following six sections: (i) Short summary, (ii) Signs & symptoms, (iii) Causes, (iv) Anatomical effects, (v) Effects on other systems, and (vi) Biological functioning. Underneath each of these headers was an instructional prompt (in italicized text) that asked students for information about the
physiology of their disease or disorder, including the causes, symptoms and biological functioning. For example, underneath the Anatomical Effects header was the question, “What part of the body system is affected? How is it affected?” The prompts served as scaffolds that guided students’ contributions and ensured that the relevant science content was captured within the knowledge base.

When developing their disease pages, students would be asked to consult a variety of information sources, which was one of the objectives listed in the curriculum documents. Students were allowed to make use of both Internet and print sources. The teachers also arranged for the school librarian to bring a cart of relevant books and journals that students could consult during class time.

With respect to assessment, the teachers decided they would not grade the disease pages or the challenge cases for the first implementation of a KCI unit. They would, however, review them for completion and accuracy before students used them for the inquiry activity (i.e., the challenge case studies). The science content that was included in the disease pages, however, would be covered on the final biology exam for all four classes. Consequently, the set of disease pages served as an important study guide for students.

Overall, the design team felt that they had created a reasonable implementation of the KCI model – particularly given our decision to restrict the scope and duration, as well as the fact that this would be the first attempt at such a design. Taken together, the sections above offer a justification that the curriculum design indeed captured KCI. Still, before proceeding with an investigation of student learning from this curriculum, it must first be determined whether it was enacted according to plan. That is, the design team
may have created a curriculum that was consistent with KCI, but unless that curriculum was enacted faithfully, any conclusions about its effectiveness would be unsubstantiated.

4.4 Enacting the KCI Curriculum

The first iteration of the curriculum was implemented towards the end of the spring term. Although I attended all the classes where students were participating in KCI activities, my involvement was limited to that of an observer and occasional provider of technical support (e.g., if students had login problems or had forgotten their password). Technical problems were quite minimal, and overall the teachers had no problems taking ownership of the curriculum they had helped to design, even though none of them had ever employed wikis in their classrooms before. Early in the intervention, a number of students would look to me when they had questions about an activity. If these questions were about the content requirements for the activity, I would refer them to their teacher. In general, the students paid little attention to my presence in the classroom. In the following sections, I describe the outcome of students’ participation in the KCI activities as a means of analyzing the enactment of the curriculum.

4.4.1 Creating a community knowledge base

After students had created their disease pages, I reviewed the contents of the community knowledge base. Between the four classes, students created resource pages for 23 system diseases (see Table 3). Students made use of the headers, and responded to the instructional prompts that were included in the web form. Each page was similarly organized, and included a number of images depicting the anatomies of the human body system. Figure 8 presents an example of a completed disease page.
### Table 3

*Disease Pages in Community Knowledge Base (N = 23)*

<table>
<thead>
<tr>
<th>Circulatory</th>
<th>Respiratory</th>
<th>Digestive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aneurysm</td>
<td>Asthma</td>
<td>Appendicitis</td>
</tr>
<tr>
<td>Angina</td>
<td>Bronchitis</td>
<td>Crohn’s Disease</td>
</tr>
<tr>
<td>Congenital Heart Disease</td>
<td>Emphysema</td>
<td>Familial Adenomatous Polyposis</td>
</tr>
<tr>
<td>Coronary Heart Disease</td>
<td>Pleural Effusion</td>
<td>Lactose Intolerance</td>
</tr>
<tr>
<td>Diastolic Dysfunction</td>
<td>Pneumonia</td>
<td>Stomach Ulcers</td>
</tr>
<tr>
<td>Haemophilia</td>
<td>Squamous Cell Cancer</td>
<td>Whipple’s Disease</td>
</tr>
<tr>
<td>Hypertrophic Cardiomyopathy</td>
<td>Tuberculosis</td>
<td>Colitis</td>
</tr>
<tr>
<td>Myocardial Infarction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Varicose Veins</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The average number of words in the completed disease pages was 927.91 (Figure 9), which was fairly lengthy considering that students were not given guidelines regarding the length of their resource page. The average number of page revisions (i.e., each time the wiki page was opened and saved) was 16.78 (see Figure 10). Since students used the Internet for their research, each disease page was run through Copyscape©, a web-based utility that compares web pages and checks for instances of plagiarism. Of all 23 pages, there were no instances that warranted concern.

*Figure 8. Example of a circulatory Disease Page.*
The disease pages were also reviewed for their compliance to the instructional prompts that were included beneath each of the six section headers on the disease pages. Based on the teachers’ review of these pages, I rated the completion of each section on a 0-3 scale as follows:

**Level 0: No information.** If the section was not included in the resource page, it received a score of 0.
Level 1: Inaccurate or irrelevant. If the section contained inaccurate or off-topic information, it received a score of 1.

Level 2: Partially complete, but accurate. If the section was only partially completed, but the information was accurate, it received a score of 2.

Level 3: Complete and accurate. If the section was fully completed, and all the information was accurate, it received a score of 3.

Overall, the students did a thorough job of addressing the physiology content requested by the wiki page headers (Figure 11). Both teachers were satisfied with the comprehensiveness and level of detail that were included in the resource pages, and felt they would be a good resource for the challenge case activity. Thus, there is evidence of a successful enactment of the initial phase of the curriculum design, where all students in the class collaborate to construct a common knowledge base.

![Bar chart showing content completion scores for sections of Disease Pages.]

Figure 11. Content completion scores for sections of Disease Pages.

4.4.2 Connecting inquiry and community knowledge

After establishing that students had created a collaborative knowledge base, the next step was to review their enactment of the inquiry activity (i.e., the challenge cases).
Together, the four classes created 50 different challenge cases for the diseases of the three body systems. Table 4 shows the number of cases created for each of the circulatory, respiratory and digestive systems. Students took advantage of the creative opportunity when writing their challenge cases and gave them unique names such as “I. M. Hurtin” and “Snow White and the Seven Smokers” (see Figure 12). Many of the patient backgrounds that were described were humorous and silly; however, they did describe feasible illnesses that could be scientifically diagnosed.

Table 4

Number of Challenge Cases per Human Body System (N = 50)

<table>
<thead>
<tr>
<th>Body System</th>
<th>No. of Challenge Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circulatory</td>
<td>21</td>
</tr>
<tr>
<td>Respiratory</td>
<td>15</td>
</tr>
<tr>
<td>Digestive</td>
<td>14</td>
</tr>
</tbody>
</table>

*Figure 12. Example of a respiratory disease Challenge Case.*
While students were solving their challenge cases, the teacher circulated the room to answer any questions the students had. During this time I observed the activity from the back of the room. Before the class began, I had predicted that students would use Google when solving their case studies, however, it became evident that students were relying on their peers’ disease pages from the resource base. An interview comment from a student helps explain why this was the case:

“...It was the organization for sure. The way the wiki pages were sectioned, like, everything in the same order, it made it easy to know where to find the information. It was sometimes hard to pinpoint what the exact disease was, but you knew the answer was there somewhere…. I actually thought the whole [activity] was kinda interesting and fun. (Nadia)”

Upon reflection, I realized that many students probably did begin their searches with Google, but then found it more expedient to go to the source of the challenge cases (i.e., the disease pages) for the solution. The search terms students likely would have used in Google, “coughing” or “cigarette smoke” for example, would have yielded a random search result rather than a thematic list of diseases that could be narrowed to a diagnosis. It was encouraging to note that the design of the inquiry activity led to a natural reliance on the knowledge base when students were solving their challenge cases.

4.4.3 Integrating community interests and themes

It is important that the inquiry activities in KCI are designed so they reflect students’ interests as represented in the knowledge base. When evaluating the design of the curriculum, we realized that the disease page activity was not conducive to the emergence of student-driven interests. Nevertheless, because this research sought to establish a methodological paradigm for the analysis of KCI, it was important to evaluate
this aspect of the model. At a minimum, the design of the challenge case activity left the
topic open, the only requirement being that students had to create a case study for their
assigned body system. The activity was successful in that students did use their peers’
disease pages when solving their challenge cases, however, they only needed to consult
them briefly to be able to find the correct diagnosis. In terms of integrating community
interests and themes into the curriculum, the basic design of the first KCI curriculum did
not leave much room for developing activities that reflected the evolving interests of the
community.

4.4.4 Addressing curriculum content expectations

The most accessible measurement of student learning in this iteration was the
students’ final biology exam scores, which included a physiology section on human
diseases and disorders. By convention, the school in this study divides the final science
exam into four major sections that are administered as separate smaller exams. Students
are given 40 minutes to complete the first section, and are then moved to different rooms
to complete the second, third and fourth sections. All 102 students completed a final
exam that was divided into the following four topics: (i) diversity and plants, (ii) genetics,
(iii) physiology, and iv) cellular functions. Because of the way the exam was structured, I
was able to isolate the exam scores associated with the physiology section (the KCI topic)
from those associated with the remaining aspects of the course. This was useful as I was
interested in a specific measure of KCI on students’ final exam performance.

To achieve this, I compared students’ exam scores with those from the same
biology classes of the previous two years. To minimize the effects of different teaching
styles, I used only classes taught by Erin for each of the three comparison years (n = 94).
A review of the physiology sections of all three years revealed that exam formats were similar, with each physiology section consisting of three open-ended questions. Appendix A shows an example of a physiology exam question from each year.

A one-way ANOVA was conducted to determine if there were significant differences between students’ exam scores across the three years. Homogeneity of variance was examined using Levene’s test, and found to be non-significant ($p = .338$). The results of the ANOVA revealed that the average physiology score was different across the three years, $F(2, 91) = 8.19$, $p = 0.001$. Tukey multiple comparisons performed at the 0.05 significance level found the mean score for the intervention year ($M = 90.91$, $SD = 7.98$) was significantly higher than that for Year 1 ($M = 82.50$, $SD = 9.75$) and Year 2 ($M = 84.40$, $SD = 8.19$). Thus, students in the intervention year improved their performance significantly on the physiology section of the final exam, when compared with previous cohorts who were taught with the regular physiology curriculum. Figure 13 shows a boxplot of the exam scores for the physiology section across the three years.

*Figure 13. Boxplots for physiology exam scores across three years.*
To determine if there was a significant difference between the scores on the other sections of the exam (i.e., with the physiology section excluded), the same procedure was repeated. The results of the second ANOVA found no significant differences in the average score for the rest of the exam $F(2, 91) = 1.26, p = .288$. Thus, students across the three years had consistent grades when the physiology section was excluded from the analysis. Figure 14 shows a boxplot of the exam scores with the KCI unit excluded.

![Boxplot](image)

*Figure 14.* Boxplots for the rest of the exam across three years.

To further explore student learning gains, I reviewed a subset of final exams ($n = 48$) from 2006-2007 (the intervention year). Since the physiology exam questions were long answer, I was able to qualitatively code the content for commonalities among student responses. I selected one question from the final exam that offered an opportunity for students to demonstrate conceptual connections to the KCI knowledge base:

“*Question 2: Other than the factual information you gained from the use of the wiki for learning about human physiology, what overriding concepts did you take away from the disease lesson? Discuss at least two concepts.*”
Following Chi’s (1997) approach to content analysis, I reviewed the exam responses and developed a coding scheme of conceptual categories based partially on my initial reading of exam responses. Six distinct concept categories were identified. Since students were specifically asked to discuss two concepts, there were typically two distinct conceptual codes assigned to each exam question. Table 5 shows a frequency distribution of the concept categories reported in students’ exams.

Table 5

*Concepts Taken Away from KCI Activities*

<table>
<thead>
<tr>
<th>Concepts Reported by Students</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is interdependency of biological processes between body systems</td>
<td>23</td>
</tr>
<tr>
<td>Multiple perspectives on a topic is valuable</td>
<td>21</td>
</tr>
<tr>
<td>There is an overlap of symptoms in diseases and disorders of the body</td>
<td>16</td>
</tr>
<tr>
<td>I learned how to identify credible and relevant web information</td>
<td>14</td>
</tr>
<tr>
<td>Lifestyle choices are important for disease prevention</td>
<td>11</td>
</tr>
<tr>
<td>There is a margin of error when diagnosing diseases and disorders</td>
<td>10</td>
</tr>
</tbody>
</table>

Altogether, students reported 95 concepts that fell within these six categories. Out of the 48 exams reviewed, 36 students reported two or more concepts from Table 5, 11 students reported one concept, and one student did not report any. One of the teachers, Rebecca, remarked how students’ responses to this exam item reflected the physiology curriculum expectations: “When I was doing my marking, I was actually pretty surprised… with this lesson they definitely covered the [Ontario] Ministry content, and they ended up learning a lot more about how the different body systems interact.”
4.5 Lessons Learned from Design Cycle 1

While the results from this first implementation of a KCI-based curriculum were encouraging, there were a number of shortcomings in terms of how it corresponded to the KCI model. The following section describes these shortcomings, including the lessons learned from the experiences with the first design cycle. These lessons informed the design efforts in the second implementation of a KCI unit, which is described in Chapter 5.

4.5.1 Lesson 1

*The amount of time spent on the topic needed to be longer, to allow community interests to emerge and to build stronger connections to science concepts.*

A key objective of the KCI model is to connect the emerging themes and interests of the community within a substantive shared knowledge base, and to create inquiry activities that encourage deep connections with that knowledge base. The relatively short duration of the KCI unit (one and a half weeks) made it difficult to establish a sense of community, and to design a curriculum where themes and interests could emerge within the knowledge artifacts. Although the students took an interest in the challenge cases, the activity itself was not deeply connected with the contents in the community-owned knowledge base. A longer unit focusing on a broader scope of content would allow more time for the community to mature and for common themes and interests to become established. These themes and interests could then be used to inform the design of subsequent inquiry activities within the curriculum.
4.5.2 Lesson 2

*Stronger connections are needed between the community knowledge base and the inquiry activities.*

Students in the first KCI iteration relied on the community knowledge base (the repository of wiki pages) to solve the challenge cases, however, they did not engage with the material in those pages very deeply. Rather, they simply consulted each disease page within a certain body system to see if it provided a diagnosis, and did not build on the ideas in that page, or synthesize the material in any way. Consequently, this unit did not fully realize one of the goals of the KCI model: to engage students in making deep connections between their inquiry activity and the community knowledge base. A deeper interconnection or dependency between the knowledge resources and the requirements of the inquiry activity could have drawn students’ attention to more of the big ideas of the physiology unit (e.g., the implications for health and disease). Thus, the next design iteration needed to make such connections explicit by scripting the inquiry so that students could engage more deeply with the content from their knowledge base.

4.5.3 Lesson 3

*Student collaboration must be better defined and measured.*

It was evident from reviewing the database that students from all four biology classes had contributed to the knowledge artifacts. What was not evident, however, was whether all students were collaborating, or whether the majority of work was being done by a few individuals within a group (i.e., within a specific disease page). For example, it was not easy to determine whether students within a group had built on one another’s ideas or generated new ideas as a result of their collaboration. This is an important issue
for the KCI model, since collaboration is central to learning within a knowledge community. In the next iteration, it was important to consider more deeply how students were contributing to a co-authored document, and what benefits they gained as a result of their exchanges. As a result, the next design cycle required specific measures to determine the degree to which students collaborated and interacted when creating their wiki-based knowledge resource.

4.6 Summary

Overall, the first KCI curriculum unit was a success. In terms of student understanding, both teachers felt that the KCI activities had helped students develop a deeper understanding of how the three physiological systems were interconnected. Students were also able to make connections between the different diseases of the body systems (e.g., how a low red blood cell count from anemia could make a person more susceptible to a respiratory disease). In their interviews, both teachers communicated their enthusiasm for the new curriculum. They both agreed that designing the activities was time-consuming, but that the workload was manageable and not too overwhelming. One of the teachers, Erin, admitted feeling apprehensive before beginning the unit, and expressed her concern about covering the required material:

We weren’t going to do [the activity] just for the sake of doing it… we’re very much classroom teachers. If it’s not going to help the kids learn really well, we’re not interested in it. But it worked. I mean, we put a lot of time into negotiating things, but I think it ended up being a really good quality lesson. (Erin, teacher)
CHAPTER 5: DESIGN CYCLE 2: CANADIAN BIODIVERSITY

5.1 Chapter Overview

In this chapter, I discuss the second cycle of design and enactment of a KCI curriculum unit. I begin by reviewing the specific methods and analyses employed, including the details of materials and sequencing of activities. This is followed by a description of the curriculum that resulted from our co-design efforts. The chapter concludes with a section on the lessons learned from this second implementation, and offers a set of design recommendations for future implementations of the KCI model.

5.2 Methods and Analyses

As in the first design cycle, the analyses for the second design cycle are organized according to the four main elements of the KCI model: (i) creating a community knowledge base, (ii) connecting inquiry and community knowledge, (iii) integrating community interests and themes, and (iv) targeting content expectations. In this second iteration, I take a deeper look at students’ interactions during the construction of their community knowledge base, as well as their use of that knowledge base during a subsequent inquiry activity.

5.2.1 Participants

A new cohort of 112 students, distributed into four class sections, participated in the second design cycle. The participating teachers included the same two female teachers from the first intervention, Erin and Rebecca, and a third male teacher named Daniel. Rebecca and Daniel each taught one section of the biology class, and Erin taught two sections.
5.2.2 Data Sources

Data sources in the second design cycle included the following: all student-generated wiki artifacts (i.e., student’ resource pages in the community knowledge base), archives of wiki revisions, computer web logs of students’ activity, student and teacher interviews, and final exam scores. A supplementary data source used in the second design cycle was computer logs of students’ online activity in the wiki. The following table outlines how the data sources were used to inform the research questions:

Table 6

Data Sources Used in Design Cycle 2

<table>
<thead>
<tr>
<th>Question</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did the co-design team design a curriculum that aligned with the objectives of the KCI model? (RQ1)</td>
<td>• Co-designed curriculum materials, student artifacts</td>
</tr>
<tr>
<td>Did students collaborate when constructing their community knowledge base? (RQ2)</td>
<td>• Archive of wiki revisions, student artifacts</td>
</tr>
<tr>
<td>Did students use each other’s knowledge artifacts when working on their inquiry activity? (RQ2)</td>
<td>• Computer logs of students’ online activity</td>
</tr>
<tr>
<td>Did students learn the content expectations with the KCI curriculum? (RQ3)</td>
<td>• Student artifacts, final exam scores, teacher interviews</td>
</tr>
</tbody>
</table>

5.2.3 Analysis

Unlike in the first design cycle, the wiki pages in the knowledge base were analyzed for patterns of individual and group participation. Aside from this, the same basic analyses were performed: first, the designed curriculum was evaluated in terms of its adherence to the KCI model. Once that adherence was ascertained, the enactment of the curriculum was then evaluated to ensure that it was faithful to the design. The effectiveness of the curriculum was then analyzed in terms of student achievement on
final assessments, as well as the content of their inquiry artifacts. The inquiry activity was assessed for its effectiveness in requiring students to make connections between the knowledge elements in the resource base, and for integrating students’ interests as represented in that knowledge base. Finally, students’ final biology exam scores were examined to determine the effects of the KCI unit on student learning of the required science material.

Additional analyses were conducted in the second design cycle that were not conducted in the first. One of the lessons learned from the first intervention was that we needed to better understand how students were collaborating during KCI activities. The process of collaboratively constructing a shared knowledge base – a fundamental aspect of the KCI model – would be significantly undermined if students were producing their knowledge artifacts individually (e.g., dividing up the work load, not considering the contributions made by classmates). If some students collaborated deeply with peers and others did not, we might predict that the more collaborative students would derive greater benefits from the curriculum. Thus, there is a potential analytic advantage for knowing which students collaborated in the wiki activities, and how well. Since the collaborative element is critical to KCI, it was important to take a closer look at patterns of students’ participation as they constructed the community knowledge base.

To determine how students were engaging in collaborative knowledge construction, it was necessary to analyze their individual contributions within the wiki (i.e., edits, reorganizations, formatting, adding images and links, etc.). Since there are no published methods for analyzing wiki revisions, I developed one that was targeted specifically for the needs of this research. I began by defining a unit of analysis referred
to as a “transaction,” which is a marked-up section in the revision history of a wiki page that indicates the changes a user has made between versions (i.e., the changes a student made in the wiki before clicking “Save”). By default, the Confluence wiki used in this study labels such sections as “changes”, however, this characterization is imprecise since it suggests that only a single change is occurring. For this reason, I treat these changes as individual transactions, since it would allow for multiple codes to be assigned to a single editing effort.

An example of a wiki revision that includes two transactions can be seen in Figure 15 below, which shows a screen capture of the tool that allows wiki administrators to compare two consecutive versions of the same wiki page. In this example, the student made two transactions labeled in Figure 15 as T1 and T2.

![Revision history showing two transactions](image)

*Figure 15. Revision history showing two “transactions”: the first (T1) contains text that was deleted and inserted into existing text; the second (T2) contains newly added text.*

The bolded segments in the first transaction (T1) indicates text that has been added and deleted within an existing section of text (i.e., the text was already there before
the student made the edit). In the second transaction (T2), the highlighted section indicates text that has been added without altering any of the surrounding text (i.e., a new sentence or paragraph). These examples show how edits could include more than one change in a single transaction. In the revision archive of the knowledge base, it was not uncommon to see wiki pages where a student had made 20 or more transactions in a single revision of a wiki page.

The next step was to devise a coding scheme for documenting students’ transactions. The result was a four-tier coding scheme (Figure 16) that was used to code each transaction in each version of each wiki page. The first tier that was coded was “Transaction Type” (i.e., was content moved, added, deleted or formatted?). A format included changes that did not affect content meaning. This includes changes made to images, spelling and grammar corrections, or any structural changes. Replaced words were considered a format if they did not change the semantic meaning of the sentence. The transaction was then coded for “Content Type” (i.e., did the content consist of text, an image, an internal link or external link?). Internal links were hyperlinks made to another classmate’s wiki page, and external links were links to outside web pages.

![Coding scheme for “transactions” in wiki revision history.](image)
Since my analyses in this dissertation focused on contributions of written prose, only text-based transactions were coded at the third tier as either “embedded” or “detached”. Embedded edits were those made to segments of previously contributed text (such as the text in T1 of Figure 15), while detached edits were those that were not attached to any existing text (such as the text in T2). Finally, the fourth tier of coding was concerned with whether the edited text was that of “self” or “peer”. If the edit was made to a classmate’s text, it was coded as peer, if it was made to one’s own text, then it was coded as self.

In the example shown in Figure 15, the first transaction (T1) would receive two coding sequences because text was both added and deleted. Thus, if the text in T1 was a classmate’s, the transaction would be coded as: (i) delete>text>embedded>peer, and (ii) add>text>embedded>peer. If the text in T2 was the student’s own, then it would be coded as follows: add>text>detached>self.

Although this coding scheme characterizes all possible edit types, it is not without limitations. For example, it cannot capture the intent of an edit, such as whether a student was extending or elaborating on a classmate’s idea. Additionally, with this coding scheme a new section or paragraph would always be coded as “detached >self” – regardless of whether it followed text written by a peer, and regardless of whether it was about the same topic as the preceding text. The reason for this conservative coding of new sentences or paragraphs was based on my observation of what I call the “addendum phenomenon” – cases where students added discrete facts about a topic that someone else had added to the page (e.g., adding a list of animals or plants to an established section about flora and fauna). Although it could be argued that a student was deeply engaged
with a classmate’s idea when they were adding new text, it could also be argued that they were’nt. For this reason, I chose to interpret such transactions as edits to self.

5.3 Co-Designing the KCI Curriculum

The co-design team began planning the KCI unit in the summer, with the goal of implementing the materials in the following fall term. Over the summer and early fall, the co-design team meet 17 times to discuss the design, delivery and content of the KCI curriculum. As in the first design cycle, we used our own wiki space to record meeting notes and document the evolving curriculum. Encouraged by the overall outcome of the first iteration (the physiology unit) as well as the design recommendation that we should develop a longer curriculum, we decided to extend the second intervention to a 3-month curriculum unit on biodiversity. This unit addressed a major component of the content requirements for Sustainability of Ecosystems, and allowed for more substantive collaborations and inquiry. We decided that the new KCI unit would cover approximately two-thirds of the content on Canadian Biodiversity, which included the ecology of the marine and terrestrial ecozones of Canada, as well as the general ecology of biodiversity.

5.3.1 Creating a community knowledge base

The Canadian biodiversity unit began with a collaborative knowledge construction phase. Once again, we designed an activity where students would co-create a knowledge base that was comprised of wiki pages with links and keywords, as well as comments made by peers on one another’s pages. This time, the focus of the knowledge base was Canada’s ecosystems, biomes and biodiversity issues, which would be developed collaboratively and used collectively by all 112 students. The teachers began
the unit by placing students into one of eight Canadian biome regions. Working in these groups, students choose a geographical area in Canada that constituted an ecozone (e.g., Atlantic Maritime). As in the previous iteration, students used a customized web form to create a new “Ecozone Page” (Figure 17). As each class section met to create their resource pages, there were fewer unique ecozone pages to choose from, obliging some students in later classes to join existing groups. Students were given approximately four class periods over the next several weeks to create their ecozone pages, with unfinished pages assigned as homework.

![Figure 17. Customized “Create a new Ecozone Page” web form.](image)

Since the ecozone pages were to be graded in the biodiversity unit, students were diligent about creating resource pages that were comprehensive and accurate. To guide students in including the necessary science content, students used the wiki template with pre-specified headers and instructional prompts that were generated from the customized web form (Figure 18).
During one of the co-design meetings, the team decided to add a second knowledge construction activity that also involved some collaborative inquiry. This activity took the form of a “Biodiversity Issue” page where students, in pairs or small groups, described a problem or issue that was threatening the biodiversity in their ecozone, as well as the ecological implications of the problem (see Appendix B for an example of a biodiversity issue page). We designed another web form for this purpose that included headers and instructional prompts (Appendix C). Since ecozones overlap geographically, students were asked to make connections between regions by explaining how the problem or issue in their ecozone affected surrounding regions. Students were also asked to include links to their peers’ wiki pages that they referenced, along with a description of how the ecozones were connected.

Another addition to the second KCI-based curriculum was a peer review. After the ecozone pages were complete (and before they were graded), students were assigned the task of reviewing two of their peers’ resource pages so they could gain a wider understanding.
understanding of biodiversity within Canadian biomes. They were then asked to incorporate the feedback or recommendations received from their peers into their own ecozone page. Students were asked to use the wiki’s “Comment” feature for this purpose. Students’ comments appeared as separate annotations at the bottom of each wiki page, similar to how one might leave a comment on a blog (Figure 19). These comments were visible to the entire class community as well as the teacher.

![Figure 19](image.png)

*Figure 19. Example of student peer review comments.*

### 5.3.2 Connecting inquiry and community knowledge

Our next challenge was to design a scaffolded inquiry activity that would require students to engage deeply with the community knowledge base – a design feature that we wanted to improve upon from the previous design cycle. The co-design team decided that this activity should take the form of an individual research proposal, where students recommended a research plan for remediating one or more of the biodiversity issues they had discovered. An objective of this activity was to encourage students to make real-world connections between the ideas and concepts presented in the knowledge base (i.e., the ecozone and biodiversity issue pages), and to encourage them to reflect on the
implications of these connections for Canada and their local school community. The teachers asserted that this assignment would need to be an individual one, so that students would have an individual grade assignment within the Canadian biodiversity unit.

As part of the instructions for the inquiry activity, students were asked to imagine themselves as scientists applying for a research grant. Their proposal, addressed to a government agency, would request funding for a project aimed at addressing a current environmental problem within Canada. In approximately 1000 words, the project summary was to include the following: (i) a justification of why the project deserves to be funded, (ii) a plausible action plan for addressing the problem; (iii) an explanation of the plan’s impact on Canada’s ecozones that articulates the science of biodiversity, (iv) a prediction of what will happen in 50 or 100 years if the plan is not put into effect; and (v) suggestions for new legislation that would support or enforce the proposed remediation.

In their research proposals, students were to make connections between as many ecozone and biodiversity issue pages as possible, and to include links to all referenced pages. Once again, a customized web form was developed that collected initial information and then generated a new wiki page with headers and italicized subtext to scaffold students to include the components described above.

The teachers planned to evaluate the research proposals using a rubric that outlined the components of the research proposal (see Table 7). Students were invited to help construct the rubric, and were asked to email their teacher with thoughts about what should be included in the evaluation. These emails were sent to the grade 10 biology list serve, and were therefore available to students from all four classes. The final version of
the rubric was a negotiated product that reflected input from the whole design team, as well as from the students themselves.

Table 7

Assessment Rubric for Final Research Proposal

<table>
<thead>
<tr>
<th>ASSESSMENT - FINAL PROPOSAL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Title /3</strong></td>
</tr>
<tr>
<td>• Relevant to proposal</td>
</tr>
<tr>
<td>• Creative</td>
</tr>
<tr>
<td>o Gives a different perspective on the idea/topic</td>
</tr>
<tr>
<td>o Uses a play on words</td>
</tr>
<tr>
<td>o Makes the reader stop and think</td>
</tr>
<tr>
<td><strong>Proposal /16</strong></td>
</tr>
<tr>
<td>• Proposed solution is clearly and briefly stated at the beginning of this section (1-2 sentences...&lt;100 words.)</td>
</tr>
<tr>
<td>• Proposed action needs to be plausible (it can be done) and viable (it needs to be able to potentially produce results) and the results need to be able to last beyond the project.</td>
</tr>
<tr>
<td>• Proposed solution is expanded upon in an organized way so that the reader can have a good understanding of what is expected to happen. Possible, but not required, items could include...</td>
</tr>
<tr>
<td>o What is going to be studied (e.g. the variable)</td>
</tr>
<tr>
<td>o What type of research is being proposed?</td>
</tr>
<tr>
<td>o Where are your study sites? Why did you choose these? (keep this succinct) Some description is present.</td>
</tr>
<tr>
<td>o When this is going to happen...over what time range?</td>
</tr>
<tr>
<td>o Are you looking into existing data or information from previous years?</td>
</tr>
<tr>
<td>o Some sort of public education around the issue</td>
</tr>
<tr>
<td>o What is your goal? What do you expect to happen at the end of the 5 years?</td>
</tr>
<tr>
<td>• The plan should be creative</td>
</tr>
<tr>
<td>• Proposed solution is expanded upon in an organized way so that the reader can have a good understanding of what is expected to happen. Proposal does the following:</td>
</tr>
<tr>
<td>o Does not restate something that is already being done</td>
</tr>
<tr>
<td>o More than building on current actions</td>
</tr>
<tr>
<td>o Provides a new perspective on the problem and/or solution to the problem</td>
</tr>
<tr>
<td>o It attacks the problem from a different angles</td>
</tr>
<tr>
<td><strong>Justification for Plan of Action</strong></td>
</tr>
<tr>
<td>• Why is your proposal essential to the future biodiversity of Canada?</td>
</tr>
<tr>
<td>• Why should your project be funded? (over other great projects?)</td>
</tr>
<tr>
<td>• If your project is funded, what results would you expect to see</td>
</tr>
<tr>
<td>o After 50 years? After 100 years?</td>
</tr>
<tr>
<td><strong>Biodiversity Impacts /6</strong></td>
</tr>
<tr>
<td>• List of potential biodiversity issues if your plan of action isn't put into effect (min of 3)</td>
</tr>
<tr>
<td>o Reasonable and relevant</td>
</tr>
<tr>
<td>o Ecozones that will be impacted</td>
</tr>
</tbody>
</table>
5.3.3 Integrating community interests and themes

When designing the inquiry task for the second KCI unit, a conscious effort was made to ensure that any inquiry activities reflected the voice of the student community. To this end, we planned a “critical juncture” phase where the co-design team met to identify the themes and interests that were reflected in the ecozone and biodiversity issue pages, with the intent of using those themes to guide our final design of the inquiry activity. We recognized that the timing of this process would be challenging, as the critical juncture meeting would not be able to take place until after the knowledge base was completed. This meant that the scaffolded inquiry activity could not be fully
designed in advance, since we would not know the contents of the resource pages – hence the name “critical juncture.” As a result, the team decided they would have a planning meeting a few days before the inquiry activity was scheduled to begin. Given that the structural details of the inquiry assignment (i.e., the research proposal) had already been articulated, we felt that one or two days would be sufficient for reviewing the contents of the community knowledge base and infusing the inquiry activity with any themes that we could identify.

5.3.4 Addressing curriculum content expectations

As in the first design cycle, we consulted the Ministry of Education curriculum documents when designing the knowledge construction and inquiry activities. We noted the following expectations for Sustainability of Ecosystems in the Ontario Science Curriculum documents (1999, 2008) for Grades 9/10 (see Table 8, below):

Table 8

Ministry of Ontario Curriculum Standards for Biodiversity

<table>
<thead>
<tr>
<th>Curriculum Content Expectations for Sustainability of Ecosystems</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Students should understand that ecosystems are dynamic and have the ability to respond to change, within limits, while maintaining their ecological balance. Students should understand that there is a relationship between ecological balance and the sustainability of life.</td>
</tr>
<tr>
<td>• Students should understand that ecosystems have limiting factors (e.g., nutrients, space, water, energy, predators) that affect the carrying capacity of an ecosystem (e.g., the effects of a declining moose population on an ecosystem), and that there are consequences as a result of changing these factors.</td>
</tr>
<tr>
<td>• Students should be aware that human activity can affect the ecology and sustainability of aquatic and terrestrial ecosystems. People have the responsibility to regulate their impact on the sustainability of ecosystems in order to preserve them for future generations.</td>
</tr>
</tbody>
</table>
• Students should analyze natural and human threats to a local ecosystem and propose viable solutions to restore ecological balance. Students should be aware of problems or issues related to environmental sustainability, with a particular focus on issues in Ontario and Canada.

We used another web form to scaffold students to include the required science content when working on their resource pages. Section headers were used to organize the ecozone pages into five sections: (i) Short summary, (ii) Physical parameters (iii) Biological organization, (iv) Physical location, and (v) Biodiversity overview. The instructional prompts asked students for information about the biodiversity of their ecozone region, which included climate and temperature, rainfall, and native organisms. For example, underneath the ‘Biological Organization’ header were the instructions: “Discuss the archae bacterial, eubacteria, protista, fungi, plantae, and animalia of your ecosystem. Provide examples where possible.” When researching their topic, students were allowed to use both the Internet and print sources.

Unlike the previous KCI iteration, the teachers decided that they would grade students’ resource pages (i.e., the ecozone pages) for the Canadian Biodiversity unit. The students would be evaluated as a group based on the final version of their ecozone page, and evaluated individually on the quality of their research proposal. The science content for this unit (outlined in Table 8) would be covered on the final biology exam at the end of the year. Students were instructed that this unit would serve as their primary source of instruction concerning the ecology of terrestrial and marine ecosystems, although supplemental lectures and activities were included periodically by the teachers.
5.4 **Enacting the KCI Curriculum**

The second KCI curriculum was implemented in the fall term. As in the physiology unit, my main role during the intervention was that of an observer. In the second design cycle, I was interested in students’ engagement levels with respect to the quality and quantity of their contributions: What kinds of edits did students make, and how often did they make them? Did their participation levels affect their learning gains on the final exam? I was similarly interested in the level of peer interaction: Did students actively edit their peers’ text, or did they mostly edit their own? In the second implementation, I also took a closer look at the connections between the inquiry activity and community knowledge base, and the extent to which the curriculum integrated the interests of the classroom community.

Consistent with the previous cycle, I evaluated the enacted curriculum according to the four core principles of KCI – collaboratively constructing a knowledge base, integrating community interests and themes, connecting inquiry and community knowledge, and addressing content expectations. This pattern provided a useful framework for comparing and contrasting the activity structures in both iterations of a KCI-based curriculum.

5.4.1 **Collaboratively constructing a community knowledge base**

Towards the end of the Canadian biodiversity unit, I reviewed students’ knowledge artifacts in the community knowledge base. Between the four classes, students had created resource pages for 31 unique ecozone systems, guided by the headers and instructional prompts that were generated by the web form. Figure 9 lists the different ecozone pages that were created by students.
Table 9

Ecozone Pages in Community Knowledge Base (N = 31)

<table>
<thead>
<tr>
<th>Ecozone Resource Pages</th>
<th>Freshwater</th>
<th>Grasslands</th>
<th>Pacific Maritime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antarctic Tundra</td>
<td>Antarctic Tundra</td>
<td>Grasslands</td>
<td>Pacific Maritime</td>
</tr>
<tr>
<td>Arctic Archipelago</td>
<td>Arctic Archipelago</td>
<td>Grasslands</td>
<td>Pacific Maritime</td>
</tr>
<tr>
<td>Arctic Basin</td>
<td>Arctic Basin</td>
<td>Grasslands</td>
<td>Pacific Maritime</td>
</tr>
<tr>
<td>Arctic Cordillera</td>
<td>Arctic Cordillera</td>
<td>Grasslands</td>
<td>Pacific Maritime</td>
</tr>
<tr>
<td>Arctic Tundra</td>
<td>Arctic Tundra</td>
<td>Grasslands</td>
<td>Pacific Maritime</td>
</tr>
<tr>
<td>Atlantic Marine</td>
<td>Atlantic Marine</td>
<td>Grasslands</td>
<td>Pacific Maritime</td>
</tr>
<tr>
<td>Atlantic Maritime</td>
<td>Atlantic Maritime</td>
<td>Grasslands</td>
<td>Pacific Maritime</td>
</tr>
<tr>
<td>Black Oak Savanna</td>
<td>Black Oak Savanna</td>
<td>Grasslands</td>
<td>Pacific Maritime</td>
</tr>
<tr>
<td>Boreal Cordillera</td>
<td>Boreal Cordillera</td>
<td>Grasslands</td>
<td>Pacific Maritime</td>
</tr>
<tr>
<td>Boreal Plains</td>
<td>Boreal Plains</td>
<td>Grasslands</td>
<td>Pacific Maritime</td>
</tr>
<tr>
<td>Boreal Shield</td>
<td>Boreal Shield</td>
<td>Grasslands</td>
<td>Pacific Maritime</td>
</tr>
</tbody>
</table>

Because students used the automated web form, the pages were uniformly organized, with descriptive images and detailed information about the biodiversity in the ecozone. Students were given several periods of class time, and most students spent time working from home to refine and improve their resource page, in many cases working past the due-date. Figure 20 shows an example of a completed Taiga ecozone page.

Figure 20. Example Ecozone Page.
Overall, the content of the 31 Ecozone wiki pages was quite extensive, with an average word length of 1992.94 – more than double the length of the disease pages from the physiology unit (Figure 21). All 112 students contributed to these pages, with an average of 777.53 words inserted or edited per student (Figure 22, next page). The average number of page revisions (i.e., each time the wiki page was opened and saved) was 82.32 (Figure 23, next page), which was five times higher than the revision count for the previous iteration. The descriptives of the ecozone pages demonstrate that students were much more involved in the construction of their resource pages than they were in the previous physiology unit.

Copyyscape© was used to check the ecozone pages for plagiarism. Of all 31 pages, there were two instances that potentially warranted concern. In both of these cases, the students had simply listed animals belonging to their ecozone in more or less the same order that had been reported on an external web site. In both instances, the students included the full bibliographic reference of the web site at the bottom of their ecozone resource page.

![Figure 21. Histogram showing total word count of Ecozone Pages.](image)
Students’ peer review comments were also reviewed. Comments were coded at the sentence level using the qualitative analysis software NVivo. A second coder analyzed a subset of the comments, with an inter-rater reliability rate of 0.91 (Cohen’s kappa). A review of the data revealed some unanticipated results. In addition to peer reviews, almost half of all comments (47%) were remarks about a student’s own
contribution to their wiki page (see Figure 24). These kinds of comments typically characterized the types of edits a student made (e.g., “I added the section on anthropogenic effects”). Slightly fewer in number (41%) were comments that suggested page improvements (e.g., “Please describe the protista in this ecozone”), followed by supportive or encouraging comments (5%) (e.g., “Awesome page!”). A small number of comments (4%) were off-topic (e.g., “The Internet is sloooow”), or questions about how to do something (3%) (e.g., “Can anyone tell me how to right justify an image?”).

Figure 24. Breakdown of students’ peer review comments in wiki.

Post-study interviews revealed that students wanted to ensure their work was recognized, since individual contributions in the wiki are not easily discernable. In the words of one student, “I don’t agree with people making deletions right away on your own thing. I think it’s better that they leave a comment and say ‘you could just do this’ but you don’t actually change the original text”.

An important objective for the second design cycle was to investigate the kinds of edits that students were making during the construction of their shared knowledge base. To determine this, I reviewed the transactions that were coded using the coding scheme described earlier in this chapter (Section 5.2.3). Across all the 31 Ecozone pages, students contributed a total of 3810 transactions. Of these, 1072 (28.98%) were formatting-type transactions (i.e., spelling or grammar corrections, image resizing, etc.). Almost three-
quarters of the transactions (71.02%) were non-formatting transactions involving page content (Figure 25).

![Pie chart showing transaction types with text and non-text categories.]

**Figure 25.** Total transactions: formatting vs. non-formatting.

Of the non-formatting transactions, 1841 (70.08%) involved text, 372 (14.16%) involved external links, 365 (13.89%) involved images, and 49 (1.87%) involved internal links (i.e., links to a peer’s resource page). Figure 26 illustrates the breakdown of the non-formatting transactions by content type. To obtain inter-rater reliability for this coding, a second coder analyzed a subset of transactions \(n = 350\), drawn randomly from the 31 ecozone pages. Using the kappa statistic, a reliability test was performed to determine the consistency between the two coders, and was found to be 0.91 \((p < .000)\).

![Pie chart showing transaction types with text and non-text categories.]

**Figure 26.** Total transactions by content type.
The largest portion of the pie chart in Figure 26 represents the subset of wiki transactions that were relevant for this analysis – namely, the text-based edits that were made by a student to either his or her own text, or to a peer’s text. Figure 27 shows the relative frequency of peer versus self edits. Of the 1841 text transactions that were coded, 1246 (68%) were edits made to a student’s own text, and 595 (32%) were edits made to a peer’s text.

![Pie chart showing peer vs. self edits](image)

*Figure 27. Total text transactions: peer vs. self.*

Figure 28 breaks these categories down further, into the level of embedded versus detached edits. Recall that embedded edits were those that were interspersed within existing text, whereas detached edits were those that were independent of existing text. Transactions coded as “embedded self” would include edits where a student made revisions to his or her own text. Edits coded as “embedded peer” could be considered more collaborative, as they represent those edits where a student revised text that was contributed by a peer. Of the 1246 self-edits that were coded, 879 (47.75%) of these were detached and 455 (24.71%) were embedded. Of the 595 peer-edits, 140 (7.60%) were detached, and 455 (24.71%) were embedded.
The primary reason for coding transactions was to enable some understanding of students’ collaborative processes during the construction of their community knowledge base. Because collaboration is a crucial aspect of the KCI model, it was important to understand whether students were really building on their peers’ ideas. To determine the extent to which the wiki pages were edited collaboratively, it was necessary to look at the contributions of individual students. As expected, the volume of contributions varied considerably both within and between groups, which is not surprising as the wiki pages themselves were varied in length. As was shown by the histogram in Figure 21, the average length was approximately 2000 words, with a range of between 600 and 5000 words.

The type of text contributions also varied, depending on their timing and purpose within the wiki construction. For example, sections of prose added to blank sections of the wiki page were lengthier by nature than small refinements made to a peer’s contribution. At a minimum, it was necessary to demonstrate that all students made meaningful contributions, and that all ecozone groups were interactive in terms of students building on each other’s work.
To achieve a more accurate picture of student participation, I devised a weighted measure of students’ individual contributions to their respective ecozone pages (i.e., the number of words contributed by the student, weighted by the overall length of the wiki page). For example, a student who had contributed 400 words to an ecozone page that was 3000 words in length would have made a lesser proportional contribution than a student who had contributed 400 words to an ecozone page that was only 1500 words in length. The “ideal contribution” for a student in a group of size N with a word count of L would be L/N, which would reflect an equal number of words for each student. Of course, it is important to note that student contributions will naturally vary even in highly collaborative groups, as some words will be “cheaper and easier” at different points in the process, and some of the more important edits will be light on word count, but heavy on impact. Nevertheless, the weighted measure of contributions provides a mechanism for adjusting gross differences in page length.

If all groups had been the same size (e.g., n=4) then the weighted contribution score would be sufficient to allow comparisons across groups. But since the group sizes varied, the measure was adjusted one step further to account for the size differences between groups. For each group the “ideal contribution” was calculated (using L/N as described in the previous paragraph). Students’ individual contributions were then divided by this ideal value, resulting in a “participation quotient”. A student who contributed the exact amount as the ideal contribution would receive a quotient of 1.0, and students who contributed more than the ideal would receive quotients higher than 1.0. Figure 29 displays a histogram of the weighted contributions of all 112 students. As shown in the histogram, most students appear in the central bins, and fewer in the
extremes. This chart suggests that the 112 students in the four classes tended to collaborate more or less equitably during the creation of their ecozone pages.

*Figure 29.* Histogram of participation quotients for all 112 students.

The level of collaboration can also be analyzed at the group level with a one-sample t-test that compares the mean transactions of all 31 ecozone groups with the overall mean. Figure 30 shows a chart that plots the average number of transactions of each ecozone group (excluding formatting transactions). The horizontal line on the chart indicates the mean transaction number for all groups ($M = 23.46$, $SD = 17.28$), and illustrates that most groups tended to fall close to this central mean. The vertical lines indicate the 95% confidence interval, and provides a visual representation that few groups have means that are significantly different from the overall group mean. As demonstrated in the chart, some of the groups have substantial variance (particularly groups where $n = \leq 3$), reflecting the different participation levels within ecozone groups. Despite this variance, Figure 30 demonstrates that there was a fairly equitable level of participation within all groups during the construction of the community knowledge base.
While the above analyses demonstrate that students were actively engaged in constructing their ecozone pages, it does not indicate the extent to which they actually edited their peer’s text, as opposed to simply adding new text or editing their own. One of the collaborative affordances of a wiki is the ability to easily edit the text of others. Thus, one would expect to see a certain level of peer editing during the construction of the community knowledge base. To determine whether this happened, I calculated the percentage of each student’s edits that were made to a peer’s text. As shown in Figure 31 (next page), the mean percentage of peer edits was .34 (SD = .25). This value is relatively high considering that early contributions made to a wiki page would almost always be coded as a detached self-edit (“self detached”).

To illustrate, when a student creates a brand new wiki page (i.e., with the “Create a New Ecozone Page” web form), their initial efforts will typically be to add the first content to the page. Subsequent students who contribute to early versions of that page are...
also likely to add new content, either by adding new material to an existing section, or adding to a new section where no one had yet made a contribution. As the wiki page matures, text edits are more likely to be made to existing text – either to one’s own text, or text that had been contributed by a peer. Thus, a student who contributed primarily to the earlier versions of a wiki page would likely receive a lower peer quotient score, while a student who contributed more in the latter stages would likely receive a higher peer quotient score.

![Histogram of percent peer edits for all 112 students.](Image)

*Figure 31.* Histogram of percent peer edits for all 112 students.

The different measures of participation and peer editing in these analyses suggest that students were contributing relatively equally within their respective ecozone groups – adding new content, and editing the contributions of both themselves and their peers. Building on the measures of participation and peer editing, and the within-group variance of those measures, it is possible to define a combinatorial measure of the level of collaboration within groups. In particular, I was interested in knowing whether students in an Ecozone group participated more or less equally, or if some students did the
majority of the work while others did a minimal amount. I was also interested in gauging the overall level of peer editing that occurred within each group. To answer these questions, I created a compound measure based on the following four measures of students’ contributions:

1. Volume of contribution (the average number of words inserted or edited within a group);
2. Equity of contributions (the variance of the “participation quotient” within a group);
3. Level of peer editing (average percentage of peer edits within a group);
4. Equity of peer editing (the variance of peer edits within a group).

Since these four measures vary in terms of their baseline values, I needed a way to normalize them so they could be combined. One method is to simply rank each measure across all 31 groups and assign a tertile score of 1, 2 or 3 (1 for lowest third, 3 for highest). Then, for each group, the four ranking measures are summed and divided by four, resulting in a final group “collaboration score,” of which the lowest possible score was 1.00, and the highest possible score was 3.00.

Table 10 shows the sub-measures and final collaboration score for all 31 Ecozone groups, ordered from the highest collaboration score to the lowest. The number beside each value indicates the tertile ranking for that measure. This total score produces an overall ranking of groups according to their level of collaboration. While the teachers and researchers felt that all groups had collaborated well, it is still of interest to spread out the groups in terms of how well they engaged in collaboration. It was encouraging to note that of all the 31 ecozone groups, 22 had collaboration scores of at least 2.0 or higher.
Taken together, these analyses provide a level of detail about students’ editing practices during the construction of their community knowledge base, and provides evidence that students were engaging in peer collaboration during the collaborative knowledge construction phase of the KCI curriculum unit.

Table 10

Measures and rankings used for Compound Collaboration Score

<table>
<thead>
<tr>
<th>Ecozone Group</th>
<th>Collaboration Score</th>
<th>Avg. words edited</th>
<th>Var. words edited</th>
<th>Avg. peer edits</th>
<th>Var. peer edits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grasslands</td>
<td>3.00</td>
<td>1504.00 – 3</td>
<td>0.10 – 3</td>
<td>0.48 – 3</td>
<td>0.00 – 3</td>
</tr>
<tr>
<td>Atlantic Marine</td>
<td>2.50</td>
<td>2722.50 – 3</td>
<td>0.14 – 3</td>
<td>0.16 – 1</td>
<td>0.00 – 3</td>
</tr>
<tr>
<td>Pacific Maritime</td>
<td>2.50</td>
<td>1739.40 – 3</td>
<td>0.19 – 2</td>
<td>0.35 – 3</td>
<td>0.03 – 2</td>
</tr>
<tr>
<td>Freshwater</td>
<td>2.50</td>
<td>1688.50 – 3</td>
<td>0.24 – 2</td>
<td>0.41 – 3</td>
<td>0.03 – 2</td>
</tr>
<tr>
<td>Black Oak Savanna</td>
<td>2.50</td>
<td>2129.50 – 3</td>
<td>0.17 – 2</td>
<td>0.31 – 2</td>
<td>0.00 – 3</td>
</tr>
<tr>
<td>Antarctic Tundra</td>
<td>2.50</td>
<td>1354.67 – 2</td>
<td>0.06 – 3</td>
<td>0.42 – 3</td>
<td>0.05 – 2</td>
</tr>
<tr>
<td>Hudson Plains</td>
<td>2.50</td>
<td>956.00 – 2</td>
<td>0.09 – 3</td>
<td>0.29 – 2</td>
<td>0.00 – 3</td>
</tr>
<tr>
<td>Boreal Cordillera</td>
<td>2.25</td>
<td>2035.25 – 3</td>
<td>0.51 – 1</td>
<td>0.32 – 2</td>
<td>0.02 – 3</td>
</tr>
<tr>
<td>Northern Arctic</td>
<td>2.25</td>
<td>1200.00 – 2</td>
<td>0.00 – 3</td>
<td>0.44 – 3</td>
<td>0.06 – 1</td>
</tr>
<tr>
<td>Atlantic Maritime</td>
<td>2.25</td>
<td>611.75 – 1</td>
<td>0.06 – 3</td>
<td>0.52 – 3</td>
<td>0.04 – 2</td>
</tr>
<tr>
<td>Southern Arctic</td>
<td>2.25</td>
<td>772.00 – 1</td>
<td>0.14 – 3</td>
<td>0.30 – 2</td>
<td>0.02 – 3</td>
</tr>
<tr>
<td>Arctic Basin</td>
<td>2.00</td>
<td>1535.25 – 3</td>
<td>0.15 – 3</td>
<td>0.20 – 1</td>
<td>0.07 – 1</td>
</tr>
<tr>
<td>Prairies</td>
<td>2.00</td>
<td>1807.25 – 3</td>
<td>0.26 – 2</td>
<td>0.23 – 1</td>
<td>0.05 – 2</td>
</tr>
<tr>
<td>Northwest Atlantic</td>
<td>2.00</td>
<td>1649.5 – 3</td>
<td>0.49 – 1</td>
<td>0.07 – 1</td>
<td>0.00 – 3</td>
</tr>
<tr>
<td>Savanna</td>
<td>2.00</td>
<td>1575.67 – 3</td>
<td>0.61 – 1</td>
<td>0.24 – 1</td>
<td>0.02 – 3</td>
</tr>
<tr>
<td>Taiga Cordillera</td>
<td>2.00</td>
<td>1202.00 – 2</td>
<td>0.16 – 3</td>
<td>0.35 – 2</td>
<td>0.14 – 1</td>
</tr>
<tr>
<td>Arctic Tundra</td>
<td>2.00</td>
<td>1488.25 – 2</td>
<td>0.08 – 3</td>
<td>0.32 – 2</td>
<td>0.39 – 1</td>
</tr>
<tr>
<td>Marine</td>
<td>2.00</td>
<td>1001.43 – 2</td>
<td>0.25 – 2</td>
<td>0.36 – 3</td>
<td>0.06 – 1</td>
</tr>
<tr>
<td>Boreal Shield</td>
<td>2.00</td>
<td>937.50 – 2</td>
<td>0.57 – 1</td>
<td>0.32 – 2</td>
<td>0.01 – 3</td>
</tr>
<tr>
<td>Montane Cordillera</td>
<td>2.00</td>
<td>1441.20 – 2</td>
<td>0.45 – 1</td>
<td>0.33 – 2</td>
<td>0.02 – 3</td>
</tr>
<tr>
<td>Taiga Biome</td>
<td>2.00</td>
<td>574.00 – 1</td>
<td>0.00 – 3</td>
<td>0.11 – 1</td>
<td>0.02 – 3</td>
</tr>
<tr>
<td>Taiga</td>
<td>2.00</td>
<td>608.00 – 1</td>
<td>0.23 – 2</td>
<td>0.44 – 3</td>
<td>0.05 – 2</td>
</tr>
<tr>
<td>Pacific Marine</td>
<td>1.75</td>
<td>1501.80 – 3</td>
<td>0.91 – 1</td>
<td>0.11 – 1</td>
<td>0.04 – 2</td>
</tr>
<tr>
<td>Mixedwood Plains</td>
<td>1.75</td>
<td>1058.75 – 2</td>
<td>0.43 – 1</td>
<td>0.32 – 2</td>
<td>0.04 – 2</td>
</tr>
<tr>
<td>Temperate Deciduous</td>
<td>1.75</td>
<td>677.43 – 1</td>
<td>0.39 – 2</td>
<td>0.47 – 3</td>
<td>0.07 – 1</td>
</tr>
<tr>
<td>Arctic Cordillera</td>
<td>1.75</td>
<td>480.00 – 1</td>
<td>0.24 – 2</td>
<td>0.66 – 3</td>
<td>0.14 – 1</td>
</tr>
<tr>
<td>Boreal Plains</td>
<td>1.75</td>
<td>570.40 – 1</td>
<td>0.49 – 1</td>
<td>0.48 – 3</td>
<td>0.04 – 2</td>
</tr>
<tr>
<td>Taiga Plains</td>
<td>1.50</td>
<td>933.67 – 1</td>
<td>0.25 – 2</td>
<td>0.29 – 2</td>
<td>0.14 – 1</td>
</tr>
<tr>
<td>Osoyoos</td>
<td>1.50</td>
<td>474.40 – 1</td>
<td>0.18 – 2</td>
<td>0.28 – 1</td>
<td>0.03 – 2</td>
</tr>
<tr>
<td>Arctic Archipelago</td>
<td>1.25</td>
<td>1203.25 – 2</td>
<td>0.45 – 1</td>
<td>0.27 – 1</td>
<td>0.08 – 1</td>
</tr>
<tr>
<td>Taiga Shield</td>
<td>1.00</td>
<td>808.50 – 1</td>
<td>0.46 – 1</td>
<td>0.19 – 1</td>
<td>0.07 – 1</td>
</tr>
</tbody>
</table>
5.4.2 Integrating community interests and themes

Soon after the students had completed their ecozone pages, the co-design team held a critical juncture meeting to review the contents of the knowledge base and identify students’ interests and any emerging themes. Since the teachers had graded the ecozone pages by this time, they were already quite familiar with the content of the resource pages. At this meeting, the researchers and teachers reviewed the ecozone and biodiversity issue pages and agreed upon five strongly represented themes. These themes included: (i) Habitat loss and destruction, (ii) Invasive species, (iii) Climate change, (iv) Pollution, and (v) Demands of growing urban populations. One of the teachers, Erin, pointed out that these five themes coincided with the proposed changes in the Ontario Curriculum documents that called for increased emphasis on environmental education. The co-design team decided to use the five themes as guiding topics for the individual research proposal, and updated the design of the inquiry activity to include these themes. For their research proposals, students could choose to write about any biodiversity concern that fell within one of these five broad categories.

5.4.3 Connecting inquiry and community knowledge

As in the first design cycle, students in the Canadian biodiversity unit completed an inquiry assignment as part of their KCI curriculum. Unlike the physiology unit, where they collaboratively created their challenge cases, students in the second design cycle completed their research proposals individually. Since the second KCI curriculum was given a higher grade-weight than in the first implementation, it was important to the teachers that students have an individual grade assigned. As a result, the students did not co-author their research proposals with any peers. Moreover, at the request of the
teachers, this inquiry phase was treated as a course assessment, and students’ wiki-based research proposals were only viewable to the individual students who authored them, as well as the teacher and researchers.

The students were given the research proposal assignment shortly after beginning the biodiversity issue page activity. In this way, the students could start thinking about a research problem while investigating a biodiversity concern within their ecozone. The only criterion for the topic of the proposal was that it fit within one of the five categories that were identified in the community knowledge base. Although students could choose the category that interested them, the distribution of these five categories turned out to be relatively even. Table 11 shows a breakdown of the research proposal categories. As shown in the table, the two most popular categories were Habitat loss and destruction and Invasive species. When writing their research proposals, many students choose to elaborate on the problem that was identified in their biodiversity issue page. Figure 32 shows an example of a student’s final research proposal that was within the Invasive species category.

Table 11

Breakdown of Research Proposal Categories

<table>
<thead>
<tr>
<th>Research Proposal Categories</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat loss and destruction</td>
<td>26</td>
</tr>
<tr>
<td>Invasive species</td>
<td>25</td>
</tr>
<tr>
<td>Climate change</td>
<td>24</td>
</tr>
<tr>
<td>Pollution</td>
<td>19</td>
</tr>
<tr>
<td>Demands of growing urban populations</td>
<td>18</td>
</tr>
</tbody>
</table>
Figure 32. Example of a completed Invasive Species research proposal.

One of the recommendations that resulted from our efforts in the first design cycle was to encourage students to make extensive use of the community knowledge base for their inquiry assignment. In order to determine the extent to which students made use of their peers’ ecozone and biodiversity issue pages, I examined the computer web logs of students’ wiki activity. Computer web logs are a recorded history of the access of a web page – in this case, any of the ecozone and biodiversity issue pages or individual research proposals. With this data, it was possible to determine how often any of these pages had been edited or visited, and whether those pages had been accessed by the author of that page or by another student. Since I was interested in knowing whether students were using the wiki pages as a resource for their inquiry project, I looked only at the web logs that had recorded activity of a student editing his or her own research proposal.

The web log data was extensive as it recorded every instance of a student accessing any wiki page. As a result, I restricted my analysis to examine student activity during a five-week time frame extending from the date the research proposal was...
assigned until the due date. The students continued to access the wiki for another several weeks, during which time the web log became increasingly voluminous. Nevertheless, this defined portion of the web log data provided a sufficient slice of student activity from which I could draw inferences about their patterns of access of the various pages within the knowledge base.

Student activity from the web log data was measured in terms of their interactions during a “session”. A session is a period of time during which a student accessed a section of the biodiversity wiki site, either from school or from home. Every time a student visited a resource page, the web log recorded the page ID, location, time and author. Sessions are defined by the length of time between page visits that are from the same ISP (Internet Service Provider) address. When 60 or more minutes of inactivity passed between page visits, the next visit was then considered the start of another session. The notion of a session was necessary in order to differentiate between students’ editing efforts. Table 12 shows the different variables that were recorded and used for the analysis of the web log data.

Table 12

<table>
<thead>
<tr>
<th>Variables in Computer Web Log Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web Log Variable</td>
</tr>
<tr>
<td>Research Proposals edited:</td>
</tr>
<tr>
<td>Biodiversity Issue pages read (Self):</td>
</tr>
<tr>
<td>Biodiversity Issue pages read (Peer):</td>
</tr>
<tr>
<td>Ecozone pages read (Self):</td>
</tr>
</tbody>
</table>
A review of the wiki web logs revealed that students were visiting their peers’ resource pages (Ecozones and Biodiversity Issues) more often than their own pages during a session of editing their research proposal. Altogether, there were 72 recorded sessions in which a student made an edit to his or her own research proposal. In 71 of those sessions, the student visited a Biodiversity Issue page authored by a peer, and in 48 of those sessions, they visited their own Biodiversity Issue page (see Figure 33). Students also read their peers’ Ecozone pages more frequently than their own: in 61 of the 72 sessions, a student visited a peer’s Ecozone page, and in 26 sessions they visited their own Ecozone page (see Figure 34, next page).

Figure 33. Biodiversity Issue pages (peer and self) accessed during research proposal editing sessions.
The examination of the web log data helps confirm that students were indeed using pages from the community knowledge base that were constructed by their peers. While more analyses could be designed that uses web log data to ask specific questions about patterns of access of the wiki pages, this was not necessary for the current study. However, the patterns reported here offer some encouraging evidence that students were using their community knowledge base in its full capacity as a resource for their inquiry activities. They also point to new technology features that can inform the design of new diagnostic and analytic tools for future KCI studies.

5.4.4 Addressing curriculum content expectations

Unlike the first iteration, where teachers chose not to assess the students’ disease pages, teachers in this iteration did elect to evaluate the Ecozone pages. Overall, the students received high scores for their Ecozone pages ($M = 88.03, SD = 8.67$). The histogram in Figure 35 displays the final grades awarded to the Ecozone pages. All three

![Figure 34. Ecozone pages (peer and self) accessed during research proposal editing sessions.](image)
teachers were impressed with students’ work, particularly with the detail provided about the biological organization of the ecozone.

*Figure 35.* Ecozone page final grades.

Rather than grading the Ecozone pages holistically, the grades were determined using a rubric that evaluated six different aspects of the Ecozone page: (i) Completion & accuracy, (ii) Organization, (iii) Overall quality, (iv) Links & sources cited, (v) Value of contribution, and (vi) Written communication. Figure 36 displays an overview of ecozone page scores in each of the six categories. As the chart shows, the groups had high scores in each category, particularly in the categories of Completion & accuracy and Organization.
As in the first design cycle, I compared students’ final exam scores with those from the previous two years. To minimize the effects of different teaching styles, I once again used only classes taught by Erin for each of the three years ($n = 119$). Levene’s test for homogeneity of variances was conducted and was found nonsignificant $p = .529$. A one-way ANOVA revealed the average biodiversity score was different across the three years, $F(2, 116) = 7.61, p = 0.001$. The Tukey multiple comparisons performed at the 0.05 significance level found the mean score for the intervention year ($M = 91.92, SD = 8.06$) to be significantly higher than that for Year 1 ($M = 85.08, SD = 9.48$) and Year 2 ($M = 85.32, SD = 7.24$). The mean grades for Year 1 and Year 2 were not significantly different from each other. Thus, students in the intervention year significantly improved in their performance on the biodiversity section of the final exam, compared with students in the previous two years who were taught with the regular biodiversity unit. Figures 37 shows a boxplot of the exam scores for the biodiversity section of the exam across the three years.

Figure 36. Ecozone page scores per rubric category.
To determine if there was a significant difference on the rest of the exam (i.e., with the biodiversity section excluded), the same test was repeated. The results of the second ANOVA found no significant difference between scores across the three years, $F(2, 116 = 2.35, p = .129$. Thus, across the three years students had consistent grades in the non-intervention portion of the final exam. Figures 38 shows a boxplot of the exam scores for the rest of the exam across the three years.

Figure 38. Boxplots for rest of biodiversity exam across three years.
We were also interested to know what relationship, if any, existed between collaboration and student achievement. To determine this, a Pearson’s correlation coefficient was calculated between the Ecozone groups’ collaboration scores and the Ecozone groups’ mean scores on the biodiversity section of the final exam. The results of the Pearson correlation revealed a moderately strong relationship between these two variables, \( r(29) = .65, p = <.000 \) (see Figure 39, below). For these data, the mean collaboration score was 2.03 (\( SD = .41 \)), and the group mean exam score was 80.43 (\( SD = 6.42 \)). The scatterplot in Figure 39 depicts the linear nature of the correlation. Thus, the mean exam score for any given Ecozone group correlated positively with the degree of collaboration within that group. This analysis shows that student achievement can be seen to correlate with their group’s level of collaboration, and provides support for the KCI claim that collaborative knowledge construction promotes deeper learning.

![Figure 39](image)

*Figure 39.* Relationship between Ecozone group collaboration score and Ecozone group mean exam score.
5.5 Lessons Learned from Design Cycle 2

The second KCI curriculum had a number of design improvements over the first implementation. First, the longer duration of the curriculum (extended from two weeks to twelve), allowed community interests to emerge, which came to be reflected within the knowledge base. In addition, the inquiry activity (i.e., the research proposal) required students to engage much more deeply with their peers’ resource pages. Despite these improvements, however, there were still a number of challenges in the design and enactment of the curriculum. As in the previous chapter, these are described in terms of the lessons learned, which may serve to guide revisions to the model itself, to the co-design process, and to the scaffolding technologies employed.

5.5.1 Lesson 1

*There was too much emphasis on collaborative knowledge construction.*

In this second KCI curriculum, students became overwhelmed with the amount of wiki editing that they were required to do. This may have been a consequence of the longer duration of the curriculum, which encompassed a fairly substantial scope of content. Perhaps the design team overestimated how much the student groups could achieve, in terms of the specific details they requested for the Ecozone and Biodiversity Issues pages. From informal comments made by students, as well as comments made on the interviews, the students felt there was too much content that needed to be generated for their community knowledge base. The open-ended aspect of the wiki assignment may also have caused some confusion about “how much is enough.” Since there were no strict length restrictions on the Ecozone or Biodiversity Issue pages, some students were
concerned that their pages weren’t long enough relative to their peers. One student explained her perspective as follows:

And it was hard because there were no set guidelines – so you always felt bad about your project because there was always somebody who was better than you. Some people were, like, their projects were 15 pages long. And then you looked at yours and it was maybe like 5 or 10, and you were like, oh my gosh! (Jenny)

The heavy emphasis on the collaborative knowledge construction phase also meant that there was less time for students to develop their individual research proposals. Ideally, students would have received feedback – either from the teacher or from their peers – before their proposals were due. In addition, since the research proposals were assigned towards the end of the curriculum unit (which also happened be the end of the fall term), the students had become anxious about preparing for their mid-term exams. Introducing the inquiry assignment earlier would have not only given the students more time to work on the assignment, but they would also have been able to develop their Ecozone and Biodiversity Issue pages while reflecting on their inquiry assignment.

5.5.2 Lesson 2

*KCI needs to be more integrated into the existing curriculum.*

Since the teachers attended all the co-design meetings and contributed heavily to the design process, the KCI curriculum was a very good fit for their classrooms. However, even though the KCI activities were compatible, they were still disconnected from the rest of the curriculum (i.e., the non-KCI curriculum) that students were working in tandem with the KCI activities. Despite its ecological validity, the KCI unit was still seen as something novel in the classroom. A more seamless integration with the existing curriculum would have downplayed the “research experiment” aspect of the KCI
activities, and perhaps extend the nascent learning community past the boundaries of the research investigation.

5.5.3 Lesson 3

The inquiry activity should be collaborative.

This lesson is one where there may be some disagreement amongst the members of the co-design team. Because the KCI activities covered such a large portion of the school science curriculum, the teachers felt strongly that there should be an individual evaluation of achievement, which was underscored by the strong culture of grades and assessments in the school (which are seen as a top priority by students and parents). This illustrates an aspect in which co-design can be challenging, since such strongly held values must be allowed into the final product. Thus, researchers may not be able to completely dictate the design of their own research materials.

In our case, we were on new ground with regard to the design of such a substantive knowledge community curriculum. We wanted to listen to the teachers, and ultimately reached an agreement for the design of the inquiry activity. However, there was a clear sense of “falling back” to more conventional approaches, which resulted in losing some aspect of the community and exchange we desired to establish. In future iterations, it is hoped that we can find some balance of individual achievements and collaborative inquiry. Placing such evaluative weight on an individual assignment gives the wrong message in a collaborative learning model, and separates the students from their peers just when they were learning the importance of working together.
5.5.4 Lesson 4

The resources found by students should be added into the community as part of the knowledge base.

Throughout the collaborative knowledge building phase, we were aware that students were finding excellent resources on the Internet, which they used to create their Ecozone pages, and also used as references for their Biodiversity Issue pages and research proposals. It occurred to us that such resources ought to be added to the knowledge base, with contextual annotations and keyword tags, so that students could experience the benefits of their community when finding quality, relevant resources. In future iterations of KCI, we would like to design a new technology infrastructure for supporting the knowledge base, which would allow students to upload links and PDF files, and then tag those resources with keywords so they could quickly search through the growing resource base at any point in time. Indeed, it is not hard to imagine such resource bases persisting across multiple semesters, allowing teachers to revisit a curriculum design from one year to the next without completely flushing the contents of the community knowledge base.

5.5.5 Lesson 5

We need a greater level of specification and scripting in the collaborative knowledge construction and inquiry activities.

In the KCI unit, students did collaborate when constructing their Ecozone and Biodiversity Issue pages, however, there was significant variation with respect to their participation levels. The KCI activities included web forms for scaffolding students to include the required science content, but their engagement and interactions were loosely
defined, and completely unscaffolded. Students were simply instructed to “collaborate” with their peers, with little instruction as to how they should go about collaborating when constructing their community knowledge base.

One of the advantages of a wiki, and of Web 2.0 in general, is the capacity for supporting free-forming communities. Although a lack of constraints is suggestive of what happens “out there” in the real world, students would likely have benefited from supports for guiding their collaborative interactions. In particular, the co-authoring aspect of creating wiki documents was entirely new to students, and they were unsure about the norms and procedures for working with their peers’ text. Such open forms of collaboration are atypical of most classrooms, where students are accustomed to individualized activity structures and assessments. Even if students maintained a level of open ended collaboration, it would be helpful to provide them with specific mechanisms or tools for controlling their workflow – such as task lists, problem tracking or productivity software.

In general, it was felt by the co-design team that we needed better support for students’ collaborative process, such as guidelines and specific roles for individual students. This might be a topic for research in subsequent iterations. One topic that could be of interest in future research are specific collaboration models. There is an established research community that investigates computer supported collaborative learning (CSCL), and the developments within this community would be of interest to a pedagogical model where scripted inquiry activities are integrated within a knowledge community.
5.6 Summary

While this second KCI curriculum involved a higher level of complexity, content and curriculum time, it was still remarkably smooth in its operation. Teachers and students were clear on most aspects of the curriculum, with the exception of some of the issues previously discussed. Students were engaged in creating their knowledge resources, and were adept at making use of them during the inquiry activity. This was not the same student cohort that participated in the physiology unit, so there was no sense of transfer involved. This is attributed to the effective enactment to the co-design process, to the structure of KCI, and to the use of wiki scaffolds that ensured all content and materials were developed according to plan. As intended, KCI was able to support teachers as they adopted a substantive new model of curriculum and assessment that involved the use of technology scripts.

Co-design became a higher stakes process for teachers and researchers alike, as they were not designing a simple two week lesson with well defined parameters and scripts, but a much longer running sequence of student collaborations with open ended inquiry products. From the outset, we sensed that we were designing something ambitious given the preceding iteration, but the scope of activities felt suitable to the model. Still, there were ongoing issues of time management, assessment, and the pressure of deviating from conventional curriculum and assessment models. As the research in KCI moves forward, it is expected that the relationship with teachers and school science departments will be increasingly important, with a need for deep discussions about the role of the research within the school community.
CHAPTER 6: DISCUSSION AND CONCLUSIONS

6.1 Chapter Overview

This thesis reported on two cycles of planning, design and enactment of secondary science curricula based on the Knowledge Community and Inquiry model. The project was a large effort, involving contributions from several teachers, two technology developers, the research supervisor and myself. The outcome of this effort was two curriculum units that contained a high level of cooperative learning activity – creating shared knowledge artifacts and then using those artifacts within inquiry projects. The first iteration was relatively short – only two weeks, with five classroom sessions devoted to time on task. The second iteration was more substantive – a three month unit with approximately 50% of class days devoted to time on task. Both units were responsible for covering the required science content.

It is important to note that these were not supplemental lessons, but complete instructional units. While supplemental activities are valuable, the ultimate goal of KCI is to offer a replacement curriculum for instruction in secondary science (Slotta, 2007). Taking the first strides toward that end, these two implementations served to establish some basic understanding about the KCI model: what it takes to succeed, how it works with students, and what it might require to go further.

This chapter discusses the findings in regard to the three research questions presented in Chapter 1, as well as some broader implications of this work for the knowledge community approach in secondary science. I offer some comments on the co-design methodology that was used throughout the study, and comment on patterns of
collaboration that emerged within student groups. Finally, I discuss future directions for research on the KCI model, and offer some concluding thoughts.

6.2 Addressing the Research Questions

This section discusses questions that guided this research with respect to the outcomes of the study and their broader implications for learning sciences research.

*Question 1: What design elements are important for a secondary science curriculum that is consistent with the theoretical commitments of the KCI model?*

Chapters 4 and 5 present four key design principles: (i) to engage students in collaboratively constructing a shared knowledge base, (ii) to include inquiry activities that require students to make use of their knowledge base; (iii) to ensure that inquiry activities reflect any themes that emerge within the shared knowledge base; and (iv) to explicitly target a set of science content goals. While these design principles provided a sufficient level of specificity to guide the co-design team in creating their materials, they were, at the outset of this study, relatively vague in terms of any specific design recommendations. Based on the outcome of each design cycle, I was able to make specific recommendations about each of the four principles. In design cycle 1 (Chapter 4), these recommendations directly informed the design process for the second iteration. In design cycle 2 (Chapter 5), they serve as a set of final recommendations of this dissertation that might guide subsequent implementations of KCI.

One of the more challenging design aspects of KCI was the need for sensitivity to the emerging interests of the community, and how to weave those into the design of the inquiry assignment. Since community interests develop over time, any inquiry task must
be at least partially designed after the community has become established. This requires some careful balancing, since there is no guarantee that community interests will be aligned with the curriculum content expectations. Moreover, the community’s interests, as reflected in the inquiry assignment, must also be compatible with conventional measures of assessment. As a result of these challenges, designing curricula based on the KCI model will require ongoing refinement and adjustment at all stages of the design process.

Like many other innovations, the scaffolds in KCI play a particularly important role. On a social level, the wiki enabled the students to collaborate in a way they had never done before – by contributing to and editing a shared document. In this study, technology scaffolds guided students to include specific physiology and biodiversity content in their resource pages. The content was carefully selected by the researchers and teachers to ensure that they meet the Ministry of Ontario curriculum expectations, and to ensure that students were working with concepts and ideas that were complex enough to support deep inquiry. Again, the teachers’ involvement was paramount since the effectiveness of curriculum scaffolds will be dependent upon teachers’ enactment of the curriculum (McNeill & Krajcik, 2009).

The design and sequencing of collaboration scripts was a key consideration in both KCI curriculum cycles. Early in the physiology and biodiversity units, students needed to construct a knowledge base that was comprehensive enough to allow them to succeed in the inquiry task. The smaller knowledge elements within the curriculum (e.g., the different diseases of the human body, the different ecozones of Canada) needed to be distributed across class sections so students could gain expertise in a specific content
area. The co-design team then had to develop an inquiry activity that required students to work with the different knowledge elements, and provide the opportunity to synthesize the material and make connections between ideas.

Although the sequencing of activities in this study engaged students in the construction of a knowledge base before they began the inquiry assignment (i.e., the challenge cases and the research proposal), it remains an open question whether it could be helpful for students to start thinking about their inquiry assignment from the outset. This might require some adjustments to the inquiry task, but it would give students more time to consider the nature of scientific claims and practices.

Finally, while not a design feature of the KCI model, the co-design process was essential for ensuring that the teachers could enact the unit autonomously, and that the KCI activities satisfied the curriculum content expectations. Although it was often challenging to coordinate meetings, when the co-design team did get together, we were generally highly productive. My own experiences of co-design are similar to those reported by Penuel, Roschelle and Shechtman (2007), where researchers and teachers gradually come to understand each other’s needs and perspectives as the study progresses. Co-design was also important for ensuring that the teacher’s didn’t stray off course while they enacted the curriculum. Because they were so deeply involved with the design process, the KCI activities were already familiar to them.

Nevertheless, as is typical in any secondary school classroom, circumstances change and problems arise that might thwart teachers’ efforts from enacting the curriculum as planned. Technology glitches, a school assembly, or teacher absence can all interfere with planned activity structures. Although it can be difficult to anticipate the
constraints a teacher might face, having a co-designed “Plan B” at hand could help salvage an otherwise compromised curriculum innovation. Such additional resources may help avoid the challenges identified by Mintrop (2004) and Rico and Shulman (2004), where teachers subordinated the innovation to the regular instruction, or omitted aspects of the curriculum altogether, resulting in what Brown and Campione (1996) refer to as a “lethal mutation” (p. 292).

Essentially, when planning and co-designing a curriculum of such scope, it is vital to remain pragmatic in terms of what can be achieved, and what actions can be taken to salvage various aspects at any point in time. It is also critical to have the teacher’s fullest commitment and deep identification with the innovative method.

**Question 2: What forms of student collaboration and inquiry are supported by a KCI curriculum?**

In both the first and second design cycles, the KCI curriculum engaged over 100 students in collaboratively constructing a community knowledge base. Students contributed to the creation of shared artifacts with their peers both within and across multiple sections of a secondary school biology course. The analysis of student editing during this collaborative knowledge construction phase revealed that every student was actively involved in constructing his or her resource page, and that there indeed was collaboration within all the groups. In previous research on wiki editing, Lih (2004) measured the quality of Wikipedia articles according to “rigor” (number of wiki edits) and “diversity” (number of unique editors). Based on such a measure, the students in this study produced considerably high quality knowledge artifacts.
The process of constructing a shared knowledge base supports the development of a number of critical 21st century literacy skills. For example, during the creation of their resource pages, students were required to locate and critique both print and Internet-based materials. Once a resource was found, the students had to identify relevant and credible information that then had to be synthesized into their resource page, and linked to any related content within the knowledge base. Students were also required to identify keyword search tags for their pages to facilitate searching within the wiki. Thus, the design of supports for resource searching, critiquing and synthesizing was instrumental in making the wiki activity a valuable learning experience with relevance to several important knowledge construction and collaboration skills.

In both KCI implementations, students were responsible for including specific biology content. In the physiology unit, this included the conditions and regulations of human diseases and disorders; in the biodiversity unit, this included the archae bacteria, eubacteria and protista of ecozones and biomes. When searching for resources, the act of reading and making sense of a text involves more than just scanning the article’s contents, students also need to engage in reflection and articulation, which are important for learning (Brown & Campione, 1996). Sharing their resources in the wiki further helped students to engage with content, as they frequently had to justify their research findings to their peers.

An important lifelong knowledge skill is the capacity to work closely with peers and collaborators. In this study, the collaborative construction of wiki pages scaffolded students to critique and improve their peers’ work. This involved more than just providing feedback, as students often took up a half-written paragraph where a peer had
left off, correcting or improving upon the sentences. This kind of exchange required
students to carefully consider the impact of their actions before they went ahead and
made changes. Moreover, it repositioned ownership of the artifacts from being
individually owned to belonging to the wider class community. Editing and commenting
on peers’ work in this way was a new experience for the students, but the result was a
comprehensive knowledge base that was a genuine collaborative effort.

In terms of inquiry, it is recognized that there is likely a much wider range of
possible activities that could be included within KCI, in addition to the challenge cases
and research proposals used in this study. Many forms of inquiry have been studied
within the learning sciences (as reviewed in Chapter 2), and many of them could
potentially be woven into the activity designs within KCI. In future implementations, it is
possible that students could engage in concept mapping, simulations, models and even
the collection and analysis of observational data. All such inquiry elements could be
supported, but it remains to be seen how they would be integrated into KCI. In the
present research, the design team was satisfied with the challenge cases, which were a
creative way to engage students in re-describing the deep structure of a human disease.
The research proposals offered a challenging design project where students had to make
connections across the wider curriculum topic. In this way, the inquiry assignment
challenged students to apply and extend their understanding of science concepts from
within their community knowledge base.

Question 3: How does KCI support students in meeting the content learning expectations,
as well as in developing knowledge skills?
Activities in KCI are designed around specific disciplinary learning goals. By connecting the science topics into a meaningful large-scale knowledge base, and giving students a shared responsibility for developing that knowledge base, a comprehensive (e.g., all Canadian ecozones) content domain can be actively explored by the community, with each individual member developing a sense of shared ownership of the overall knowledge base. Carefully designed inquiry tasks are connected with the evolving content of the knowledge base, making it possible to focus students’ attention on specific science content, and support their development of scientific understanding within an authentic inquiry task (e.g., crafting a challenge case or research proposal).

Both KCI curricula met their content expectations within a challenging grade-ten biology course. Indeed, one of the teachers remarked that she believed that students went beyond what they would have learned within the regular version of the curriculum. The teachers’ continued involvement in the design process ensured that early design decisions and later modifications did not interfere with delivering the mandated subject material. In addition, certain activities were developed with assessment requirements in mind. For example, in the second design cycle, the inquiry assignment (i.e., the research proposals) was an individual rather than a collaborative effort because the curriculum standards required that each student receive an individual grade.

In KCI, technology scaffolds are developed in close collaboration with teachers to help guide student attention to the required content elements. These scaffolds (which in this study took the form of wiki templates with headers and instructional prompts) focused students’ attention on specific science topics, and ensured that the products of their collaborations could be used in a subsequent inquiry task. In the second design
cycle, a rubric for the Ecozone pages (created with input from students) provided another important reference for students, helping them understand what elements should be included and how they would be assessed. The wiki gave the teachers access to student work in context, and provided them with an ongoing view of students’ progress. For the researchers, the wiki preserved an invaluable trace of all editing revisions (including what changes were made, and by whom). As well, the preserved content in a wiki allows teachers to potentially re-use and extend the resource base for future course offerings. One of the teacher participants from this study has already used the physiology and biodiversity knowledge base in her later classes, independent of any research involvement.

Perhaps the most important way in which KCI helps students develop a deep understanding of science topics and lifelong knowledge skills is through its epistemological positioning, where students come to understand science learning as more than a simple digestion of formulas and problem solving strategies. KCI allows them to see science learning as a process of collaboration, co-construction of shared resources, and meaningful application of ideas for purposes of inquiry. Through such deeply social, contextualized learning, students will come to understand science class as more than just a challenging intellectual obligation, but as a personally relevant exposure to a way of knowing and learning.

6.3 Participation Patterns in Collaborative Groups

One topic that is of interest to this research, but not addressed explicitly by the analyses of KCI enactment and student learning, is the characteristic patterns of participation within collaborating groups. Early on in the first iteration, it appeared that
some groups had distinct patterns of engagement: In one group, perhaps one or two students would dominate the editing, while in another, the group might act with a remarkable level of coordination and control. Although patterns of student collaboration were not central to this research, the fine-grain analysis of wiki edits provided some insight into group collaboration patterns. Since collaboration is a foundation for many learning approaches, and since little is known about how student interact in a wiki-based collaboration task, I performed some initial explorations of participation patterns in the second implementation of the KCI curriculum.

First, I was interested to know the overall balance of types of edits and interactions. Obviously, not all edits could be “peer embedded” – if only because someone had to be the first to contribute. The question then arises: What is the appropriate balance of interactions in a collaborative wiki task? A comprehensive response to this question was not an objective of this study. But nevertheless, this work did provide a reasonable data set to examine – one that provided an example of substantive wiki contributions to a resource base by more than 100 students. As such, I conducted a formative analysis of how students were interacting during the construction of their wiki pages.

Figure 40 shows a representation of an “interaction index” with four levels of engagement that are based on the transaction analysis presented in Chapter 5. The first layer, “Add new content”, include transactions where students added new content to a wiki page without affecting the text of their peers. As discussed previously, these kinds of contributions make up almost half (43.67%) of all transactions contributed. The second layer, “Edit own content” includes transactions where a student made revisions to their
own text. These kinds of contributions make up just over one-quarter (25.48%) of all transactions. The third layer, “Add to peers’ content” represents transactions where a student added to pre-existing text that was contributed by a peer. These types of contributions make up 17.44% of contributed transactions. Finally, the top fourth layer “Edit peer” is transactions where a student directly altered their peers’ text; these account for 13.42% of transactions.

![Diagram showing the interaction index based on students' wiki transactions during collaborative knowledge construction.](image)

*Figure 40.* “Interaction index” based students’ wiki transactions during collaborative knowledge construction.

Such an index may be helpful for curriculum designers for guiding their understanding about what might be the right blend of interactions. Clearly, to populate a wiki, a certain level of new content is required. As the wiki page matures and the article develops, there is more opportunity to interact with peers’ text. The timing of contributions also plays a role. Students who contribute later in the page development process will have less groundwork to cover than students who contributed earlier. Thus, we can begin to see the intricacies involved in analyzing a co-authored document, as well as the complexity of characterizing productive peer collaborations. More work is required
to examine the temporal patterns of interactions, and where student effort would be most profitable during collaborative knowledge construction.

Participation profiles might help explain how students collaborate on a wiki editing task. Here, I describe a few profiles that were suggested within some of the groups in this study. While it was possible to infer these patterns from the relative weights of different types of contributions, these are offered here as a discussion of how we might interpret the characteristics of students’ interaction patterns within their groups. More detailed analyses would need to be performed to determine a set of distinct profiles, and then to compare each group with the taxonomy to see where each one fit. The following profiles emerged from the examinations of patterns of editing and interaction in this study. This is not an exhaustive list, and the scenarios described below are not suggested to be mutually exclusive.

**The predominate contributor**

In this scenario, one of the group members dominates the construction of the wiki page, contributing the majority of the content and deciding how the page should be structured. When another group member does contribute content, this student often deletes it, moves it, or leaves explicit instructions on how it should be changed. If some of their text is edited, they restore it to its previous state. After a while, the other group members come to expect such control, perhaps believing that their overall grade will be higher as a result.

The pattern of data that would be expected here (and was evident in several of the groups in this study) is that a single group member would have a higher total of contributed words, and a much higher ratio of “Add new content” than others. In fact, the
predominant contributor in such groups typically shows up as outweighing his or her teammates in nearly every category of interaction: formatting, editing peers’ content and adding new text. Predominant contributor groups may achieve high quality outputs, but it seems clear that nobody in such a group derives the benefits of collaboration.

From the data, such a group would have a student who contributed a significantly higher number of overall transactions (both formatting and non-formatting), such as in the Taiga Shield group in this study. This group had only two group members, with a combined transaction count of 62. One of these two students contributed 50 transactions (81%), while the second contributed only 12 (19%). Not surprisingly, this group had high variance on both their participation score (.45) and their peer edits score (0.07). Interviews with students Jennifer and Will provide insight as to why this may have happened:

I find it difficult to get along with people and accept their ideas as well as adding in mine. I’m a control freak. And I find that I have a very particular style of writing, and when [the resource page] doesn’t conform to that it’s very hard for me not to go in and just rewrite the entire thing. (Jennifer, Taiga Shield group)

It was kind of hard working together because my partner didn’t really do much, so I pretty much ended up doing most of the site. Plus, since the teachers could track your changes, there was real pressure to have your name be associated with big blocks of changed text and added information and everything. When you’re writing your own self-contained assignment, then you don’t really need to worry about that. (Will, Northwest Atlantic group)

*The technical editor*

In this scenario, one student enters the group effort with technical expertise that is greater than his or her peers. It becomes quickly evident amongst all group members that this student can help the overall wiki page by formatting all the content, adding images, links and other media such as video. The student thus assumes the role of technical
editor, and takes on responsibility for the formatting and aesthetics of the wiki page. As a result, other students within the group may assume greater levels of responsibility for authoring the text – either contributing the text directly within the wiki (and waiting for the technical editor to come and fix it up), or simply emailing it to the editor (i.e., in a Microsoft Word document) who then adds it for them.

The student who assumes the role of technical editor may end up contributing little or no content to the final resource page. For example, one of the students in the Boreal Cordillera group, Melissa, contributed a total of 115 transactions to her resource page. Of these, 82 (71%) were formatting transactions involving edits such as image resizing, bolding or italicizing text, and adding a table of contents. This finding is reflected in the high variance of that group’s participation quotient (0.51). Students who participated in such groups revealed the following:

I was fortunate to have a partner who was good with technology, because I’m really, really not. So I sat down at my computer and I worked for three or four hours, and I put in all the information, typed it all up and then I sent an email to my partner and said heads up, I’ve done pretty much all the information stuff, do you want to go and format it and put hyperlinks and headings where they need to be put. And I trusted her to know where those things needed to go. And she respected my content. (Melissa, Boreal Cordillera group)

I know like, for me, the thing that took the most time was the pictures and adding the captions and then fitting them using the Photoshop, so the picture sizes wouldn’t like overlap with the text. That took me forever. But nobody else in my group could use Photoshop, so I just sort of took on that job. (Ravi, Taiga Biome)

**Divide and conquer**

Students in the Divide and Conquer scenario each take responsibility for a certain section of the resource page. To the detriment of the collaboration goal, they work independently, contributing their respective sections once they are completed. Some students do their authoring within the wiki, while others use a word processing program
and contribute their content later. Their efforts are typically coordinated with a student meeting, where they deliberately develop a strategy that will let them focus their energy on producing quality sections to contribute to the resource page. More often than not, students edit their own text rather than that of their peers. After each student has contributed his or her final section, there is typically a round of editing and improvement, where any sections that are seen to be incomplete or inconsistent are adjusted.

The pattern one might expect to see here is low variance in a group’s participation and peer editing scores, such as the Hudson Plains and Arctic Basin groups. In this group participation and peer editing scores were .09 and .00, respectively. The following excerpts from student interviews provide insight into their group’s participation:

Content wise I didn’t really communicate with anyone outside of the class. I would talk to my partner and we did what we had to do, and kind of left it for anyone else who felt they had something pressing to add, they could add it. (Courtney, Arctic Basin group)

I thought the wiki was mostly individual. Nobody, I thought, really helped each other much. We kind of just split the sections up and then we said ok, we should finish it by this time and then we can just edit each others and add whatever we thought was good. (Janet, Hudson Plains group)

**Symmetric collaboration**

In the collaborative scenario, which is the ideal scenario, students contribute equitably to the wiki – adding new content, editing existing content and contributing to the organization of the resource page. Each student assumes some responsibility for the overall quality of the resource page, noting areas that could be improved and making adjustments accordingly. Students may not feel they have complete ownership of the page, but they all participate in developing the ideas on the wiki page. The pattern of data one could expect here was not uncommon in this study: a veritable jumble of edits from
all students all over the page, more or less in accordance with the interaction index shown previously. Groups that were more collaborative frequently communicated amongst themselves, often through e-mail, but sometimes through leaving comments at the bottom of their wiki page (e.g., “we still need to add parts about the bacteria on the seafloor”).

The participation of the Antarctic Tundra group was suggestive of this kind of “symmetric” collaboration: Each group member’s contribution fell within 16% - 28% of all total transactions (including formatting edits). The Antarctic Tundra group also had low variance scores for both participation (.06) and peer edits (.05), and an overall collaboration score of 2.50 (out of a possible 3). The reasons for such participation may be explained by the following:

I don’t really have a problem with people editing my work. I find that usually if people make a change it’s for the better. When editing other people’s work I normally didn’t go so much for the fact-based editing as for the writing, and so I would usually make a new paragraph and take all of the facts from their old paragraph and all the ideas and express them more fluently. I found, and maybe it was just the page I was editing was really good, I found that they had all of the facts pretty well done. (Anita, Antarctic Tundra group)

Well, I think that was a good idea to work with partners, just because our group was responsible and tried to do an equal amount of work. But I know in one group there were complaints because some people would be doing everything and then the other person wouldn’t be caring at all. But I saw people making good improvements on my page, or adding stuff. I don’t think anyone took away anybody’s work, or something like that. If my work was wrong and someone made it better, then it’s better. (Michael, Pacific Marine group)

It is interesting to think about how one could support such collaborative processes, where all members contribute ideas and provide feedback to peers within the group. In future work, we might try to develop more explicit “scripts” where members of the group depend on one another, pass off ideas explicitly, and are prompted to reflect on how their group is progressing. A specific tool or scaffold for groups to use in
coordinating their authoring efforts would also be desirable, perhaps informed by a discussion area where students could leave comments, ask questions, and negotiate content.

Indeed, we might consider what kinds of pedagogical supports or real-time feedback could help respond to some of the more aberrant groups – particularly “divide and conquer” and “predominate contributor”, where the students are not gaining the pedagogical benefits from their collaborations. Perhaps the teacher could play a role here – receiving a “flag” that was automatically generated when patterns of participation deviate from a certain characteristic of an index or model. Real time feedback from intelligent agents (such as an intelligent tutoring system) is also possible, if the technology framework was designed to include some data mining for the patterns of edits occurring within the group. It is not difficult to imagine a technology prompt sent to the teacher or the students that simply said: “There is evidence that this group is not collaborating deeply. They appear to be following a divide and conquer strategy. Perhaps they can find ways to help on one another’s sections.” Such work remains a possible area of future research for the wider research community. Although the students in this study were working in a wiki, the participation profiles described in this section could easily extend to other kinds of collaborative learning tasks and environments.

6.4 Implications for the Knowledge Community Approach

The fundamental goal of the KCI model is to help scaffold the knowledge community approach, particularly in secondary science classrooms. In both design studies reported here, the students were engaged in collaborative knowledge construction, and used their community knowledge base in meaningful ways for an inquiry task. The
inquiry was designed so that it addressed the science content requirements, and the technology environment served to scaffold students, focusing their attention on the relevant science domain and inquiry elements. As a result, students demonstrated learning gains when compared to their predecessors from previous years on the physiology and biodiversity sections of their final biology exam. They also demonstrated a deep understanding of science content within their created knowledge artifacts, and applied that knowledge in their achievement of the inquiry goals.

Thus, KCI was a success in supporting new forms of collaborative learning and inquiry. But to what extent did it establish a knowledge community? This question is difficult to answer, in the sense that one could argue that there is always a knowledge community in any classroom, and that curricula that is based on KCI simply reinforces and enhances that community. It is probable, however, that adding a collaborative wiki activity is not enough to transform the learning in science classrooms. There is much yet to discover about how classrooms can be reoriented into a community of knowledge workers. In the following section, I explore the aspect of knowledge community in terms of the broader implications of this study for researchers and educators wishing to implement a community-oriented approach in secondary school science.

To begin, it is apparent that learning in a knowledge community involves more than simply participating in a series of highly collaborative activities. The flow of activities in a knowledge community is cyclical, and influenced by ongoing cycles of knowledge construction and inquiry. There is no definitive beginning or end to the inquiry process, and any community-oriented model needs to reflect the interconnectedness of the activity structure. For example, in this study it may have been
preferable to have students work on their knowledge resource and inquiry assignments simultaneously, with each informing the other as students work through the curriculum unit. As a result, a more realistic representation of KCI may be the revised flow diagram shown in Figure 41.

![Figure 41. Potential revision of flow diagram for KCI model.](image)

There is a strong social component that also needs to be addressed if classrooms are to function as knowledge communities. KCI and other community models, such as Progressive Inquiry (Hakkarainen, 2009) are currently in active development, and are exploring the important social dimensions that play a critical role in fostering community-oriented classrooms. In particular, there are deep epistemological commitments held by students and teachers alike about the nature of learning, and of school learning in particular. As such, any serious transformation of learning within classrooms will entail an explicit metacognitive and epistemological treatment. This study did not pursue these elements, but informal comments from teachers suggested that they were rethinking how they engaged their students in learning.
Students will also need to rethink learning, and how a learning community differs from a traditional classroom. There is certain level of public exposure of ideas when learning within a community. Even if students’ work is not available to the general public, they must still share their work with what could be the most critical audience of all – their peers. Learning within a community means taking risks and a willingness to make mistakes, something that students will not necessarily feel comfortable doing. The notion of working for the benefit of the wider community, rather than for themselves, runs counter to deeply engrained school culture (Scardamalia & Bereiter, 2003; 2006). However, given the opportunity (and potentially nurtured by a meta-level discussion) students can warm up to the idea of sharing their work openly with their peers (Bryant, Forte, & Bruckman, 2005). Indeed, it is conceivable that students are entering school with increasingly high expectations of social forms of knowledge, based on their frequent informal experiences on the Internet. This would be a hopeful phenomenon for pedagogical approaches like KCI.

Real knowledge communities tend to develop over a long period of time. The “citizens” within a community must learn about their peers and develop shared practices and patterns of discourse (Lave & Wenger, 1991; Brown & Campione, 1996). As a result, any notion of knowledge community within a classroom is highly ambitious in terms of such definitions. Even establishing a simplified notion of real community could require years of students working together as they go through consecutive grades. This is the much broader area of work that is being addressed by researchers who investigate such models. Pragmatically speaking, it will take the better part of a school year before students understand the norms and expectations of any community model. Students will
need explicit instructions for producing and working within a community, which will likely require a metacognitive dimension. Indeed, FCL (Brown & Campione, 1996) was historically conceived as a metacognitive treatment, with a strong focus on student reflections. In future implementations of KCI, researchers may want to consider incorporating students’ reflections into the curriculum.

Another important aspect of knowledge community models involves capturing students’ knowledge in assessments (for both formative and summative purposes). This is important for teachers, who will continue to be held accountable for learning expectations, and researchers, who need a robust way of documenting students’ collaborative processes, preferably in way that could be replicated by other researchers. One important contribution of this dissertation study was a specific method for coding collaboratively constructed knowledge artifacts (i.e., wiki pages). Analyses of computer-supported collaboration are of much interest to the learning sciences community, and I have presented the work here in conference symposia that were dedicated to the assessment of collaboratively constructed knowledge artifacts (Peters & Slotta, 2010a; 2010b). The whole notion of assessing collaboration needs to be revisited. In most classrooms, students’ success is judged relative to their peers: the worse their classmates perform, the better a student’s own performance looks in comparison. This approach, of course, runs counter to the ideas behind knowledge work, and would drive student epistemological beliefs in a counterproductive direction.

Despite the difficulty in achieving a knowledge community within a classroom, it is important that we take strides in this direction. Students must learn the new kinds of skills required for the 21st workplace, which include collaboration within social
networks, critique and improvement of ideas, and flexible use of a wide range of digital media. This means that new forms of learning will be required, as well as the development of new forms of instruction. Such efforts are already underway – the Assessment and Teaching of 21st Century Skills (ATCS, 2009), is operationalizing a 21st century skill set. These efforts are important because they support innovative approaches such as the KCI model that engages students as a learning community so they can develop critical knowledge skills.

How can we help teachers survive the transition from their previous “traditional approaches” to community-oriented approaches? While this question is not central to this dissertation, nor even KCI more broadly, it is important to note that all three teachers in this study had to be full, participating members in the co-design process. This entailed a good deal of learning on their part, even implicitly, about the nature of a knowledge community approach, and the required epistemological shifts. In general, a deeper understanding of teachers’ experience would help curriculum designers create learning activities that help them make such transitions. Understanding the teacher’s specific role within KCI would also be of great value: How are they interacting with students? What kinds of feedback did they provide, and under what circumstances was this feedback effective?

6.5 Closing Thoughts

This dissertation provides the first empirical study of the KCI model, which was developed to enable a knowledge community approach in secondary science in a way that is compatible with heavy content and assessment demands. KCI is a pragmatic model that aims to insert a level of cooperation and collaboration into science learning, giving
greater relevance to some of the inquiry techniques that have long been investigated by
science educators. The model opens doors to a wider research program investigating
student and teacher epistemologies, and the role of Web 2.0 technologies in transforming
our understanding of content and curriculum (Slotta, 2007; Peters & Slotta, 2008; 2010).
But the model cannot move forward without several cycles of implementation and
reflection on the outcomes. This dissertation provided the first such opportunity, and the
discussion above offers some insight for future efforts to revise and implement the model.

Through an intensive co-design process, the co-design team was able to establish
a successful research partnership with teachers, resulting in curriculum materials in which
the teachers had a strong sense of ownership. This kind of partnership can be seen as a
positive step towards the “hybrid culture” described by Bereiter (2002), in which
researchers and teachers rely on each other when working towards an educational
objective. It is not a goal of KCI that curriculum be designed in the context of a huge
collaborative effort. Indeed, the eventual aim is to provide a simplified point of entry for
science teachers and researchers, and to open up the knowledge community approach for
a wider community of participants. In this respect, the co-design approach cannot be
emphasized enough, and it is difficult to imagine coordinating such a complex
pedagogical design without a close working relationship with teachers in a supportive
school setting. In future work, the Knowledge Community and Inquiry model will
continue to be refined in terms of its theoretical conjectures about learning, its specific
design principles for collaboration and inquiry, and its scaffolding technology
frameworks for secondary school science.
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APPENDICES
## Appendix A: Physiology Exam Questions

<table>
<thead>
<tr>
<th>Year</th>
<th>Example Exam Question</th>
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| 2004 - 2005 | Read the above case study about Doug Dorval and Hooligan Creek. Use the evidence in the file to answer the following questions:  
1. Would the fingernail scrapings turn up any useful DNA evidence? Why or why not?  
2. What additional biological evidence might you wish to acquire from Doug Dorval’s body? How would it help you confirm your suspicions about his death? |
| 2005-2006   | The pancreas is a multi-purpose organ in the body. If the organelle responsible for picking up and transporting synthesized proteins had membrane damage resulting in inefficient transport of the products, what implications would this have for the Digestive System? |
| 2006-2007 (Intervention Year) | Diseases and disorders of human internal systems often demonstrate the interrelatedness of human physiology and biological processes. Explain what this statement means by citing a specific example from the research you conducted for this project. |
Appendix B: Biodiversity Issue Page

Fragmentation and Habitat Loss in the Boreal Forest

Short summary of issue

The Boreal Forests of Canada contain 35 percent of the world’s ancient forests. Sadly, these forests are being depleted by logging, hydroelectric development, and increased farming practices. 45 percent of the forest has been allocated to logging firms, and less than 4 percent is actually protected by the government. Off the large area that is used by logging companies, 90 percent of the ancient trees are clearcut.

Canada’s boreal forests are being destroyed to create building materials and other consumer products, such as office paper, books, toilet paper, and advertising catalogues or pamphlets. It is estimated that about 600,000 to 700,000 tons of “tissue” products are consumed every year in Canada (Greenpeace, 2007).

Canada’s Boreal forest is one of the most ecologically diverse regions in Canada, but due to habitat loss and fragmentation, this one day may no longer be the case.

Environmental concern

The destruction of the Boreal Forest has resulted in fragmentation into small, isolated pieces, and the loss of habitat for many species that rely on this ecozone for survival. Not only are many species influenced by this destruction of their habitat, this issue will affect climate change: the Boreal Forest is a huge carbon sink, taking in 30 to 100 times more carbon than agricultural crops for large amounts of time. Because more and more trees are being cut down, this sink is rapidly disappearing.
Appendix C: Biodiversity Issue Page Web Form and Template
Appendix D: Student Consent Form

To: Students of [Teacher’s name]
From: Vanessa Peters, Ph.D. Candidate
Subject: Letter of Consent to Participate in a Research Study

I am interested in conducting a research project in your school entitled: Knowledge Community and Inquiry in Secondary School Science. This project will investigate how technology can be used to help students learn science. Your science teacher and I will design activities that allow you to collaborate with your classmates in small groups or take part in whole class cooperative learning. 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 science teachers.

It is important you know that both your science teacher and the school principal have approved of this study. The research activities will involve only normal teaching practices. We will analyze the curriculum designs and observe students’ activities in the classroom. Occasionally, we will ask students to participating in a voluntary interview to gain insight into their experience of the curriculum

Because these science lessons will be part of your regularly scheduled science class, we do not require any additional effort on your part. Efforts will be made to ensure this research does not interfere with your regular learning and only improves you and your classmate’s 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 a brief interview. No one other than myself 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 research and you are free to withdraw from the study at any time.

If you or your parents/guardians have any questions about the study please feel free to contact me by phone: 416-978-2522, ext. 6310 or through email: vpeters@oise.utoronto.ca

Sincerely,

Vanessa L. Peters
Ph.D. Candidate
Dept. of Curriculum, Teaching and Learning, OISE/UT
I agree to participate in the research project outlined above. I understand I do not have to be a part of this study, and can withdraw my participation at any time.

________________________________
Print Name

________________________________
Signature  Date
Appendix E: Teacher Consent Form

To:       [Teacher’s Name]
From:     Vanessa Peters, Ph.D. Candidate
Subject:  Letter of Consent to Participate in a Research Study

I am interested in conducting a research project in your class entitled: *Knowledge Community and Inquiry in Secondary School Science*. As part of a research project, I am interested in how teachers can use technology to engage students in collaborative inquiry. Specifically, students would be participating in an activity that involves students collaborating with their classmates to create a wiki-based knowledge resource for use in later activities. 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 a new way of learning science that utilizes technology and aligns with new curriculum standards and conceptions of learning. Consenting students in your biology class would be participating in the study during regularly scheduled class time. 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, I might need to interview a student after school or during their 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, and for any reason.

Some of the things your students would do during the study are: learning about and using a wiki technology, engaging in discussions about biodiversity with their classmates, and participating in brief interviews with the researchers. All information collected during the study will be used for the purposes of data analysis. No one other than 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 participating in this study.

A copy of this consent form will be given to you for your reference. If interested, research results will be made available upon completion of the study. If you have any questions about this study please feel free to contact me by phone: 416-978-2522 ext. 6310 or through email: vpeters@oise.utoronto.ca.

Sincerely,

Vanessa L. Peters
Ph.D. Candidate
I give my permission for Vanessa Peters to conduct the research project outlined above.

________________________________________________________
Print Name

________________________________________________________
Signature  Date
Appendix F: Parent/Guardian Consent Form

To: Parents and/or Guardians of students in Grade-10 Biology
From: Vanessa L. Peters
Subject: Consent for your child to participate in a Research Study

I am interested in conducting a research project in your child’s class this year entitled: *Knowledge Community and Inquiry in Secondary School Science*. This project investigates how technology can be used in the curriculum to help students learn about science. This letter requests your permission for your child to participate in this study. It is important you know that this study has been approved by the principal of your school, and by the University of Toronto Research Ethics committee.

All research activities will be part of your child’s regularly schedule science class, and no additional effort will be required of your child. Every effort will be made to ensure this research improves your child’s learning experiences in the classroom. Some possible activities your child may participate in include: learning about and using new technologies, having discussions about science with their classmates, and participating in a brief interview. No one other than myself will have access to any of the information collected for the study.

Any data collected from the interviews will be held in the strictest confidence and will not be seen by your child’s teacher. At no time will your child’s name, their teacher’s name, or the name of their school be identified in published documents. There are no risks associated with their involvement in this study, and your child is free to withdraw their participation at any time, and for any reason.

If you consent to your child participating in this study, please return the attached permission form. If you have any questions or concerns, please feel free to contact me by phone: 416-978-2522, ext. 6310 or through email: vpeters@oise.utoronto.ca.

Sincerely,

Vanessa L. Peters
Ph.D. Candidate
Dept. of Curriculum, Teaching and Learning, OISE/UT

I consent for my child to participate in the research project outlined above.

____________________________________
Print Name

____________________________________
Signature Date
Appendix G: Student Interview Questions

1. What do you think was the purpose of creating wiki resources?

2. What did you like best about this curriculum unit? Was there a particular activity that you liked/didn’t like? Please explain.

3. How did the activities in this curriculum fit with the rest of your schoolwork? (Either science or another subject.)

4. How did you feel about editing other students’ wiki pages? How did you feel when other students edited your wiki pages?

5. Did other students’ Physiology/Ecozone wiki pages affect the way you crafted your own wiki page?

6. How did you use the Physiology/Ecozone pages? Were you ever concerned about the credibility of the content?

7. What would you change about the Physiology/Biodiversity unit to make it more effective for your learning?

8. How do you learn best in school? How do you know when you’ve learned something?
Appendix H: Teacher Interview Questions

1. Do you think the KCI unit was a good fit for the physiology/biodiversity unit? What would you like to see changed?

2. How comfortable did you feel about the technology aspect of the curriculum?

3. What factors in the KCI unit do you think most contributed to student learning?

4. Has this research partnership changed the way you think about student learning?

5. Do you feel the KCI unit addressed the required content expectations? Please explain.

6. What did you feel least comfortable about during your involvement in this research study? (E.g. planning, enactment, assessment, etc.)

7. How is the KI unit different from the way you would normally teach physiology or biodiversity?

8. How would you describe your role in the co-design process?

9. As a teacher, how do you think the co-design process might be improved?