THE ROLE OF EPISTEMIC COGNITION IN COMPLEX COLLABORATIVE INQUIRY CURRICULA

by

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ABSTRACT

This thesis examines the role of epistemic cognition within the context of a Knowledge Community and Inquiry (KCI) curriculum for secondary science. The study employs a new form of design-based research, called Model-Based Design Research (MBDR), which first maps a formal pedagogical model onto the curriculum design, and then assesses how the enacted curriculum adheres to the design. The curriculum design was a ten-week Grade 11 Biology unit that met the Ontario Ministry requirements for evolution and biodiversity, and included activities situated within a unique immersive environment called EvoRoom. The thesis includes an assessment of students’ epistemological views about science and science learning, and evaluates the epistemic commitments of KCI using a relevant theoretical framework of epistemic cognition. The analysis reveals the complex interconnections amongst the epistemological, pedagogical and technological elements of the design, resulting in recommendations for future design iterations as well as theoretical insights concerning the KCI model.
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CHAPTER 1: INTRODUCTION

1.1 Motivation for the Study

A 2007 report by the OECD describes how shared knowledge distribution has become increasingly critical to innovation and economic success in a 21st century economy—both for individuals as well as entire nations (OECD, 2007). Contemporary science, for example, demands that knowledge be created, built-upon and mobilized freely between citizens rather than restricted to a small class of scientific élite (Nisbet & Mooney, 2007). Large-scale, collaborative, multi-stakeholder advancements such as the Human Genome Project, galaxy mapping, or ocean floor mapping require the creation and mobilization of knowledge through time and space to enable the exchange of methods, tools, data, diagrams and theories. The spatial and temporal coordination of such projects has been facilitated by the increased prevalence of broadband and mobile Internet, as well as the development of Web 2.0 tools and social networks.

However, despite the increased availability of Internet technology in schools and the growing societal demand for collaborative knowledge creation, few core pedagogical changes have been made to introduce such forms of collaborative knowledge construction and advancement into the teaching and learning of school science—particularly at the secondary level. Instructors maintain heavy reliance on textbooks and lecture-style delivery of lessons, while Internet use remains somewhat conservative—primarily for purposes of retrieving supplemental multimedia content or conducting independent research projects. Despite the pervasiveness of “group-work projects,” true collaboration is often stifled by competitive assessment policies that stipulate, for example, that “each student’s work within the group project is evaluated independently and assigned an individual mark” (Ontario Ministry of Education, 2010, p. 39).

While collaboration between students could serve to increase the levels of knowledge mobility and exchange within a classroom, it is a great challenge for educators to integrate these methods effectively into lesson designs while ensuring active participation and engagement of all learners. One recent method that has emerged where educators attempt to introduce collaborative knowledge advancement activities is that of “flipped-classrooms,” where students learn course content at home, typically through an online video, and then
practice this content within their classroom activities (Ash, 2012). One of the challenges of such models is the heavy load they place on the teacher to orchestrate effective, collaborative interactions within the classroom. Further, many of the so-called technological ‘innovations’ that get pushed into classrooms are treated under the assumption that the technology alone will serve to democratize knowledge, or, alternatively, that technology paired with good intentions will be enough to bring about change (Scardamalia et al., 2012; Laferrière 2001; Law 2006).

Technological solutions that are offered for pedagogical transformation are typically not effective, in part because they are not grounded in educational research. Educational software developers are often driven by commercial interests, developing flashy new platforms that merely replicate antiquated forms of pedagogy and have little concern for the underlying cognitive processes or demonstrable learning gains. As McLuhan contends, the content of a new medium often blinds us to the character of the medium (McLuhan, 1994, p. 9), which is why new technologies, when introduced into educational contexts, have the tendency to be used as glorified content delivery systems. The lecture has moved online; textbooks are now multimodal. Such incremental shifts are great for supporting differentiated instruction, but they are a far cry from the systemic ‘reinvention’ of education that may be essential for bringing our students into the age of networked intelligence (Tapscott & Williams, 2012).

The motivation for this study stems from an idea that piqued my interest upon first joining Jim Slotta and his research group in the ENCORE Lab: What if the purpose of technology in the classroom is not about content delivery, but is instead about orchestrating the flow of information, student interactions, and discourse patterns within the physical space of the room? Computer-based tools and materials can support the challenging pedagogical aspects of orchestrating students’ movements through the classroom and curriculum, providing instructions, and making knowledge visible and accessible. This can free up the teacher to play a more meaningful role in providing support amongst students and groups.

Several research programs have employed technology enhanced learning environments and materials to support new forms of collaborative learning where students work collectively to create and advance knowledge. Scardamalia and Bereiter (1999, 2006) have advanced a theoretical perspective of knowledge building, employing an innovative
technology environment called “Knowledge Forum,” where students contribute and edit inquiry notes. Other researchers in the field of Computer Supported Collaborative Learning (CSCL) have explored various forms of online discussion tools (Hmelo Silver, 2010), wiki-based environments (Slotta & Najafi, 2012) and handheld data collection activities (Metcalf et al., 2010). While discussed in more detail in the review section below, there is a wealth of research activity that is exploring new forms of learning where technology supports students’ engagement in collective inquiry.

One aspect of collective inquiry that has not yet received much research attention is that concerned with students’ epistemological knowledge – their beliefs about knowledge and learning, and how those beliefs influence their participation in the curriculum activities. Substantial research has addressed this topic for student inquiry in more structured, constructivist designs (e.g., for small groups or individuals learning in structured inquiry tasks). For example, several lines of work have examined students’ beliefs about the nature of science, and science learning (Tsai, 2000; Liang & Tsai, 2010; Lin et al, 2013). However, it is important to note that very little work on student epistemology has been applied to collective inquiry models. This is a topic of great interest and relevance because if students have little experience learning as a collective community, and if their understandings or expectations about learning are not aligned with those of the designed curriculum (e.g. if students are expecting to learn content with the aim of individual achievement), then the outcome of the enacted curriculum may diverge widely from what was intended. As learning scientists, we must understand the role of students’ epistemic cognitions in order to design effective inquiry activities that leverage networked technologies in a way that makes ideas and interactions both visible and emergent from student-contributed content.

This type of research goes beyond testing whether a particular intervention “works” or “doesn’t work.” Whereas most research on collaborative learning aims to demonstrate its effectiveness through the use of a generalizable pre/post-test instrument or task performance assessment, Pierre Dillenbourg (1999) notes “talking about the effect of such a broadly defined term would be as meaningless as talking about the benefit of taking a medicine without specifying which one” (p. 12). Such metrics typically fail to address qualitative factors such as the aims, attitudes, values, behaviours, and underlying epistemic beliefs of students and teachers within a particular learning context. What is needed is a methodology
that enables researchers to examine the beliefs, actions, and artifacts produced by students within the learning environment, and then compare these to the epistemic aims and assumptions that have been built into the learning design. Identifying any disconnects between the two would allow researchers to iteratively refine the design such that ‘progress’ can be achieved in that particular classroom setting.

This thesis research entails a new form of design-based research that utilizes a formal model of learning, mapped onto the curriculum design, to assess when, where, why and how the enacted design is achieving or failing to achieve its aims (Fischer et al., 2013). Model-based design research requires that the curriculum be designed according to a theoretical model, which in the present case is known as “Knowledge Community and Inquiry (KCI), developed by Slotta and his colleagues to describe collective inquiry (Slotta & Najafi, 2012). The curriculum that was designed to fit this model was a ten-week Grade 11 Biology unit that meets the Ontario Ministry requirements for evolution and biodiversity, and includes activities conducted within a unique immersive environment called EvoRoom. At the time of this research, this curriculum design was undergoing its third iteration, with prior research having focused on activity sequences, the role of immersive simulations, and smart classroom interactions (Lui & Slotta, 2012; 2013). The present research aims to take an “epistemological pass” at the design by examining the role of epistemic cognition throughout the design narrative and mapping these onto the underlying Knowledge Community and Inquiry (KCI) model. The specific research questions that will be addressed are as follows:

1.1.1 Research Questions

1. What are the current epistemic commitments of KCI, and how were these manifested in elements of the designed curriculum?

2. What were the epistemic beliefs of the students, and how did these influence the enactment of this curriculum design?

3. How can the enacted curriculum provide feedback to inform the epistemic elements of future design iterations, in addition to theoretical insights that may contribute to the refinement of the KCI model itself?
1.2 Organization of the Thesis

This thesis begins with a literature review detailing the role of epistemic cognitions (EC) in learning, as well as some existing EC frameworks that have informed the design of materials, activities and analytic materials of the present work. This is followed by an overview of current research in collaborative learning and knowledge communities, including the Knowledge Community and Inquiry (KCI) model that serves as the basis of this research. The literature review concludes with a review of technology supports for collaborative inquiry, including a description of the SAIL Smart Space (S3) infrastructure that was used to build the EvoRoom smart classroom activities.

The methodology chapter describes a new approach to design-based research, called Model-Based Design Research (MBDR), which is used to evaluate the EvoRoom curriculum design in relation to the epistemic commitments of the underlying KCI model. This chapter details the two-step process for evaluating the EvoRoom curriculum using MBDR; (1) the design analysis, in which the epistemic commitments of KCI are mapped onto the curriculum design, and (2) the enactment analysis, which analyzes how the epistemic elements of the design were actually enacted by the students. The findings and discussion from the design analysis and enactment analysis are then presented in the two proceeding chapters. This thesis concludes with a series of design recommendations for future iterations of this curriculum, as well as insights to contribute to the refinement of the KCI model itself.
CHAPTER 2: LITERATURE REVIEW

2.1 Chapter Overview

This chapter presents a body of literature that is used to motivate the present research on the role of epistemic cognition in a knowledge community context. The chapter begins with an overview of epistemic beliefs and learning, followed by a description of the theoretical foundations of epistemic cognition that contributed to the development of Chinn et al.’s (2011) expanded EC framework. Next, research on inquiry-based learning is presented, including literature on some of the technological and pedagogical scaffolds that are used to support this approach. The literature review concludes with an overview of several knowledge community approaches, and identifies the importance of examining the epistemic cognitions and epistemological commitments that are inherent in these curriculum designs.

2.2 Epistemic Beliefs and Learning

Epistemology is a branch of philosophy that entails the study of knowledge and the nature of knowing. Derived from the Greek words episteme (knowledge) and logos (explanation), it addresses broad questions pertaining to the form and scope of knowledge as well as the processes by which knowledge can be acquired and justified. Historically, epistemology has remained a core topic in philosophical literature. However around the turn of the twentieth century several prominent authors – including William James (1890), Charles S. Pierce (1877), and John Dewey (1916) – began to frame their epistemological inquiry using a more psychological perspective (Buehl and Alexander, 2001). The infusion of human psychology into discussions of knowledge and knowing prompted a proliferation of literature related to epistemology and schooling (Buehl and Alexander, 2001). Researchers became interested in how the process of schooling transformed individuals’ epistemic beliefs, and, in turn, how students’ beliefs about knowledge affected their scholastic achievements and their approaches to learning (Chinn and Brewer, 1993; Buehl and Alexander, 2001).

Contemporary researchers have used both qualitative and quantitative measures to empirically assess students’ epistemic beliefs in relation to their academic learning. A
number of studies have shown that students’ epistemic beliefs are an important predictor of achievement in a variety of learning domains, including information processing (Garner and Alexander, 1994), reading comprehension (Jacobson and Spiro, 1995; Rukavina and Daneman, 1996), test performance (Schommer et al, 1992), argumentation (Kuhn, 1991, 1993), and the ability to synthesize information from multiple sources (Strømsø and Bråten, 2009). Other studies have revealed the role of epistemic beliefs in affecting chosen learning strategies (Ryan, 1984; Schommer et al, 1992), motivation and behaviour (Pintrich et al, 1993), and attitudes such as learned helplessness (Qian and Alvermann, 1995).

In the domain of school science, Windschitl and Andre (1998) demonstrated that students with more sophisticated epistemic beliefs (e.g. the belief that knowledge is complex, cumulative, and context-dependent) exhibited greater learning gains when engaged with constructivist pedagogies compared to individuals with less sophisticated beliefs (e.g. the belief that knowledge is simple, quick, and certain). Tsai (1999) showed that students who held epistemological beliefs about science and science learning that were orientated towards constructivist knowledge structures possessed stronger conditional inferential reasoning skills in secondary physics compared to students who did not. Kardash And Scholes (1996) revealed that students’ beliefs about the certainty of knowledge affected the ways they handled and presented contradictory evidence in scientific research, and Qian and Alvermann (1995) further showed that students’ beliefs about the simplicity and certainty of knowledge impacted the levels of conceptual change they experienced in school science.

Students’ epistemic beliefs have also been shown to vary across domain-general and domain-specific subject areas (Buehl & Alexander, 2005). Within the domain of biology, for example, students may believe that scientific knowledge is certain for some topics (e.g. cell theory) and uncertain for other topics (e.g. evolution) (Elby & Hammer, 2001; Muis et al, 2006; Chinn et al., 2011). It is therefore important to consider students’ epistemic beliefs and their interaction with learning when developing instructional strategies and curriculum designs for school science.

2.3 Epistemic Cognition

“Epistemic cognition” is a term used to describe any explicit or tacit cognitions that pertain to epistemological matters, such as knowledge, beliefs, truth, sources, justification,
evidence, understanding, and explanation (Chinn et al., 2011). Although various researchers use different terms to describe these cognitions, (e.g. “personal epistemology,” “epistemic beliefs,” “epistemic positions,” “epistemic reflection,” and “epistemic judgments”), Chinn et al., (2011) use “epistemic cognition” (EC) as an umbrella term that encompasses all of these cognitions. For the purposes of this thesis, use of the term “epistemic cognition” (EC) will follow the Chinn et al (2011) definition, however the terms “epistemic cognition” and “epistemic beliefs” are used somewhat interchangeably. Sandoval (2012) also highlights a semantic distinction between uses of the terms “epistemic beliefs” and “epistemological beliefs.” According to Kitchener (2002), “epistemic beliefs” refer to beliefs about the nature of knowledge and knowing, whereas “epistemological beliefs” refer to beliefs about epistemology (i.e. meta-epistemology). An effort will be made to maintain Kitchener’s distinction throughout this thesis, referring mostly to the epistemic beliefs of students throughout their scientific inquiry.

Several scholars have attempted to identify specific dimensions of epistemic cognition to provide general models or frameworks. One prominent model arose in the 1970s through the work of William Perry (1970), whose landmark longitudinal study posited that epistemic growth occurred following a series of developmental stages (what Perry termed “positions”), reminiscent of Piaget’s theory of cognitive development. Perry’s nine “positions” were commonly collapsed into four sequential categories: Dualism (where knowledge was seen as either right or wrong, true or false), Multiplicity (where knowledge was seen as diverse and uncertain, but absolute truth still existed, even if it was unknown), Relativism (in which the self was perceived as an active meaning-maker, with knowledge being contingent and contextual), and Commitment within relativism (where individuals forged commitments to personal values and relationships that affected their standards of reasoning and evidence in various contexts) (Perry, 1970, 1981). Similar models postulating a developmental progression of epistemic cognition were presented by Baxter Magolda (1992), King and Kitchener (1994, 2004), and Kuhn and Weinstock (2002). However, developmental psychologists have generally dismissed the idea that cognitive development occurs in a stage-like manner, as the growing body of empirical evidence failed to support the existence of such stages (Carey, 1986; reviewed by Sandoval, 2012).
In the early 1990s, Schommer (1990, 1993) proposed a more analytic view of epistemic beliefs that consisted of five independent dimensions rather than a series of developmental stages. Schommer developed a widely-used survey instrument, called the “Epistemological Beliefs Questionnaire,” to detect and measure these five dimensions, which she hypothesized as Structure, Certainty, Source of Knowledge, Control of Knowledge Acquisition, and Speed of Knowledge Acquisition (Schommer et al., 1992). Factor analysis in subsequent studies has typically collapsed these five dimensions into four: Simple Knowledge, Certain Knowledge, Fixed Ability and Quick Learning (as reviewed by Hofer & Pintrich, 1997). However, despite the wide adoption of Schommer’s survey instrument worldwide, the resulting data have failed to produce the hypothesized dimensions that her model predicts (Sandoval, 2012). Moreover, although Fixed Ability and Quick Learning were argued to be related to knowledge acquisition, these two dimensions were criticized as falling outside of the construct of epistemic beliefs (Hofer & Pintrich, 1997).

Building upon Schommer’s model, Hofer and Pintrich (1997) developed a framework for epistemic cognition that consisted of two dimensions. The first dimension refers to beliefs about the nature of knowledge, and includes constructs such as “simplicity of knowledge” and “certainty of knowledge.” The second dimension refers to beliefs about the process of knowing, and includes constructs such as “sources of knowledge” and “justification of knowledge.” This conceptualization of epistemic cognition has remained prominent in the literature, with many researchers explicitly drawing upon Hofer and Pintrich’s framework (reviewed by Chinn et al., 2011). However, although this model has demonstrated statistically significant correlations between one’s epistemic beliefs and learning outcomes, the predictive validity between epistemological factors and outcome variables has been shown to be low (e.g. Shraw and Olafson, 2008). Moreover, DeBacker et al., (2008) have identified considerable psychometric problems in the designs of three prominent EC survey instruments, which they suggest would prevent the operationalization of the targeted epistemic constructs within this model. Chinn, Buckland and Samaranpungavan (2011) further suggest that current instruments fail to address several important aspects of epistemic cognition, and they argue that expanding Hofer and Pintrich’s EC framework would have the potential to improve the predictive validity between epistemic beliefs and learning outcomes. It should also be noted that many epistemic beliefs are
conceived to be *tacit* rather than *explicit* (i.e. possibly inferable from one’s actions, but not able to be articulated explicitly), which raises questions about the appropriateness of relying on quantitative instruments to infer these relationships.

### 2.3.1 Chinn, Buckland and Samarapungavan’s Expanded EC framework

In 2011, Chinn, Buckland and Samarapungavan extended the work of Hofer and Pintrich by developing an expanded framework for epistemic cognition. Two major improvements in this model were (1) the addition of several new components and subcomponents of EC, and (2) the specification of a finer grain size of cognitions within each of these dimensions in order to account for contextual and situational differences in learning processes. The five dimensions of Chinn *et al.*’s 2011 EC framework are summarized in Table 1 below.

Chinn *et al.* (2011) suggest three possible opportunities for future study to which this framework could be applied. First, they suggest that this framework could be used to explore patterns of situational variation in EC, developing explanations for why these patterns exist. Second, they suggest that this framework could be used to explore developmental changes in EC along each of the five dimensions, including the inter-relation between various cognitions as learners become older or more experienced. Finally, they identify that a limitation of their paper was its focus on individual cognitions and suggest that the five dimensions of EC could be further explored at the level of groups, for example for students engaged in collective inquiry within a constructivist learning environment (Chinn *et al.*, 2011). This thesis aims to study the epistemic aspects of learning at the group level in relation to an innovative pedagogical model for secondary science called “Knowledge Community and Inquiry,” described in section 2.6.3.
<table>
<thead>
<tr>
<th>Dimension</th>
<th>Description</th>
<th>Examples</th>
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| **Epistemic aims and epistemic value** | Epistemic aims – the goals to which all other epistemic beliefs and activities are directed | - acquisition of justified, true beliefs;  
- avoidance of false beliefs;  
- deep conceptual understanding  
- explanatory coherence |
| | Epistemic value – the amount of worth people associate with particular epistemic aims | - scientists valuing unified explanations over descriptive narratives;  
- some disciplines/institutions perceiving theoretical knowledge as more valuable than practical knowledge; |
| **Structure of knowledge and other epistemic achievements** | Structure of knowledge – the beliefs people hold with regards to their mental representations of the ontological structures of reality | - universality vs. particularity of knowledge  
- deterministic vs. stochastic knowledge  
- structure of causation as linear vs. reciprocal/non-linear |
| **Sources and justification of knowledge and related epistemic stances** | Sources of knowledge – where/how knowledge originates | - perception  
- reasoning  
- testimony  
- introspection  
- memory |
| | Justification of knowledge – something to ensure that beliefs aren’t true merely by accident or luck | - Deduction  
- Induction  
- Abduction  
- Empiricism  
- Occam's razor  
- Pragmatism  
- Probability  
- Logical positivism |
| | Epistemic stance – the judgment or position one takes towards a knowledge claim | - Certainty/uncertainty  
- Entertain an idea  
- Consider an idea  
- Utilize an idea as a working hypothesis  
- View a claim as partially true  
- Withhold judgment on a claim |
| **Epistemic virtues and vices** | Epistemic virtues – a learned, stable disposition that is directed at epistemic aims and is relatively efficacious in achieving these aims | - Intellectual carefulness  
- Open-mindedness  
- Perserverence  
- Insightfulness  
- Conscientiousness  
- Impartiality |
| | Epistemic vices – a disposition that impedes, rather than facilitates, the acquisition of epistemic aims | - Dogmatism  
- Closed-mindedness  
- Wishful thinking  
- Conformity  
- Unwillingness to give up beliefs  
- Need for closure |
| **Reliable and unreliable processes for achieving epistemic aims** | Reliable processes – the causal processes, including strategies and other procedures and activities, by which one can achieve epistemic aims | - Cognitive processes (e.g. perception, reasoning, memory, emotion)  
- Processes of formal inquiry (e.g. experimentation, opinion polls, surveys, correlational studies)  
- Interpersonal processes (e.g. argumentation, group decision-making procedures)  
- Community and institutional processes (e.g. processes for funding research, processes for sharing/disseminating knowledge, reliability of media/media practices) |

Table 1 – Framework for EC, including description and examples, adapted from Chinn et al., (2011)
2.4 Inquiry-Based Learning

In contrast to traditional knowledge-transmission models of pedagogy, inquiry-based learning requires students to actively engage in an investigative approach to science learning through the pursuit of open-ended questions (Bransford et al, 1999; Slotta & Linn, 2009). Rather than simply reducing ‘the scientific method’ to a series of prescriptive pseudo-experiments designed to confirm existing results, students are instead challenged to investigate authentic scientific problems or questions, to search for and evaluate sources of evidence, to generate explanations for phenomena through reasoning and argumentation, and to revise their ideas and approaches in light of new findings (Lock, 1990; Singer et al, 2000).

Edelson, Gordin and Pea (1999) describe four ways in which inquiry-based learning contributes to the development of scientific understanding: (1) It elicits curiosity in situations where the limits or gaps in one’s knowledge are revealed, thereby increasing students’ motivation to learn; (2) It creates a demand for content knowledge in order to complete an investigation successfully; (3) It enables students to pursue answers to their own questions, allowing them to uncover new scientific principles along the way; and (4) It allows students to apply their scientific knowledge in new contexts, thereby reinforcing connections to their other knowledge.

Inquiry-based learning can pose a number of challenges when set within the confines of existing school structures. For example, the amount of time required for an effective implementation of an inquiry activity can be extensive, often requiring several days or weeks of class time, which can be challenging for teachers to orchestrate. Moreover, students who are not accustomed to managing such complex learning processes over an extended period of time may have difficulty sustaining these activities, possibly resulting in the failure to achieve the full potential of the inquiry if they are unable to do so (Edelson et al., 1999). Studies have also demonstrated some of the challenges students have with even the most fundamental aspects of inquiry-based learning, such as their ability to ask research-worthy questions, to conduct investigations systematically, and to use collected evidence to draw conclusions (Krajcik et al., 1998; Hug et al., 2005).
2.4.1 Scaffolded Inquiry

To help overcome some of these challenges, a large body of research has examined the role of technological and pedagogical scaffolds in helping students attain the intellectual competencies required for successful inquiry (Palincsar & Brown, 1984; Hajafi, 2012; Slotta & Peters, 2008). Scaffolds offer students a form of cognitive or procedural support, allowing them to execute tasks that they would not otherwise be able to accomplish unaided. Examples of scaffolds include ‘chunking’ an activity into a series of constituent steps, supporting content knowledge acquisition and integration, or providing metacognitive prompts to facilitate collaborative discourse (Hajafi, 2012; Linn, Clark & Slotta, 2003; Slotta & Linn, 2009). Well-designed scaffolds not only support students in how or when to do a particular task, but also help problematize certain aspects of students’ work, forcing them to consider why a particular task is being completed in that manner (Hmelo-Silver, 2006; Reiser, 2004). As students’ competencies begin to increase, scaffolds are ideally “faded” (i.e., gradually removed). Although scaffolds are commonly provided to students by the teacher, current literature on scaffolded inquiry generally refers to scaffolds that are delivered through instructional materials such as technology-based learning environments (Slotta & Linn, 2009).

2.4.2 Technology Scaffolds for Collaborative Inquiry

In order to support the effective enactment of complex inquiry designs, as well as to facilitate data collection, researchers often develop technology environments that are specifically matched to the epistemic commitments of the research. Over the past two decades, many technology environments have been developed to support the coordination of materials and interactions throughout scaffolded inquiry activities. For example BioKIDS (Songer, 2006) provides a handheld technology environment to support students as they collect observations of biodiversity in their school playground. BGuILE (the Biology Guided Inquiry Learning Environment - see Reiser et al., 2001) offers a computer-based learning environment where students manipulate historical data from Darwin to create empirical arguments about evolutionary phenomena. The Web-based Inquiry Science Environment (WISE – see Slotta & Linn, 2009) provides a Web-based environment to
support secondary students and teachers as they adopt week-long inquiry projects in many science topics and domains. In addition to scaffolding students and teachers throughout inquiry activities, these technology environments have reinforced the specific epistemic commitments valued by the theoretical positions of the research. For example, in the BGuILE environment there is a strong emphasis on the autonomous creation of evidence-based hypotheses by students (Riser et al., 2001). In the WISE environment there is a strong emphasis on critical thinking, making ideas visible, and enabling students to reflect upon these ideas (Slotta & Linn, 2009). As such, these environments provide students with scaffold supports that are uniquely designed to support the epistemic commitments they value.

2.5 Collaborative Learning

While the terms ‘co-operative learning’ and ‘collaborative learning’ are often interpreted as synonymous in everyday practice, these two terms are, epistemologically, quite different. In its broadest terms, collaborative learning is “a situation in which two or more people learn or attempt to learn something together” (Dillenbourg, 1999, p. 1). In order for a situation to be considered ‘collaborative’ several conditions must be met. Firstly, peers must be symmetrical in terms of their knowledge (i.e. at the same developmental level, though they may possess differing viewpoints), their hierarchical status, and their available choice of actions (Dillenbourg & Baker, 1996). In contrast, teaching, coaching and tutoring are generally considered ‘asymmetrical’ situations for these three factors. Secondly, collaborators must have shared goals, and must be mutually aware of these shared goals (Scardamalia, 2002), although goal discrepancies may be identified and negotiated in a course of action. Thirdly, collaborators work together with a low division of labour (Miyake, 1986; Dillenbourg, 1999).

Criteria have also been advanced for what constitutes collaborative interactions. ‘Collaboration’ is not as much defined by the frequency of interactions, but rather by the influence that these interactions have upon the cognitive processes of one’s peers (Dillenbourg, 1999). O’Conaill et al. (1993) suggest that this implies synchronous communication, although synchronicity is more of a social rule than a technical parameter. For example, while there may be a delay between messages in some technology-based
learning environments, the expectation is that there is a conversational etiquette in which the ‘listener’ will wait for and respond to the ‘speaker’s message as soon as it is delivered. Finally, collaborative interactions require some degree of negotiation (Dillenbourg & Baker, 1996). Students should not simply impose their views onto their peers, but should be required to justify their statements using argumentation and reasoning. Factors that can inhibit negotiation include overly-defined roles, trivial tasks, and unambiguous information in which there is nothing to be negotiated (Dillenbourg & Traum, 1996).

Conversely, co-operative learning occurs when a “divide-and-conquer” approach is used to complete group tasks. A common example would be a group assignment in which tasks are divvied up between group members and completed independently, with the final product consisting of a compilation of each individual’s contributions. Although students may be working as part of a group in order to complete the assignment, each student ultimately undergoes his/her own independent cognitive processes that have little bearing upon the cognitive processes of his/her peers (Dillenbourg, 1999). In cases where students must be accountable for mastering the entirety of this curricular knowledge (rather than merely his/her ‘piece’), it is therefore important for cooperative tasks to include opportunities for meet-up and exchange between group members so that all students may have access to the entire topic. Additionally, curriculum designs may include subsequent activities where students are consequentially required to draw from the full extent of this shared knowledge.

2.6 Knowledge Communities

One body of scholarship that seeks to maximize the benefits of collaborative learning is the knowledge community approach, which advocates for the transformation of classrooms into collaborative enterprises (Brown & Campione, 1994; Scardamalia & Bereiter, 1999; Bielczyc & Colins, 2005). As defined by Slotta and Najafi (2010), a knowledge community is “a collection of individuals who share a common learning goal or activity focus. The community typically shares common practices or goals, and employs characteristic media” (p. 189). In their review of knowledge communities in the classroom, Slotta and Najafi (2010) identify three defining characteristics of a knowledge community. First, members of the knowledge community, possessing a diversity of ideas, experience and expertise, must collectively contribute to the advancement of a shared knowledge base (Bielaczyck &
Second, members of the knowledge community must understand the epistemic value of the community, and must develop metacognitive awareness of their learning processes and knowledge creation (Brown & Campione, 1994). Finally, discourse within the knowledge community must support idea sharing, critique and improvement (Scardamalia & Bereiter, 2006). Epistemologically, the knowledge community approach represents a key shift from the notion of self-as-learner, potentially in competition with peers, to one of collaboration and cooperation in which shared knowledge advancement is favoured over individual gains.

In the context of K-12 classrooms, two widely researched examples of the knowledge community approach are (1) Fostering Communities of Learners (FCL) (Brown, 1997; Brown & Campione, 1996), and (2) Knowledge Building (Scardamalia & Bereiter, 2006).

### 2.6.1 Fostering Communities of Learners

FCL emerged in the late 1980s through a series of design-based research studies in inner-city elementary schools serving students from 6 to 12 years of age (Brown, 1997). In order to transform these urban grade-school classrooms into scientific learning communities, three key activities were required:

1. Research – Independent or group research had to be completed on a particular sub-topic of inquiry.
2. Information sharing – Students were required to share their expertise with their classmates such that all students had full mastery of the entire topic.
3. A consequential task – Students were motivated to master the full topic in order to complete a task or activity that demands this full knowledge. This task would be overseen and coordinated by all members of the learning community (Brown, 1997).

Jerome Bruner, who visited Brown and Campione’s FCL classrooms, identified four underlying ideas in an FCL classroom: agency, reflection, collaboration and culture (Bruner, 1996). Students are responsible for their own metacognitive activities through the use of both self-reflection as well as collaboration with other students. These discourse practices become ingrained in the culture of the classroom such that the processes of knowledge sharing, construction and negotiation are institutionalized within the community (Bruner, 1996).
With regards to the epistemic cognitions inherent in FCL, Brown maintains an interest in establishing a “developmental corridor” whereby students progressively delve more deeply into the underlying principles of a domain as they advance in age and experience, gradually reaching towards a more sophisticated disciplinary understanding (Brown, 1997). Brown’s understanding of this developmental corridor governs her approach to reasoning at each stage of development. For example, she states that young children have the tendency to use personification as a form of analogy (i.e. describing a phenomenon using human-like characteristics). While this form of analogy supports inductive reasoning from a young age, a discussion with students later reveals the limitations of this way of thinking (Brown, 1997). Here, it is the role of the adult ‘experts’ to model thinking and self-reflection (e.g. how reasoning might occur with the information given), to continually ask students to justify their opinions, and to lead students towards higher levels of abstraction (Brown, 1997).

2.6.2 Knowledge Building

Knowledge building (KB) is an educational approach that regards classroom activities as part of the societal effort to advance knowledge frontiers (Scardamalia and Bereiter, 2006). KB differs from FCL in the level of epistemic agency given to students (for details see Scardamalia and Bereiter, 2007). Scardamalia and Bereiter (2006) identify six themes that underlie the knowledge building approach:

1. Knowledge advancement is regarded as a community endeavor rather than an individual achievement;
2. Knowledge advancement is assessed in terms of idea improvement rather than progress towards some fixed ‘truth’;
3. Knowledge of is favoured over knowledge about (i.e. the explicit and implicit knowledge that is required to actively engage with a phenomenon is favoured over declarative/factual knowledge about that phenomenon);
4. Discourse is considered to be an act of collaborative problem solving rather than a form of argumentation;
5. Constructively using and evaluating authoritative information is part of the knowledge building task; and
6. Conceptual understanding is emergent, based on the dynamic systems of idea interaction and growth that occur during the KB discourse.

Scardamalia and Bereiter have developed a software environment called “Knowledge Forum” with the specific aim to support the underlying principles of knowledge building (Bereiter and Scardamalia, 2000; Scardamalia and Bereiter, 2006). In Knowledge Forum (KF), students’ ideas are contributed to a shared knowledge base in the form of text-based notes, which become objects of inquiry that are subject to continuous improvement. Unlike threaded discourse platforms, KF presents students’ notes using a spatial configuration in which ideas can be moved around, built-upon, or clustered within the space of a blank canvas, called a ‘view.’ The KF environment provides a set of meta-discourse scaffolds to facilitate students’ contributions and interactions within the shared knowledge base. Further, an analytic toolkit provides students and teachers with a means of formatively assessing one’s contributions to the knowledge base, both in relation to other students in the knowledge community as well as to past performance (Teplovs et al., 2007; Matsuzawa et al., 2011; Resendes et al., 2013). The KB researchers argue that the Knowledge Forum environment distinguishes itself from existing discussion board, management, planning, and productivity platforms by serving as an idea-centered technology that is specifically designed to foster KB discourse based on its underlying principles (Scardamalia, 2004).

A recent study by Chen et al. (2013a) examined how epistemic growth and conceptual change were influenced by the use of a “promising ideas” tool within the Knowledge Forum environment. The purpose of the promising ideas tool is for students to identify and highlight ideas within their notes that they consider to be potentially fruitful towards achieving progress in the shared knowledge space (Chen et al., 2013b). Students’ decisions surrounding which ideas are considered promising are referred to as “promisingness judgments.” Chen et al. (2013a) revealed that students’ promisingness judgments followed a developmental progression, beginning with the conception that “promising ideas = true ideas” and concluding with the notion that “promising ideas are those that produce further investigation or discussion.” Using an epistemological beliefs survey developed by Conley et al. (2004), Chen et al. showed that the sophistication of students’ epistemological beliefs increased significantly in parallel with their developmental
progression in promisingness judgments and their conceptual understanding (Chen et al., 2013a).

2.6.3 Knowledge Community and Inquiry

FCL has been successfully implemented at the elementary level, KB at elementary to tertiary levels, and in out-of-school contexts. However, current school structures and content-heavy curriculum demands may make various forms of the knowledge community approach inaccessible to course instructors – particularly at the secondary level, and particularly in content heavy domains like science. Knowledge Community and Inquiry (KCI) is a pedagogical model that was developed for secondary science as a means of blending the core philosophies of the knowledge community approach with the structural and scripted affordances of scaffolded inquiry (Slotta & Peters, 2008; Slotta & Najafi, 2010). KCI includes five major design principles, each accompanied by a set of epistemological commitments, pedagogical affordances, and technology elements. Together, these guide the creation of inquiry activities, peer interactions and exchange, and cooperative knowledge construction. The five principles are summarized in Table 2 below:
### Epistemological Commitments

1. Students work collectively as a knowledge community, creating a knowledge base that serves as a resource for their ongoing inquiry within a specific science domain.

   - **Pedagogical Affordances**: The knowledge base is indexed to the targeted science domain as well as semantic and social variables; Semantic index variables can be designed, as well as user contributed or emergent.

   - **Technology Elements**: Tablets, wikis, semantic web, metadata schemes, science content standards, tagging schemes.

2. The knowledge base that is accessible for use as a resource as well as for editing and improvement by all members.

   - **Pedagogical Affordances**: Scripts for jigsaw and collaborative knowledge construction; visualizations and interfaces for accessing the knowledge base; authorship attributions; versioning and forking.

   - **Technology Elements**: Socially editable media, wikis, notes, or collections of observations; social tagging; visualizations; recommender agents.

3. Collaborative inquiry activities are designed to address the targeted science learning goals, including assessable outcomes.

   - **Pedagogical Affordances**: Learner-centered and idea-centered activities, including critique, comparison, design and reflection. Students create artifacts, reflect on those artifacts, and apply them as resources within a larger inquiry project.

   - **Technology Elements**: Web-based learning activities, wikis, Web portal, video editing, simulations, tablet-based observation forms, laptop and tablet interfaces.

4. Inquiry activities are designed to engage students with the knowledge base as a resource, and to add new ideas and elements to the knowledge base.

   - **Pedagogical Affordances**: Need for open-ended activity designs, to connect to full index of knowledge base (i.e. to assure complete coverage), but also to respond to emergent ideas or themes within the community; possible dynamic grouping of students based on shared ideas, disagreements or other inquiry-oriented variables.

   - **Technology Elements**: Specific technology tools and materials are developed to support inquiry activities, adhering to a pedagogical “script” that defines the sequence or progression of activities, roles, groups, etc. May use a variety of technology-based learning environments, carefully designed to support the pedagogical script.

5. The teacher plays a specific role defined within the inquiry script, but also a general orchestration role, scaffolded by the technology environment.

   - **Pedagogical Affordances**: Teacher engages in specific scripted interactions with students, providing feedback and making orchestrational decisions based on the content of student interactions and artifacts. Moves inquiry forward through a progression of activities; plays specific roles within activities.

   - **Technology Elements**: Teachers rely on technology to help orchestrate the flow of activities. They may refer to representations of the aggregated community knowledge to inform reflective discussions (e.g., about ‘next steps’ in inquiry). May have specific technologies designed to support their interactions with students (e.g., a teacher tablet).

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**Table 2 – KCI design principles**
KCI curricula have been accompanied by a custom suite of technologies that have been designed and developed to support the dynamic exchange of ideas and interactions within a community of knowledge. To this end, Slotta and his colleagues have developed an open-source smart classroom infrastructure known as SAIL Smart Space (S3 – see Slotta, Tissenbaum & Lui, 2013), as detailed in the following chapter.

To date, the epistemic elements of KCI have not been firmly tested or evaluated. In order to adequately assess students’ epistemic cognitions within the context of a knowledge community for secondary science, an application of KCI is needed for which the curriculum design could be evaluated in terms of its epistemic elements as well as its faithfulness to the epistemic commitments of the model. Taking an ‘epistemological pass’ at the curriculum design would not only provide feedback that may be used to help strengthen the epistemic elements of future design iterations, but it will also provide theoretical insights that could contribute to the refinement of the KCI model itself.
CHAPTER 3: METHODOLOGY

3.1 Chapter Overview

This chapter begins by describing a new methodology for design-based research, called “Model Based Design Research” (MBDR), that uses a formal model of learning mapped onto the curriculum design to evaluate when, where, why and how the design is achieving or failing to achieve its aims. This is followed by a description of the research context and the technology environment that were used throughout this study. The co-design team and research participants are then introduced, followed by an overview of the ten-week EvoRoom curriculum narrative. The chapter concludes with a description of the data sources and the mixed-methods approach that were used to conduct the two-stage design analysis and enactment analysis presented in the following two chapters.

3.2 Model-Based Design Research

Since its inception in the early 1990s (Brown, 1992; Collins, 1992), design-based research has been widely used as a research paradigm in the learning sciences. This approach maintains a commitment to the creation and development of innovative learning environments by simultaneously engaging in design evaluation and theory building throughout the research process (Edelson, 2002). Design-based research typically includes three characteristics: (1) Systematic intervention into a specific learning context, accounting for factors such as the teachers, learners, curricular materials, and available technologies; (2) An interdisciplinary design team consisting of teachers, researchers, technologists, and subject-area specialists; and (3) Iterative design modification in which interim findings are used to improve the design throughout its implementation (Najafi, 2012; Edelson, 2002; Bell, Hoadley & Linn, 2004). Those engaging in design research are generally committed to specific outcomes. These include the development of innovative learning environments or curricula, the characterization of specific learning contexts, as well as the acquisition of knowledge about the fundamentals of teaching and learning (Sandoval, in press).

In an effort to enhance the methodological rigor of design-based research, some researchers have begun to explicitly map their designs onto their theoretical underpinnings. A prime example of this is an approach advanced by Sandoval (2004; in press), which he
calls ‘conjecture mapping.’ The purpose of conjecture mapping is to explicitly identify and make salient the specific relationships between a learning design and the theoretical conjectures that informed the design (Sandoval, 2004). Sandoval (in press) identifies three types of conjectures:

1. *High level conjectures* – the broad, theoretical, abstract “big ideas” or learning principles that are typically used to motivate or initiate the design process

2. *Design conjectures* – theoretical assertions that guide or constrain how particular design features or “embodiments” (e.g. tools and materials, task structures, participant structures, discursive practices) will yield particular mediating processes (e.g. observable interactions, participant artifacts)

3. *Theoretical conjectures* – theoretical beliefs or assertions that describe how the mediating processes of a design will yield particular outcomes (e.g. learning, interest/motivation, etc.)

By explicitly mapping such conjectures onto curriculum designs, researchers are productively required to articulate and justify their choice of design embodiments, mediating processes, outcomes, as well as the means and methods for tracing the linkages between them (Sandoval, in press).

In an approach that is similar to conjecture mapping, Fischer *et al.* (2013) have defined model-based design research (MBDR) as a method that connects the designed innovation (i.e., curriculum, technology environment) explicitly to a formal model of learning, such as KCI. However, what distinguishes MBDR from other forms of design-based research is that it adds a means of *evaluating* curriculum design and enactment in relation to the model itself. That is, as the curriculum is being designed, and once the design is completed (i.e., before enactment), it can be evaluated in terms of whether the functional and structural assertions of the model have been achieved. If they are not, then the designers must either revise the curriculum to address the deviation, or proceed to enactment with awareness of the shortcomings of the design. The *enactment* of the curriculum is then evaluated in terms of its fidelity to the design. While MDBR is only applicable in cases where a formal structural model exists, it offers an interesting form of design-based research, particularly in the sense that the outcomes of an MDBR study can directly inform revisions to or critiques of the underlying model.
3.3  Research Context: The EvoRoom Curriculum

At the time that this thesis research began, the EvoRoom curriculum was undergoing its third design iteration. The pilot run for EvoRoom was completed in June 2011, the second iteration was completed between December 2011 and February 2012, and the third iteration, addressed by this study, was completed between March and May 2013. It should be noted that while the KCI model served as an important referent and guide for design decisions, none of the designs up to this point were explicitly concerned with the role of epistemic cognition within KCI. While such elements are clearly essential to the model, they were not at the forefront of concern for researchers, who were focused on designing activity sequences that engaged students with the relevant biology content, as well as interactions within the immersive environment (Lui & Slotta, 2012). The present research examines the role of epistemic cognition within the EvoRoom designs, performing an MBDR analysis that will inform future iterations of EvoRoom and strengthen the coherence of the KCI model in terms of its epistemic commitments.

3.4  Technology Environment

To date, all KCI curricula have employed rich technology environments to support the complex activity sequences and dependencies employed within multi-week knowledge community curriculum (Slotta & Najafi, 2012; Slotta, Tissenbaum & Lui, 2013). Early KCI units employed wikis or other collaborative editing platforms like Drupal as a means of capturing the knowledge base and making it accessible as a community resource. More recently, KCI research has advanced the notion of a “smart classroom” technology infrastructure that supports interactions between students, their peers, and a variety of tools, materials and displays situated around the room. SAIL (Scalable Architecture for Interactive Learning) Smart Space (S3) has been developed as a generic open-source platform that pairs a variety of hardware devices (e.g. tablets, laptops, and touch surfaces) with intelligent agent software elements in order to facilitate real-time data aggregation and the execution of pedagogical scripts within the space of a physical classroom (Slotta, 2010; Tissenbaum,
Slotta & Lui, 2012). The S3 framework, shown in Figure 1, is built upon a set of four underlying technologies:

1. A portal for student registration and software application management;
2. An intelligent agent framework to facilitate data mining and real-time tracking of student interactions
3. A central database containing the curriculum designs and the artifacts of student learning and interactions
4. A visualization layer that is used to present materials to members of the knowledge community using various devices and displays

To date, the S3 framework has been used to support a variety of curriculum designs. For example, PLACE (Physics Learning Across Contexts and Environments) was designed by Tissenbaum and Slotta (2012) for secondary physics to engage students in inquiry activities across a variety of contexts, including at home, within their regular classroom, and in the smart classroom. Here, students had to apply their prior learning in physics in order to tag problems according to their underlying principles, and then subsequently use these principles within the smart classroom to evaluate the plausibility of several Hollywood movie clips (Tissenbaum and Slotta, 2012). Another example of S3, applied to an elementary context, is EPIC (Embedded Phenomena for Inquiry Communities) – see Cober et al., 2012), which has been used to support curriculum designs in biology (i.e. “Wallcology”) and astronomy (i.e. “Helio Room”) (Cober et al., 2012). Here, four wall monitors were embedded into the walls of the students’ regular classroom and were used to display an ambient simulation that served as a referent for ongoing inquiry (Cober et al., 2012). In each of these examples, the S3 technology environment facilitated the aggregation of students’ ideas, with intelligent agents operating on emergent semantic metadata in the physical learning environment to help orchestrate these complex inquiry designs. Likewise, the S3 framework was instrumental in supporting the EvoRoom activities that occurred within the present study.

In addition to the S3 framework, a Drupal platform was also used for the purposes of coordinating student activities, collecting homework, and periodic student reflections. This platform was used to coordinate the overall ten-week curriculum unit, providing students an ongoing common location for their various contributions to the course. Specific materials
and activities concerned with the various technology environments will be described in more detail below, in the curriculum narrative sections.

![Figure 1 – S3 software architecture](image)

3.4 The Co-Design Team

In order to ensure that the overall curriculum design (i.e., all activities, tools, materials and interactions) was suitable for high school biology, a co-design approach was used (Roschelle, Penuel & Shechtman, 2006). Roschelle, Penuel and Shechtman (2006) define 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). The co-design team consisted of three researchers (two graduate students and one faculty member), three programmers, and the classroom teacher. Throughout the EvoRoom design process, the teacher was highly involved in the development of the orchestrational scripts and technology elements that went into the design. The teacher met weekly with two researchers over a two-year period, providing valuable
feedback with regards to tool development and the overall curricular goals for the evolution and biodiversity units.

3.4 Participants

The participants for the current design iteration consisted of two sections of Grade 11 Biology (n=56) from a high-achieving secondary school within a large and ethnically diverse urban setting.

3.5 EvoRoom Instructional Narrative

The word ‘EvoRoom’ refers to an actual room that was constructed using smart classroom technologies to simulate an immersive rainforest environment. When students enter this “smart classroom”, their interactions – where they go in the room, and with whom – are carefully orchestrated, and depend on real-time ideas and observations that they enter into their tablets (see Figure 2). However, the research team also uses the term ‘EvoRoom’ to refer to the broader ten-week curriculum that was designed to fulfill the requirements for evolution and biodiversity. This curriculum included activities across a number of different contexts, including at home, at school in the students’ regular classroom, at school in the smart classroom, and on a field trip to the zoo. The main components of the EvoRoom instructional narrative, excluding the traditional classroom lecture components, are detailed in the following sub-sections.

Figure 2 – The EvoRoom smart classroom: a room-sized immersive simulation where students interact with peers and with elements of the room itself (walls, table, tablets) to conduct collaborative inquiry in the domain of evolution and biodiversity.

3.5.1 Pre-Activity “Epistemic orientation” (Week 0)

Prior to the initiation of the ten-week EvoRoom curriculum, students were introduced to the idea of “Science 2.0” through a short lecture delivered by the faculty member and one of the researchers on the co-design team. Reference was made to “Web 2.0” and web
applications such as Wikipedia, with which the students were already familiar, and was extended to the domain of science to introduce large-scale, collaborative projects such as Galaxy Zoo and the Human Genome Project. Students were asked to imagine scientists working as collaborators across large distances and scales, rather than as independently isolated units working alone in a lab. Students were also made aware of how research funding for science has become increasingly focused on broad social issues, such as HIV or climate change, and that a large part of science research has become about solving the world’s social problems.

After articulating the changing nature of 21st century science, students were then told that they would be involved in a research project where they would experience Science 2.0 as part of their school science activities. Here, students were asked to think of each other as collaborators rather than as independent, parallel learners competing for grades. After introducing EvoRoom, students were asked to engage as participants in the co-design process by researching an assigned organism and time period, and were told that their findings would be graphically rendered and incorporated into the design of the EvoRoom immersive simulation. They were also told that their species research would contribute to “Science 2.0” since they would be submitting their findings to a website called Encyclopedia of Life (EOL) – an online database cataloguing information about all species on Earth (http://eol.org/).

### 3.5.2 Online Learning Portfolio (Ongoing)

Over the course of the ten-week curriculum unit, students contributed homework, research, and other learning artifacts to an online learning portfolio, which was created using a content management platform called Drupal (Figure 3). While assignments submitted through this online learning portfolio varied in terms of whether they were completed independently or in groups, the majority of these artifacts were made accessible to all students within the knowledge community and served as part of the shared knowledge base that fed into subsequent inquiry activities throughout the unit. An example of a shared artifact that was completed independently was students’ research on an assigned organism or time period. Artifacts that were completed collaboratively (typically in groups of three to four) included predictions about the impact of a particular climatic event on biodiversity. Work that was submitted through the online learning portfolio but was not shared with other
students included student reflections, as well as survey and questionnaire items that were used to provide feedback to researchers to inform the development of the EvoRoom curriculum design.

Figure 3 – The online learning portfolio enabled students to contribute knowledge across contexts, both at home and at school, and served as part of the shared community knowledge base that fed into subsequent inquiry activities.

3.5.3 EvoRoom Evolution Activity (Week 2)

After conducting inquiry activities in their regular classroom and for homework, students were engaged in a collaborative smart classroom activity within the EvoRoom itself. The interactions within the EvoRoom were carefully designed to explore research questions related to large, immersive environments (Lui & Slotta, 2012). Here, the walls of the EvoRoom were rendered as large animated simulations of the Borneo-Sumatra rainforest at eight different historical time periods (200, 150, 100, 50, 25, 10, 5 and 2 million years ago). The teacher coordinated students’ investigation of the evolution of the rainforest as students were scaffolded by carefully designed tablet applications to add observations and reflections.

For each of the historic time periods, students were asked to observe and identify an assigned specialty species. If their assigned species was not present, students were asked to identify its common ancestor. As students entered observations into their tablets, their
contributions were graphically aggregated in real-time in the form of a co-constructed cladogram (a diagram showing evolutionary relationships among organisms) that emerged dynamically on the interactive white boards (IWB) at the front of the room (see Figure 4). Using the cladogram as a reference, students worked in groups of three to four to infer the possible evolutionary mechanisms that might have occurred for particular speciation events. Students’ responses were submitted through their tablets in the form of text-based notes, which were also added as a layer to the front IWB. The activity concluded with a teacher-facilitated class discussion in which she referred to students’ notes and the co-constructed cladogram to probe questions about evolutionary mechanisms and co-evolutionary relationships.

Figure 4 – The aggregate display on the front IWBs depicted a cladogram that traced the evolutionary history of each organism over 200 million years. This cladogram had been co-constructed using the real-time observations that students had input to their tablets.

3.5.4 Zoo Field Trip (Week 8)

The zoo field trip was situated between the two immersive experiences in the EvoRoom smart classroom. Prior to the actual field trip, students were given a full period of training on how to use the mobile app Zydeco (Cahill et al., 2010; Kuhn et al., 2010), which they would be using to collect evidence and observations whilst in the field at the zoo. On the day of the zoo field trip, students were divided into groups of three to four, and each group was given two mobile devices: an iPod touch and an iPad or iPad mini. It should be noted that all sections of Grade 11 Biology – including course sections outside of the sample population – participated in this mobile activity and used Zydeco to contribute evidence to
the shared knowledge base, (however groups that were not part of the sample population were only provided with one device instead of two).

At the zoo, groups were assigned to a particular species group (e.g. birds, fish, primates, reptiles and amphibians, plants and insects, and other mammals), as well as a designated geographic region of the zoo (e.g. African rainforest, African savanna, Australasia, Indomalaya, Eurasia, and Americas). Their task was to collect evidence, using a variety of multimodal formats (e.g. text notes, audio notes, video notes, photographs), in order to take a position on three issues: 1) the unifying principles underlying biodiversity; 2) human impacts on biodiversity, and 3) what makes an effective educational exhibit. In order to assist with their data collection, students were presented with the following four guiding questions within the Zydeco app:

1. What are the traits of the organism you’re looking at right now?
2. How does the structure of the exhibit (e.g. format, information available) affect your thinking about the organism?
3. What human activities are affecting these species?
4. What type of information is present in this exhibit?

As students explored the zoo, collecting multimodal evidence in support of the guiding questions, they were asked to tag their data so that it would be easily searchable and retrievable once it was pooled with the other artifacts collected by their classmates (see Figure 5).
Following the lunch break, students continued to explore the zoo while the researchers collected all of the students’ devices and returned to the school (i.e. an area with internet connectivity) to sync the data. Here, the full set of evidence collected by all students was aggregated to a shared evidence base, which was made available to students upon their return to school for final period. During the final period, students worked in the computer lab using the Zydeco web platform to generate claims about the unity of biodiversity. Using a ‘claim–evidence–reasoning’ structure, students had the opportunity to draw upon the full set of evidence gathered by their peers from the zoo in order to generate and support their claims (see Figure 6). Students were given one week to complete this individual, summative assignment.
3.5.5 EvoRoom Biodiversity Activity (Week 10)

During the final week of the EvoRoom curriculum, students participated in a second activity within the smart classroom. Leading up to this activity, students had learned about biodiversity throughout their regular classroom activities and were asked to make predictions on their learning portfolio as to how an assigned climatic ‘scenario’ would impact biodiversity (e.g. high temperature, low temperature, earthquake, tsunami, high rainfall, low rainfall, high temperature, low temperature). When students entered the smart classroom, the screens around the room depicted the present-day Borneo-Sumatran rainforest. After making
some initial observations, each of the four walls was transformed to represent one of the climatic scenarios that had been previously assigned. Working in groups of three to four, students used the mobile app Zydeco to collect evidence from each of the four stations in order to identify which rainforest best represented their assigned scenario. The multimodal evidence collected using Zydeco was tagged and aggregated in real-time to the front IWB. The resulting aggregate of evidence served as a reference for a full-class discussion, facilitated by the teacher, and provided visual clues as to which scenario was depicted by which station (see Figure 7).

Following the evidence-gathering stage, students worked in their groups to generate claims as to which of the four stations most likely represented their climatic scenario. Using the claims–evidence–reasoning structure within Zydeco, students took turns presenting their findings to their classmates. After all four scenario solutions were revealed, the teacher facilitated a deeper whole-class discussion related to human impacts on biodiversity.

Figure 7 – The image on the left shows the aggregate display of student collected evidence for each of the four rainforest stations around the EvoRoom. The image on the right depicts how these artifacts could be filtered by tags; in this example, use of the “tsunami” filter reveals that the majority of the evidence for this particular climatic scenario was identified at Station D.

3.6 Methods

In alignment with the MBDR methodology, analysis of the EvoRoom curriculum design occurred in two stages. The first stage – the design analysis – entailed mapping the epistemic commitments of the KCI model onto the EvoRoom curriculum design. The second
stage – the enactment analysis – entailed identifying when, where, why and how the enacted curriculum was faithful to the design (and, by extension, the KCI model).

3.6.1 Data sources

Data sources for the design analysis included design artifacts that were shared among members of the co-design team, including wiki pages, scripting diagrams, and meeting minutes. Data sources for the enactment analysis included the following:

- Digital learning artifacts, including posts to the online learning portfolio, contributions to the EvoRoom database throughout the Evolution Activity, and evidence/claims collected using Zydeco (for both the Zoo Field Trip and Biodiversity Activity);
- A ten-item pre/post Likert questionnaire measuring students’ perceived value of knowledge communities, completed before and after the entire ten-week curriculum unit (n=27), as well as before and after the Zoo field trip (n=65) (see Appendix A);
- An eleven-item open-ended EC survey completed prior to the enactment of the ten-week EvoRoom curriculum unit (n=43) (see Appendix B), and a twelve-item open-ended EC survey completed following the EvoRoom curriculum enactment (n=40) (See Appendix C).
- Student interviews, completed after the final EvoRoom biodiversity activity (n=4)
- Researcher field notes for the EvoRoom Evolution Activity, Zoo Field Trip and Biodiversity Activity

3.6.2 Design Analysis Methods

For the first part of the design analysis, the epistemic commitments of KCI were coded and reconfigured according to the five dimensions of Chinn et al.’s expanded EC framework: (1) Epistemic Aims & Value, (2) Structure of Knowledge, (3) Sources of Knowledge, Justification, and Epistemic Stance, (4) Epistemic Virtues and Vices, and (5) Reliable Processes. Through the process of coding these statements and mapping them onto Chinn et al.’s framework, gaps in the epistemic commitments of KCI were identified. The second part of the design analysis entailed reviewing the design documents for each of the
EvoRoom curriculum activities, and identifying the epistemic cognitions that were present in each of these activity sequences.

### 3.6.3 Enactment Analysis Methods

The enactment analysis used a mixed-methods approach to identify the epistemic cognitions as they were manifested in the enacted design. Each of the five dimensions of Chinn et al.’s framework were analyzed as follows:

1. **Epistemic Aims and Value:**
   
   Epistemic aims were measured using an open-ended survey (n=40) that was administered to students following the enactment of the ten-week EvoRoom curriculum, with three of the items on this twelve-item survey that were specifically targeted to students’ epistemic aims (Appendix C, Questions 2, 4, and 7). Responses were coded using open-coding, and the frequencies of each code were tallied. Additionally, quantitative data pertaining to students’ use of evidence within the Zydeco app was extracted to measure the extent to which students relied upon the contributions of other students versus their own.

   To measure epistemic value, students were given a ten-item pre/post Likert summative rating scale assessing their perceived value of knowledge communities according to three constructs: (1) value for self, (2) value for science, and (3) value for society (Appendix A). This questionnaire was administered to students before and after the ten-week EvoRoom curriculum unit (n=27) as well as before and after the Zoo field trip (n=38). This questionnaire was also administered to another section of Grade 11 Biology students (i.e. students who had not participated in the EvoRoom curriculum) both before and after the Zoo field trip (n=27).

2. **Structure of Knowledge**

   Although there is a distinction between the structure of knowledge as it exists in an individual’s mind and the structure of content within a shared knowledge base, the designers of this research were aware of this difference and were operating under the assumption that in a collective learning environment the structure of knowledge in one will follow from the other. That is to say, throughout this research the structure of knowledge contributions
within the shared knowledge bases were used as an indicator of the knowledge structures that exist within the collective knowledge community.

To evaluate the structure of collective knowledge, the shared knowledge bases were analyzed within each of the EvoRoom curriculum activities. The Online Learning Portfolio was assessed for completion of assigned topics, in addition to quantitative metrics such as the number of blog posts, reflections, and comments that were present. The EvoRoom Evolution database was also assessed for completion, with comparisons being made between groups who completed the activity using tablets versus pencil and paper. For the Zoo field trip activity and the Biodiversity activity, the structure of knowledge was assessed using quantitative metrics from the Zydeco database (e.g. number of evidence artifacts collected, number of tags used, and the frequency with which evidence artifacts were cited in claims statements). Additionally, descriptive metadata was collected from Zydeco, including the media composition and structure of evidence artifacts.

3. Sources of Knowledge, Justification, and Epistemic Stance

To assess sources of knowledge, an open-ended pre/post survey item (n=43) asked students to identify their main sources of knowledge before and after engaging in the EvoRoom curriculum (Appendix B, Question 1, and Appendix C, Question 3). Responses were coded using open-coding and then classified into three broader categories: “authority,” “self,” and “peers.”

Justification of knowledge was examined using a qualitative, descriptive analysis of the Online Learning Portfolio wiki pages as well as Question 3 from the EvoRoom Evolution activity. Zydeco claims statements from the Zoo field trip activity and the Biodiversity activity were also reviewed, with researcher field notes facilitating a comparison of the way knowledge was justified in each of these contexts. Finally, an open-ended survey item administered to students following the EvoRoom curriculum was used to identify the knowledge negotiation strategies that were used throughout the Biodiversity Activity (Appendix C, Question 8).

An analysis of students’ epistemic stance was conducted for the Biodiversity Activity only. Here, students responded to a post-survey item (n=40) asking whether their group reached a consensus on their final claims statement (Appendix C, Question 8a). Responses
to this item were then cross-referenced with the “solutions” to the Biodiversity Activity, indicating whether or not their final claims statement was actually correct. In cases where there was consensus within the group and the claims statement was correct, responses were coded as “true certainty.” In cases where there was consensus within the group but the claims statement was incorrect, responses were coded as “false certainty.” Finally, in cases where a group consensus was not reached, responses were coded as “uncertain.”

5. Epistemic Virtues and Vices

In addition to inferring epistemic virtues/ vices from some of the other EC findings, a post-survey item (n=40) was administered to students asking whether they believed students would be motivated to contribute towards an activity if it was not for marks (Appendix C, Question 9). Responses were coded using open-coding and presented descriptively.

6. Reliable Processes

In addition to inferring the reliability of learning processes from some of the other EC findings, a post-survey item (Appendix C, Question 12) (n=40) was administered to students asking how much of the EvoRoom curriculum they were likely to remember next year in comparison to the other units of the course. Code categories of “more,” “same,” or “less” were assigned to responses.
CHAPTER 4: EVOROOM DESIGN ANALYSIS

4.1 Chapter Overview

This chapter begins by mapping the epistemic commitments of the Knowledge Community and Inquiry model onto the five dimensions of Chinn et al.’s (2011) EC framework. This re-structuring aims to reveal potential gaps in how the KCI model supports students’ epistemic cognition. The design analysis follows, whereby the EvoRoom curriculum design is mapped onto Chinn’s EC framework (including the KCI mapping), to examine the gaps identified in the mapping.

4.2 Applying the Chinn et al (211) EC Framework to the KCI model

In order to examine the epistemic commitments of the KCI model more closely, as well as to identify any epistemic gaps in the model, the five epistemic commitments of KCI were re-configured using Chinn et al’s (2011) EC framework (see Figure 8). To undergo this mapping process, each of the statements within KCI’s epistemic commitments (see Table 2) were coded according to Chinn et al’s five dimensions of EC: (1) Epistemic Aims & Values, (2) Structure of Knowledge, (3) Sources of Knowledge, Justification, and Epistemic Stance, (4) Epistemic Virtues and Vices, and (5) Reliable Processes. Coded statements were then compiled and the epistemic commitments of KCI were re-framed using these five dimensions.
Figure 8 - The epistemic commitments of KCI, re-framed using Chinn et al.’s (2011) Expanded EC framework
The EC mapping process revealed three potential gaps in the epistemic commitments of KCI that could inform further design considerations or revisions to the model. The first two gaps fell into Chinn’s dimension of “Sources of Knowledge, Justification and Epistemic Stance.” The third gap is concerned with “Epistemic Virtues and Vices.” These are discussed below, including possible connections to the general KCI model.

First, the KCI model does not explicitly address any expectations or mechanisms for the ways in which knowledge should be justified within the knowledge community. It is possible that the justification of knowledge may be inherent in some of the knowledge-building processes or inquiry structures that are implemented within the curriculum designs, however the model does not suggest or commit to any forms of justification in particular. Chinn et al. (2011) recommend using a mix of evidential and non-evidential justificatory standards to support epistemic beliefs. Examples of ways that knowledge in KCI curricula might be justified include formal argumentation, evaluation of authoritative sources and/or expert testimony, as well as the coherence of new information with other established explanations or beliefs (Chinn et al., 2011).

The second gap in the epistemic commitments of KCI is concerned with the need or role for “epistemic stances” or positions that students might take in response to various knowledge contributions. Epistemic stances are particularly important in a knowledge community setting because they reflect the degree of certainty or level of satisficing a student may take with respect to the ideas he/she encounters within the knowledge space. For example, a student may be uncertain about a particular idea or course of action within his group, however to avoid conflict or the extra effort required to justify his position, this student may instead opt to take a passive or agreeable stance towards the rest of his group members. This type of satisficing can be detrimental to a knowledge community, as it may corrode the justificatory rigor that is necessary for collective knowledge advancement.

The third gap is concerned with Epistemic Virtues and Vices. While this form of EC is included in the epistemic commitments of KCI, it has been left as somewhat implicitly falling within the definition of a “knowledge community.” Explicit virtues and vices are not explicated, as in Chinn’s framework. The assumption in KCI is that an epistemic commitment toward knowledge community membership or participation would be ‘virtuous’ towards achieving the epistemic aim of learning together and advancing community
knowledge. In order to become a ‘successful’ member of the knowledge community, the epistemic virtues one must hold are (1) to contribute meaningfully to the shared knowledge base, and (2) to take part in the shared social practices, conventions, or discourse “rules” within the community. The opposite of this (the “epistemic vices”) would be to (1) hoard one’s knowledge away from the group and/or not contribute to the knowledge base, and (2) favour one’s own individual gains over and above the shared goals of the community (i.e. to have a competitive rather than collaborative mentality). Making these epistemic virtues and vices more explicit within KCI model (and hence, curriculum designs) might be an important step towards achieving its epistemic aims.

4.3 Epistemic Cognition Within the EvoRoom Curriculum Design

Using the re-framed epistemic commitments of KCI (i.e. the five categories offered by Chinn et al., 2011), the following sections detail how Epistemic Cognition was incorporated into the design of the EvoRoom curriculum.

4.3.1 Epistemic Aims and Value

The epistemic aims of EvoRoom were for each student to self-identify as a member of a knowledge community, to develop shared ideas and understandings about evolution and biodiversity, and to recognize the presence of shared learning goals as drivers for the inquiry activities within the community. The four main curriculum activities – the Online Learning Portfolio, the EvoRoom Evolution Activity, the Zydeco Zoo Activity, and the EvoRoom Biodiversity Activity – were all designed to create opportunities for students to contribute to a shared knowledge base and to use the knowledge base as a resource for subsequent inquiry. Thus, engaging in these activities would serve to further the knowledge advancement for the class as a whole. An intended consequence of these designs is for students to perceive knowledge community membership as having epistemic value towards their knowledge attainment and progress within evolution and biodiversity topics. Students should recognize the value of co-constructed knowledge and how their learning can progress through collective efforts using others’ contributions as a resource.
4.3.2 Structure of Knowledge

The EvoRoom curriculum design employs several different shared knowledge bases, each with its own internal structure and organization, as detailed below.

4.3.2.1 Online Learning Portfolio

The Online Learning Portfolio (OLP) design includes opportunities for students to contribute content both individually (e.g. blog posts and reflections) and collaboratively (e.g. wiki pages). Although the OLP was designed for use by students throughout the full academic year, the EvoRoom curriculum includes three specific assignments within the OLP for which students are to co-construct wiki pages in preparation for their smart classroom activities. The first assignment entails the creation of a Borneo Field Guide. For this task, a “divide and conquer” approach is used to assign students to a particular research topic (e.g. habitat, taxonomy, morphology, conservation status) within a particular species group (e.g. birds, primates, other mammals, plants & insects). The wiki page structure and titling hierarchy of the field guide are provided to students as scaffolds, however the remainder of these pages are left blank for students to populate with their assigned research. A similar approach is used for the design of the Borneo Timeline assignment, for which students are asked to research how (or whether) their assigned species group presents itself within one of eight historical time periods (200, 150, 100, 50, 25, 10, 5, or 2 mya). Both the Borneo Field Guide and the Borneo Timeline were designed to be completed in advance of the Evolution Activity.

Prior to the Biodiversity Activity, the design includes an opportunity for students to use the Online Learning Portfolio as a platform for making predictions about the impacts of a particular climatic scenario on the biodiversity of the rainforest. The structure of knowledge for the Predictions assignment is less rigid than the Field Guide or Timeline assignments in that no page hierarchy or titling scaffolds exist, and students can choose to contribute their research as a group rather than taking individual responsibility for particular species/topic combinations. In this sense, the assembly of knowledge in the Borneo Field Guide and Timeline could be considered a “co-operative” task, whereas the Predictions pages could be considered as a “collaborative” task.
4.3.2.2 Evolution Activity

The structure of knowledge within the EvoRoom Evolution Activity was designed to become visually apparent through the co-constructed cladogram and supplementary notes that emerge on the front IWBs during the course of the activity. The construction of the cladogram renders in real-time based on the species observations that students report through their tablets. During the second part of this activity design, students contribute notes that supplement the information on the cladogram as they make comparisons between evolutionary time periods. In each of these instances, the visual structure of knowledge that assembles on the aggregate display is entirely automated by the technology, with sorting occurring according to the species group(s) and time period(s) that students report through the tablet interface.

4.3.2.3 Zydeco Zoo Activity

The structure of knowledge base within the Zydeco app is emergent, following the tagging and filtering mechanisms for student-collected observational data. Students are able to collect observational data in the form of images, audio notes, video notes, and text notes. Students tag their observations, and may also link their observations to a particular research question that has been input to the Zydeco database prior to the activity, to guide data collection. A search function within Zydeco enables students to retrieve data artifacts using key words, however the Zydeco app also includes filters that allow students to browse the knowledge base by user, media type, guiding question, or tag. Multiple filters may be applied simultaneously to help narrow the search results. Students then use this observational data to support the generation of knowledge claims in response to overarching curriculum questions related to the unity of biodiversity. The generation of knowledge claims within Zydeco uses a “claim-evidence-reasoning” structure that draws upon the shared pool of data artifacts within the knowledge base. As such, the quality of data tagging plays an important role in the ability of artifacts to be searched for, retrieved, and used within claims statements.

4.3.2.4 Biodiversity Activity

The structure of knowledge within the EvoRoom Biodiversity Activity is similar to the Zoo field trip activity, in that both used the Zydeco technology environment to collect
data, tag data and subsequently use this data towards the generation of knowledge claims. However, one key difference in the design of the Biodiversity Activity is the inclusion of a dynamically generated “aggregate display” that graphically organizes and filters data in real-time according to their semantic tags. By making this semantic knowledge structure visually apparent, students may identify gaps in the collective knowledge base more easily, and collect additional observations where more evidence is needed.

### 4.3.3 Sources of Knowledge, Justification, and Epistemic Stance

#### 4.3.3.1 Sources of Knowledge

Within the EvoRoom curriculum, students are asked to draw from a variety of knowledge sources in order to make contributions to the shared knowledge base. Sources of knowledge may include external authoritative sources (e.g., scientific publications, encyclopedias, or other internet resources) which they use to populate their Online Learning Portfolio, primary observations that they make while in the EvoRoom or on the Zoo field trip, or inductive/deductive reasoning that arises as they engage in discourse with their peers. Throughout all of the EvoRoom activities, students are asked to regard the shared knowledge base(s) as their community resource, representing the pooled ideas and knowledge artifacts contributed by their peers.

#### 4.3.3.2 Justification of Knowledge

Although “Justification of Knowledge” was identified as a gap in the epistemic comments of KCI, there are parts of the EvoRoom curriculum design that include opportunities for students to explicitly justify their knowledge. Specifically, the generation of claims within Zydeco requires students to support their statements using both evidential (i.e. shared evidence artifacts) and non-evidential standards (i.e. logic/reasoning). The two activities that use Zydeco – the Zoo field trip and the Biodiversity Activity – therefore have some aspects of “justification” built into their design, due to the nature and structure of the Zydeco app. It is worth noting that this affordance for justification was a direct result of the design commitment to the Zydeco environment, which was developed by another research team (Kuhn et al., 2010; Zhang and Quintana, 2012) with the explicit aim of supporting evidence-based justifications. Hence, KCI may not, on the basis of its own principles, have motivated the inclusion of such justificatory elements, but its fortuitous selection of Zydeco
as an observational data collection environment enabled this form of epistemic cognition to be present within the design.

Within the Online Learning Portfolio and the Evolution Activity, however, formal methods to justify one’s knowledge are lacking. Within the OLP, the Borneo Field Guide and Borneo Timeline were designed to simply collect factual knowledge, with each student working on his/her particular section. As such, there is no knowledge to negotiate here, and therefore no justification of knowledge that would be necessary to occur between students. The predictions pages within the OLP (to be completed in advance of the Biodiversity Activity) do require some degree of justification in that students are asked to provide reasoning behind their predictions. However, since these predictions are to be submitted as a group posting, the actual knowledge negotiations that occur within the group may not be captured explicitly as they may arise during verbal discussions.

Finally, within the design of the Evolution Activity, the knowledge work is again mostly concerned with accruing facts, based on the observation of species within different time periods. For this task, there is little requirement for knowledge to be negotiated or justified (beyond students asking each other “did you really see that?”). There is one question in the design that has the potential to include some justificatory standards: “What evolutionary processes might have occurred during this time period?” However, because of the wording of this question, the reasoning underlying the responses is ultimately left to the discretion of the students, who may instead opt to list their ideas about evolutionary processes in point form.

**4.3.3.3 Epistemic Stance**

For activities in which students collaboratively negotiate knowledge, there are opportunities for students to take a variety of epistemic stances with regards to shared ideas or decisions. Activities within the EvoRoom design for which epistemic stance may significantly impact student inquiry include the generation of Predictions within the OLP, the process of collecting and tagging evidence within Zydeco, and the generation of group claims within the Biodiversity Activity. In each of these cases, it is possible that a student may be engaged in collaboratively generating a knowledge contribution, however he/she may have an epistemic stance that is in contrast or conflict with that of her collaborating peers. Satisficing one’s true epistemic stance in order to appease group members (e.g. by
establishing consensus within the group by means of a “vote”) would detract from the justificatory rigor of the inquiry.

4.3.4 Epistemic Virtues and Vices

The epistemic virtues and vices for the EvoRoom curriculum design descend from the epistemic comments of KCI in general (as per the mapping performed in Figure 8). Students who contribute meaningfully to the shared knowledge base for any particular activity, who avoid satisficing in their knowledge negotiations, and who prioritize collective advancement over individual gains would be considered “virtuous” within the epistemic aims of the design, according to Chinn et al.’s (2011) framework. Conversely, a lack of contributions to the knowledge base, satisficing one’s epistemic position for purposes of group efforts, or maintaining a competitive, “grades-first” mentality throughout the activities would serve as epistemic “vices” in terms of the design. To prepare students to engage as collaborators, the curriculum design includes a pre-EvoRoom orientation activity that describes the increasingly social and collaborative nature of 21st century science. In an effort to directly address the epistemic aspects of KCI, students are told explicitly that this would be a new form of learning where they would be working collaboratively and collectively with their peers, rather than as competitors, throughout their upcoming curriculum activities.

4.3.5 Reliable Processes

The learning processes designed throughout the EvoRoom curriculum include theoretically inspired elements of knowledge-building and scaffolded inquiry, which take place within a shared community knowledge space. Because of their strong theoretical foundations, the reliability of these processes for supporting student learning is not the subject of this current investigation. However, the enactment analysis detailed in the next chapter examines how faithfully the designed learning processes were enacted by the students. In other words, was it the case that students were truly engaged in knowledge-building processes, and did they make sufficient use of the scaffolds provided to them throughout the inquiry process? If they did, were they successful in achieving the epistemic aims of the design? If they did not enact these processes faithfully, how did this impact the
achievement of the epistemic aims? The enactment analysis will thus examine the interaction between the engagement and fulfillment of the learning process designs, and the achievement of epistemic goals. The analysis will hopefully reveal whether students’ achievement of the epistemic aims of the design could be interpreted as an indicator that the specific learning activities within the curriculum were responsible for those epistemic gains.

4.4 Discussion

The design analysis presented in this chapter has revealed weaknesses in two key areas that may reflect gaps in the KCI model, with regard to its direct treatment of epistemic cognition. The first weakness was related to the way knowledge justification occurred throughout each of the four curriculum activities. Activities for which knowledge contributions lacked justification included the Borneo Field Guide and Timeline assignments within the Online Learning Portfolio, as well as the assembly of the cladogram within the EvoRoom Evolution Activity. This was primarily because knowledge contributions throughout each of these activities were either factual or based on primary observations and therefore did not require much negotiation between students. Activities for which knowledge justifications were partially present but optional included the Predictions pages within the OLP, as well as the evolution questions that students responded to at the end of the Evolution Activity. Justification of knowledge was strongest within the Zoo Field Trip Activity as well as the Biodiversity Activity because the Zydeco app was designed such that both evidential and non-evidential justification was required to support the generation of knowledge-claims.

The second weakness in the EvoRoom design was related to students’ epistemic stance. In cases where students had to work collaboratively in groups, there are currently no measures in place to identify and/or prevent the satisficing of one’s true epistemic beliefs. Taking a passive epistemic stance may occur in cases where knowledge is uncertain but one wishes to appease group members, avoid conflict or the additional effort required to justify one’s position. Satisficing is also likely to occur in cases where students are expected to come to a “true” or “correct” answer, as in the EvoRoom Biodiversity Activity.

Possible implications for these gaps include a decrease in the justificatory rigor of the inquiry activities. In cases where students are not obligated to negotiate or justify knowledge statements with other students, conflicts in the knowledge base may not become evident or
may be passively accepted. Likewise, in such situations students may have an epistemic stance that is in conflict with his or her group members, but rather than vocalizing their concerns and contributing to further negotiations, students may instead satisfice their position in favour of group consensus, making both the knowledge base and student participants vulnerable to misinformation. The following chapter addresses how these weaknesses were manifested in the enacted design, examining the ramifications in the observed interactions and knowledge products of students throughout the curriculum activities.
5.1 Chapter Overview

This chapter analyzes how the five dimensions of Chinn’s Epistemic Cognition (EC) framework were manifested in the enactment of the EvoRoom curriculum design, with particular attention paid to comparisons against the intended, or designed aspects of EC, as reviewed in the preceding chapter. A mixed-methods approach was used to measure a variety of psychometric constructs, including students’ perceptions of the value of knowledge communities, their ability to identify shared learning goals, and their opinions on knowledge sources and justification. Data for this analysis was also drawn from artifacts within the shared knowledge bases to examine constructs such as the reliance upon peer knowledge as a resource (via the composition of evidence within Zydeco claims) and the completion and composition of knowledge base contributions. By revealing how EC was manifested in the enacted design, the outcomes of this analysis will be used to generate two types of feedback, detailed in the concluding chapter: (1) a series of design recommendations that will feed into subsequent EvoRoom design iterations, and (2) a series of insights that may be used to refine the KCI model at the principle level.

5.2 EvoRoom Enactment Analysis

The five epistemic dimensions of the EvoRoom curriculum design were:

1. Epistemic Aims and Values,
2. Structure of Knowledge,
3. Sources of Knowledge, Justification, and Epistemic Stance,
4. Epistemic Virtues and Vices, and
5. Reliable Processes.

The sections below will evaluate each of these categories in terms of their enactment within the curriculum, with the aim of identifying potential points of engagement, or gaps where improvements could be made.
5.2.1 Epistemic Aims and Values

5.2.1.1 Epistemic Aims

As detailed in the previous chapter, the epistemic aims for the EvoRoom curriculum design were (1) for students to identify as a knowledge community, (2) for inquiry activities to be guided by shared learning goals within the knowledge community, and (3) for members of the knowledge community to develop shared ideas and understandings about evolution and biodiversity. To assess whether students in the class identified as a knowledge community, one item on the EvoRoom EC Post-Survey asked whether they felt that the EvoRoom activities had focused more on individual learning or on the collective knowledge advancement of the class as a whole. Responses were coded as “more individual” or “more collective.” Students who responded that the activities were focused on both collective and individual knowledge advancement were assigned both codes. Results indicated that 67% of responses (n=34) stated that the EvoRoom activities were more focused on collective knowledge advancement, and 33% (n=17) stated that the activities were more focused on individual learning (Figure 9).

![Perceived Knowledge Advancement](image)

Figure 9 – The majority of students perceived the EvoRoom activities as having a greater emphasis on collective knowledge advancement rather than individual learning gains.

Students were also asked the extent to which they felt that their contributions to the shared knowledge base helped the learning of others. Responses were coded as “unlikely/not at all,” “helped a little,” or “helped a lot.” Results indicated that 45% of students (n=18) felt that their contributions “helped a lot,” 38% (n=15) felt their contributions “helped a little,” and only 17% of students (n=7) felt their contributions were unlikely to help the learning of others (Figure 10). Students who responded that their contributions “helped a lot” mostly cited the uniqueness of their contributions as the most useful feature. In many instances, a
“divide and conquer” approach was used to assign research tasks to different students/groups, which meant that much of the information that students needed frequently depended on the research of other members of the knowledge community. Students who responded that their contributions “helped a little” generally felt that their contributions were merely ‘drops in a bucket.’ That is, the sheer quantity of research data that was gathered by all students meant that each student’s contributions only represented a small fraction of the greater whole. Finally, students who stated that their contributions were unlikely to help the learning of others provided reasons such as technical constraints (i.e. problems with uploading their data), poor tagging of their data, which would have made search/retrieval of their contributions difficult, as well as simply not contributing to the knowledge base.

![Perceived Value of Knowledge-Base Contributions](image)

Figure 10 – The majority of students (83%) felt that their own contributions to the shared knowledge base were helpful to the learning of others.

Students’ Zydeco claims from the Zoo field trip were also analyzed for the extent to which they relied upon data artifacts that were collected by other members of the knowledge community versus their own. On average, 84.85% of data artifacts that were used as supporting evidence in claims statements came from other members of the knowledge community, and 15.15% was data that students’ had collected themselves. Within the sample population (n=55), there was only one student who relied exclusively on evidence that he had collected himself (see Figure 11).
The second epistemic aim was the identification of shared learning goals by members of the knowledge community. In the EvoRoom Post-Survey, students were asked to identify the activities (if any) in which they most strongly felt the whole class was working towards a shared or common goal. Responses were coded using activity codes for the various curriculum activities: “Evolution Activity,” “Zydeco Zoo,” “Biodiversity Activity” or “No Shared Goals.” It should be noted that the wording of the question did not explicitly refer to the Online Learning Portfolio, and as such it was not included in this analysis. Results indicated that shared learning goals were identified in all three of the above activities, however these were most strongly felt in the Zydeco Zoo Activity (40%) and the Biodiversity Activity (38%). Fewer responses (17%) identified the Evolution Activity as having shared goals, and only two responses (5%) stated that there were no shared goals throughout any of these activities (Figure 12).
The third epistemic aim of the EvoRoom curriculum that was identified in Chapter 4 was the development of shared ideas and understandings about evolution and biodiversity by all members of the knowledge community. One preliminary test to assess for shared understanding was done through a Latent Semantic Analysis (LSA) of the Zydeco Zoo claims submissions for the three sections of students who participated in this zoo field trip (with two sections having participated in the EvoRoom curriculum and one that did not). The Zydeco Zoo claims were chosen because students completed them individually, however all students were asked to respond to the same set of culminating ideas: (1) the unifying principles of biodiversity, and (2) human impacts on biodiversity. Although the critiques of this approach were recognized and understood, it was hypothesized that the students who engaged in the EvoRoom curriculum would show a higher semantic similarity between their
notes, which would be indicative of a greater shared understanding, compared to the students who did not participate in EvoRoom. After using LSA to compute the semantic similarity score for each pair of students, the mean similarity score for each class section was calculated and an ANOVA was used to compare the mean similarity scores across the three different sections. Contrary to what was hypothesized, results indicated that the students who did not engage in the EvoRoom curriculum had a significantly higher similarity score compared to students who did participate in the EvoRoom curriculum.

One possible explanation for this finding comes from a study by Ming and Ming (2013), who used pLSA-based topic modeling to capture the semantic differences in the discussion posts from students across seventeen different online courses (n=230). Their findings indicated that students who earned the highest grades in these courses had the tendency to discuss a broader and more varied range of topics in more specialized areas, rendering their notes more semantically distinct compared to others in the class (Ming and Ming, 2013). Conversely, students who earned lower grades in these courses tended to neglect several topics and favour others, rendering their posts more semantically similar to each other (Ming and Ming, 2013). Although students’ grades were not a consideration in the present study, Ming and Ming’s (2013) findings illustrate how semantically dissimilar notes may be indicative of a deeper understanding of curricular topics. Establishing more appropriate measures to assess shared understanding within KCI curricula therefore remains an important area for future research.

5.2.1.2 Epistemic Value

In order for students to be motivated to pursue these epistemic aims, students must first recognize that these aims have some value. To assess students’ perceived value of knowledge community membership, students were given a pre/post summative rating scale that was administered both before and after the full ten-week EvoRoom curriculum unit. This ten-item questionnaire (n=26) included three sub-concepts related to the value of knowledge communities: value for self (four items), value for science (three items), and value for society (three items). The questionnaire was designed using a 7-point likert scale with values ranging from 1=Strongly Disagree to 7=Strongly Agree. The questionnaire included three reverse-worded items to avoid response bias.
A paired t-test was conducted to compare the difference in means between the pre and post survey results. The t-test revealed that there were no significant changes in students’ perceptions of the value of knowledge communities before and after engaging in the EvoRoom curriculum ($t=0.289 < t_{0.05, 25} = 1.708; p=0.775; CI [-0.2029 to 0.2691]$). The same survey was also administered to students before and after the Zoo Field Trip activity, however in this case there were two sets of students who took the survey: (1) students who had participated in the EvoRoom curriculum unit, and (2) students from another course section who had not participated in the EvoRoom curriculum. A paired t-test was conducted to compare the difference in pre/post means between the two groups of students. Results indicated that there was a significant improvement in pre/post scores for the students who participated in the EvoRoom curriculum ($t=-2.684; p=0.011; CI [-0.2771 to -0.0387]$) and a non-significant change for students who did not ($t=0.6114; p=0.546; CI [-0.116 to 0.214]$). Figure 13 depicts the results of the pre and post Zoo Field Trip questionnaire for both groups of students.
5.2.2 Structure of Knowledge

The sections below detail how the community’s knowledge artifacts were structured, tagged, and hierarchically scaffolded within each of the EvoRoom knowledge bases.

5.2.2.1 Online Learning Portfolio

The Online Learning Portfolio was used by all students enrolled in the Grade 11 Biology course (including those outside of the sample population, i.e. in the other teacher’s sections of the course) for the duration of the academic year. For the purposes of this thesis
research, only contributions made by students within the sample (n=55) during the ten-week EvoRoom curriculum timeframe were analyzed. Within this window, there were three assignments on the learning portfolio that were specifically designed to prepare students for their upcoming activities within the smart classroom; two of these assignments were in preparation for the Evolution Activity and one was in preparation for the Biodiversity Activity.

To prepare for the Evolution Activity, students were asked to co-construct both a Borneo Field Guide and a Borneo Timeline. For each of these assignments, species groups, research topics, and time periods were assigned to students using a “divide and conquer” approach such that no two students’ contributions overlapped. The wiki page titling hierarchy was created by one of the researchers so that all students had to do was fill in their assigned information under the appropriate heading. Page headings for the species pages were taken from the “Encyclopedia of Life” – a Science 2.0 project to which students would contribute their findings upon completion of this assignment (http://eol.org). The page structure for the Borneo Field Guide is illustrated in Figure 14. The page structure for the Timeline assignment followed a similar hierarchy, except the “main pages” were time periods (200, 150, 100, 50, 25, 10, 5, and 2 mya), and the “sub-topics” were “environment” plus the four species specialty groups.
Figure 14 – Borneo Field Guide wiki page structure. There were four “main pages” for each species group (birds, other mammals, primates, and plants & insects). Clicking on one of these species groups would reveal a list of individual species that are found in the Borneo-Sumatra rainforest. Clicking on a species name would take you to the species wiki page, in which students were assigned a particular research topic, as represented by the smaller sub-headings of the page.

Because there was no overlap between students’ research topics, it was easy to identify gaps in the knowledge base as well as which particular students did or did not contribute. Figure 15 shows the level of completion for both the Borneo Field Guide and the Borneo Timeline. As illustrated, the Borneo Field Guide was 86% completed, indicating that out of fifty-five students, approximately five students did not contribute fully to their research topics and five students did not contribute at all. In comparison, the Borneo Timeline wiki pages were only 47% complete, and the Timeline summary page was only 12% complete, with only thirty out of fifty-five students contributing to these pages. A few students indicated in the wiki that they had trouble finding information on their assigned topic for the Timeline pages.
One interesting possibility is that because this was a cooperative assignment rather than a collaborative one, students did not feel collectively responsible for filling the missing knowledge gaps or assisting other students with their research. That is, if a student filled in the information for her assigned section, she was “done.” Within the Timeline assignment, for example, the research topic “Environment” was not assigned to specific students and as a result it remained incomplete for all time periods. It is also likely that the Timeline assignment was given lower priority by students because the content of the Borneo Field Guide was to be contributed to the Encyclopedia of Life project and the content for the Timeline was not. Therefore, the level of investment for the Timeline assignment – as well as the social consequences for not completing it – were much lower.

Figure 15 – The image on the left depicts the level of completion (86%) of the Borneo Field Guide assignment. The two images on the right depict the level of completion for the Borneo Timeline wiki pages (47%) and the Timeline Summary (12%).

The third EvoRoom assignment within the Online Learning Portfolio was completed in advance of the Biodiversity Activity. Here, groups of three to four students were assigned a particular climatic scenario and were asked to make predictions about how it would impact the biodiversity of present-day Borneo-Sumatra. Students were told that they could submit their Predictions as a collaborative group-post. Eleven out of sixteen groups (69%) submitted a prediction. Page scaffolds were not provided for this assignment.

Finally, students contributed other content to the Online Learning Portfolio during the EvoRoom timeframe, which included blog posts, reflections, and comments to other
students’ posts. Although students completed blog posts and reflections independently, commenting on other students’ posts occurred both within and between class sections for all students enrolled in the course (including those who did not participate in the EvoRoom curriculum). There were a total of 127 blog posts, 108 reflections, and 103 comments contributed by participating students during the ten-week EvoRoom curriculum unit (Figure 16).

![Figure 16](image.png)

Figure 16 – Other OLP content contributed over the course of the ten-week EvoRoom curriculum unit. The x-axis represents each student within the sample population (n=55) arranged from most contributions to fewest contributions.

5.2.2.2 Evolution Activity

Due to technical constraints, only three out of the four scheduled EvoRoom Evolution sessions were completed. Of these three sessions, two of them used pencil and paper to complete the activities rather than the tablet interface. As a result, the enacted structure of knowledge produced throughout the Evolution Activity was different for those students who completed it using pencil and paper versus those who completed it using the tablet.

Students who completed the activity using pencil and paper did not co-construct a cladogram on the front IWBs based on their species observations. Instead, they were provided with a static cladogram at the front of the room. Students were then asked to use this cladogram, in combination with their observations of species and environmental factors
on all four walls, to make comparisons between time periods and to infer the evolutionary mechanisms that were at play between each of them. During the first half of the activity, the walls depicted the Borneo rainforest at 200, 150, 100 and 50 mya, and students (working in four groups) were asked to compare the differences between 200 vs. 150 mya, 150 vs. 100 mya, and 100 vs. 50 mya. During the second half of the activity the walls were changed to depict 25, 10, 5 and 2 mya, and students repeated this exercise. Working in groups of three to four, students used the pencil and paper to record responses to the following three questions for each of the time period comparisons:

1. What are the major differences between the two time periods?
2. What species appeared in this time period that weren’t there before? Consider climate, habitat, animals and plants.
3. What evolutionary processes might have occurred during this time period? How were these processes related to the climate, habitats, or other species at the time?

For the pencil and paper sessions, student groups worked in parallel, with each group responsible for making comparisons between every pair of time periods. Results were shared verbally in the form of a whole-class discussion at the end of the activity. However there was not really a shared knowledge “base” for the pencil and paper version of the activity, because these verbal contributions and written responses were not artifacts that could be later retrieved or built-upon by other students in the knowledge community.

Students’ responses to the time period comparison questions are shown in Figure 17. One notable finding was that students generally responded well to Question 1 and 2, for which they merely had to report observational data. However, Question 3 – which required higher-order reasoning skills – was left blank in 70% of responses.

For the students who used the tablet interface to complete the activity, the structure of knowledge was somewhat different. Here, students began the activity by recording species observations for each time period using their tablets, which allowed them to co-construct the cladogram in real-time at the front of the room. After this cladogram was constructed, student groups were then assigned a specific pair of time periods, for which they were to make comparisons and respond through their tablets to the three questions noted above. Responses to these questions were made available to the knowledge community as artifacts.
of inquiry, appearing on the aggregate display at the front of the smart room. In combination with the cladogram, these served as drivers of the whole-class discussion that took place towards the end of the activity.

Figure 17 – Structure of knowledge in the EvoRoom Evolution Activity. Student groups in Session 1 and Session 3 completed the activity in parallel using pencil and paper. Within the paper sessions, the higher-order reasoning question (question 3) was left blank by 70% of respondents. Student groups in Session 2 worked collaboratively and were able to share their knowledge artifacts with each other such that none of their responses were left blank.

5.2.2.3 Zydeco Zoo Activity

All students who attended the Zoo field trip (including those from class sections outside of the EvoRoom sample) contributed data to the shared knowledge base within Zydeco. Working in groups of three to four, students were assigned a species specialty group and a particular geographic location of the zoo. Students worked collaboratively within their groups to decide which data to collect in response to their guiding research questions, as well as how this data should be tagged for future retrieval. In total, 655 pieces of multimodal data
were collected by all participants. The media composition of these data artifacts is illustrated in Figure 18.

![Media Composition of Data Artifacts](image)

Figure 18 – Zydeco Zoo data artifacts by media type. Of the 655 pieces of data that were collected, the majority consisted of photos (79%) or the combination of photos with text (10%). The remaining 11% of data used audio (1%), video (3%), text (4%), or a mix of media types (3%).

The structure of the knowledge base within Zydeco was largely dependent upon the quality with which these data were tagged, and to a lesser extent the guiding questions to which they were linked. Students created and used a total of 203 folksonomic tags to organize their data. Of the 655 data artifacts that were collected, 437 (67%) of them contained at least one tag, as detailed in Figure 19, which also depicts a word cloud showing the relative frequencies with which each tag word was used. The quality and appropriateness of the tags affected how easily these data artifacts could be searched for and retrieved from within the shared evidence base. An additional filtering mechanism included the option to link the data artifact to a particular research question. Of the 655 data artifacts collected, 398 of them (61%) were linked to at least one research question.
Figure 19 – The image on the left shows the number of tags that were applied to each of the data artifacts within the evidence base. 67% of data artifacts contained at least one tag, while 33% remained untagged. The image on the right depicts the relative frequencies of each of the tag words. Words that were used the most frequently appear the largest. “Common name,” “physical appearance” and “scientific name” were the top three most frequently used tags, with 61, 52, and 45 uses respectively. Therefore the word “name” appears the largest in the word cloud because it was used a total of 106 times (appearing in both “common name” and “scientific name”).

When it came time for students to draw from the pooled evidence base, only 98 unique data artifacts – representing 15% of all data collected – were used towards the generation of knowledge claims. An examination of the top ten most frequently cited data artifacts that were used within claims statements did not reveal any trends or patterns with regards to media composition, tag usage, or links to a research question (see Figure 20). Therefore, one possible area for future research would be to evaluate what makes a particular data artifact more ‘useful’ than others in supporting the generation of claims statements. This might be accomplished by means of a content analysis of the evidence artifacts to assess the semantic composition or the qualitative characteristics of the media they contained. Alternatively, one could assess how these items were used within claims statements to facilitate students’ reasoning.
5.2.2.4 Biodiversity Activity

The structure of knowledge throughout the Biodiversity Activity was similar to the Zoo field trip since both used Zydeco to collect data and to generate claims. However, the knowledge base within the Biodiversity Activity was of a much smaller scale, as there were only twelve to sixteen students at a time contributing evidence to one of four separate databases. Figure 21 depicts the media composition and the tag frequency of the data artifacts that were contributed within each session. Throughout all four sessions, students tagged all of the data that they had collected.

![Media Type](image1)

![Number of Tags](image2)

**Figure 20** – Characteristics of the top ten most frequently used data artifacts

**Figure 21** - The image on the left depicts the media composition for the data artifacts collected within each of the four EvoRoom Biodiversity sessions. The image on the right shows the number of tags that were applied to the data in each session. There were no untagged items in any of the four sessions.
The student tagging that occurred throughout the Biodiversity Activity was also much simpler. Students were verbally instructed to tag their data according to the specific rainforest (A, B, C or D) from which they had obtained it, and which climatic scenario they believed it supported. Although some students chose to add additional tags to their data, the total number of tags used throughout the Biodiversity Activity was much lower in comparison to the number used in the Zoo observations. In Session A, there were a total of ten tags used; Sessions B and C each used nine tags, and Session D used eight tags.

Perhaps the most salient feature that contributed to the structure of knowledge throughout the Biodiversity Activity was the presence of the aggregate display on the front IWBs. The display included headings/columns that visually aggregated the data that was collected from each of the four walls of the smart room. Because of the way that this data was tagged, it became visually apparent that the majority of data collected at Rainforest C, for example, was tagged “Earthquake.” Working in groups of three to four, students used this shared evidence to prepare claims-evidence-reasoning statements on their tablets using Zydeco to decide which of the four rainforests represented their assigned climatic scenario. Figure 22 shows the percentage of all data collected within each session that was used to support the generation of knowledge claims. In comparison to the Zoo field trip, for which only 15% of data was used in claims, the simplified tags and visual structure of knowledge may have contributed to the observed increase in data usage in the Biodiversity activity, which averaged 54% for all four sessions.
An additional finding for the Biodiversity Activity that emerged from this data, which is further elaborated below, was related to the quantity of evidence that students used in their claims statements compared to their ability to correctly identify their climatic scenario. As shown in Figure 22 above, Session C used the highest percentage of the data artifacts they collected as evidence in their claims statements (93%). At the same time, Session C was the only session for which all four groups correctly identified their climatic scenario. In Session A, which had the second highest percentage of evidence artifacts used towards claims statements (57%), one of the four groups correctly identified their climatic scenario. However in Sessions B and D, which used 38% and 29% of evidence artifacts, respectively, none of the groups were able to correctly identify their climatic scenario. These findings highlight the importance of evidentiary justification in supporting collective knowledge negotiations, as articulated in the “Justification” section below.
5.2.3 Sources of Knowledge, Justification, and Epistemic Stance

5.2.3.1 Sources of Knowledge

In the EvoRoom Pre-Survey, students were asked to identify their main sources of knowledge in school science. Responses were open-ended, and the frequency of each response was recorded using a tally system with students often reporting multiple sources of knowledge within a single answer. As illustrated in Figure 23, the sources of knowledge identified in this pre-survey (n=43) mainly consisted of authoritative sources (89%) such as the course textbook (34%), the teacher (32%) and other authoritative sources such as online resources or publications (23%). Only a small percentage of students identified themselves (3%) or their peers (8%) as sources of knowledge.

In the EvoRoom Post-Survey, students were asked to identify the sources of knowledge they used throughout the EvoRoom curriculum unit. Here, there was a dramatic shift in the sources of knowledge that students identified. Results indicated that 33% of responses included authoritative sources (e.g. textbook, teacher, other external sources), 28% of responses identified their peers and/or the knowledge community as a source of knowledge (e.g. peer discussion, shared knowledge base, aggregate displays), and 38% of students identified themselves as sources of knowledge (e.g. through primary observations, prior learning/memory, reasoning/logic). That authoritative sources were reported in almost the same proportion as self-knowledge and peer-knowledge in the post-survey speaks to the knowledge-building principles that underlie this curriculum design. Moreover, these findings demonstrate that engaging students in activities where they rely on the ideas of their peers as well as their own observations can result in a noticeable shift in their epistemic cognitions within this dimension.
Figure 23 – Pre and post survey results showing students’ sources of knowledge in ‘traditional’ school science (pre) and in the EvoRoom curriculum (post). Pre-survey results indicate a heavy reliance on authoritative sources of knowledge (89%), whereas post-survey results show a more even distribution between authority (33%), peers (28%) and the self (38%) as sources of knowledge.

5.2.3.2 Justification

The justification of knowledge employed by students varied across the different EvoRoom curriculum activities. Within the Online Learning Portfolio, the knowledge contributions that students made were largely factual and therefore provided little opportunity for negotiation or justification. In cases where individual students were required to populate their assigned information within a wiki page (i.e. the Borneo Field Guide and the Borneo Timeline), students mostly copied and pasted this information from an external online resource. Although students often provided links or references to these sources, there
was no added requirement of evaluating these resources, thereby justifying their use and/or the authenticity of this information.

For the Predictions assignment on the OLP, the majority of posts provided some form of justification, which was primarily reasoning based on prior knowledge. However the wording of these predictions was often tentative (i.e. “this might happen”). Although it is arguable that making predictions about future events is difficult to do with a high degree of certainty, this tentative wording (reflective of an “uncertain” epistemic stance) may also indicate that these predictions were insufficiently justified (Chinn et al., 2011). Additionally, although these predictions were intended to be group posts, it was difficult to determine the nature of their authorship since only one group member submitted them through his/her account. While it is possible that these posts may have represented the product of group knowledge negotiations, it is also possible that the posts represented the ideas of only a single group member, as evidenced by statements such as “I think that” or “in my opinion.” Any negotiation or justification of knowledge between group members would have largely taken place offline and is therefore difficult to verify, which points to the potential value of technology scaffolds for supporting this type of discourse.

Within the EvoRoom Evolution activity, as mentioned previously, the only opportunity for knowledge negotiation was provided in Question 3, which asked students, for each time period comparison: “What evolutionary processes might have occurred during this time period? How were these processes related to the climate, habitats, or other species at the time?” Section 5.2.2.2 described how 70% of the students who completed the activity using pencil and paper did not respond to this higher-order reasoning question at all. Of the 30% who did provide a response, 36% of these responses did not include any justification (i.e. students merely listed an evolutionary process). The groups who completed the activity using the tablets all provided justification for their answers.

For both the Zoo field trip and the Biodiversity Activity, justification of knowledge was built into the design of the Zydeco app, as students had to provide both evidence and reasoning to support claims statements. However, the way that this justification was enacted was quite different between these two contexts. For the Zoo field trip, knowledge claims were completed individually as part of the culminating Zoo activity. Questions were open-ended, and students had to be conscientious about their choice of evidence and reasoning in
order to perform well on this assignment. The Biodiversity Activity, however, had three key differences: (1) students completed this activity in groups, (2) there was a “right” and “wrong” answer, and (3) this activity was not explicitly for marks. Field observations revealed that use of evidence artifacts to support claims statements in the Biodiversity Activity was almost an afterthought, with group consensus taking priority over evidential justification. Here, the majority of knowledge negotiations among group members occurred verbally, with Zydeco claim statements reflecting the product of these negotiations. In a survey that was administered to students following the Biodiversity Activity (n=40), the negotiation strategies students described as occurring throughout this activity included taking turns “reasoning out loud” (41%), using the process of elimination (18%), collecting additional evidence (11%), using argumentation/debate (11%), listening in to other groups’ decisions (9%), and bringing the decision to a group vote (9%).

5.2.3.3 Epistemic Stance

Epistemic stance refers to the position one takes with respect to a knowledge claim (e.g. certainty, uncertainty, entertaining an idea, utilizing an idea as a working hypothesis, withholding judgment on an idea, etc.). As the issue of Epistemic Stance was not at the forefront of this design, there was no instrument that was specifically used to measure Epistemic Stance within the sample population throughout the EvoRoom activities. However, the Zydeco Biodiversity claims were analyzed in order to identify possible instances of satisficing within group responses. Following the Biodiversity Activity, students were given a survey (n=40) in which they were asked to report whether or not their group reached a consensus about which rainforest depicted their scenario. 39% of respondents indicated that their group had consensus throughout the duration of the activity, 45% indicated that they came to a consensus after engaging in some knowledge negotiations, 11% indicated that they came to a consensus by “voting” or satisficing their response, and 5% did not reach a consensus.

These responses were then cross-referenced with the group claims statements that were submitted through Zydeco. Responses were coded for group Epistemic Stance using the following categories:
1. **True certainty** – there was consensus in the group and the claim was correct
2. **False certainty** – there was consensus in the group but the claim was incorrect
3. **Uncertainty** – there was no consensus in the group

Results indicated that “False certainty” occurred in 58% of cases and “True certainty” occurred in 37% of cases (see Figure 24). As noted above, only 5% of students reported that they did not reach consensus and their claim statements were therefore uncertain. Within the sub-set of students that reported satisficing their responses, only 25% of these groups were successful in correctly identifying their climatic scenario.

In addition to the results provided above, which showed that groups who used more evidence to support their claims were more likely to correctly identify their climatic scenario, the results provided here further highlight the importance of increasing justificatory rigor throughout these activities. Reducing student satisficing through the addition of technology scaffolds to support justification would encourage students to substantiate their knowledge contributions instead of using passive, consensus-favouring negotiation strategies such as a group vote.

![Epistemic Stance for Biodiversity Activity](image)

**Figure 24 - Inferred group Epistemic Stance for the Biodiversity Activity**

### 5.2.4 Enacted Epistemic Virtues and Vices

As detailed in the previous chapter, the Epistemic Virtues for the EvoRoom curriculum were (1) for students to contribute meaningfully to the shared knowledge bases for each activity, (2) to avoid satisficing throughout their knowledge negotiations, and (3) to prioritize collective advancement over individual gains. The corresponding Epistemic Vices would be for students (1) to contribute selfishly, selectively, or not at all to the knowledge base (2) to satisfice their epistemic stance in favour of group consensus, and (3) to prioritize individual gains over collective advancement.
The first epistemic virtue was largely achieved in the EvoRoom enactment, as the majority of students participated fully in all activities and contributed their findings to the shared knowledge base. Details supporting their completion of activities and their contributions to the knowledge base are provided above, in section 5.2.2. The enactment of the second epistemic virtue would require further evaluation in future designs and enactments of EvoRoom, once the “Justification” and “Epistemic Stance” gaps have been revisited. According to the observed data, there was some evidence of student satisficing throughout the EvoRoom Biodiversity Activity, as detailed previously.

Regarding the third epistemic virtue, section 5.2.1.1 reports that students identified the EvoRoom curriculum as having a greater emphasis on collective knowledge advancement rather than individual gains. However, to assess the corresponding epistemic vice, in which individual gains are favoured over collective advancement, students were asked to respond to the following post-questionnaire item (n=40): “Much of what you did within the EvoRoom was not for marks. In general, do you think students will put effort into something if it is not for marks?” 44% of respondents indicated that their level of effort would be reduced if no marks were awarded. The remaining 56% indicated that they would put in the same amount of effort as long as the activity was interesting and engaging. A number of students also reported that there was a certain threshold of cognitive effort or demand, beyond which marks were no longer regarded as a positive reinforcement, but rather as a negative source of stress. Therefore, in cases where no marks are awarded the curriculum design should make it easy for students to contribute to the knowledge base and the assigned tasks should not be overly burdensome.

5.2.5 Reliability of Enacted Processes

The final dimension of the enactment analysis entails evaluating how effective the processes of knowledge building, inquiry, discourse, application, and reflection were to achieving the epistemic aims of the design. As detailed previously, the epistemic aims for the EvoRoom curriculum design were (1) for students to identify as a knowledge community, (2) for inquiry activities to be guided by shared learning goals within the knowledge community, and (3) for members of the knowledge community to develop shared ideas and understandings about evolution and biodiversity. One might consider the attainment of these
epistemic aims as an indicator that the underlying processes were indeed reliable. However, as an additional measure students were asked to respond to the following post-survey question following their enactment of the EvoRoom curriculum (n=40): “Compared to the other units in the course, how much of the material from the Evolution and Biodiversity units are you likely to remember next year?” Responses were coded as either “less,” “same,” or “more.” Results indicated that 62% of students believed they would remember more from the EvoRoom curriculum compared to other units, 21% indicated they would remember the same amount, and 17% indicated that they would remember less (see Figure 25). An example that is typical of the reasons cited by students who indicated they would remember more is given by the following:

I will remember more from the Evolution and Biodiversity units next year. In the Plants, Animals, and Genetics units, I had to do a lot of memorization and passive learning, which does not help me retain the information. In the Evolution and Biodiversity units, I had to actually understand the concepts and do interactive activities. These are more useful ways of learning.

This suggests that the learning processes within the EvoRoom curriculum were more active (in comparison to the “passive learning” and “memorization” that took place in other units of the course), and that it also required students to apply their learning in order to complete these activities successfully. As reported by another student who said she would remember more:

I will have forgotten most of the scientific terms although the large ideas will be sticking with me for a long time. If I took one of my tests next year, I would probably fail the knowledge questions but do well in application and thinking & inquiry.

Students who reported that they would remember less cited reasons such as a higher level of interest in the other curriculum topics. A typical response was:

I found the genetics and animals unit significantly more interesting from a personal perspective and studying that information was, as a result, not quite as challenging.

Other students who reported they would remember less cited that they preferred learning independently. For example, one student reports:
In these two units, the way we learned was mainly by doing activities as a class together. However, since I learn best by working and reading material by myself, I don't think that I will be able to remember a lot of this material next year.

Figure 25 – Proportion of students who were likely to remember more (62%), the same (21%) and less (17%) from the EvoRoom curriculum compared to other units of the course.

5.3 Discussion: EvoRoom Enactment

The enactment analysis of the EvoRoom curriculum revealed weaknesses that were consistent with those identified in the design analysis (Chapter 4). However, the enactment analysis also provided new findings that could not have been identified without the actual enactment of the curriculum.

The epistemic aim for students to identify the activities within this curriculum as a collective endeavor rather than an individual enterprise was achieved for 67% of students. Students were able to identify shared goals within each of the curriculum activities, and 83% of students felt that their knowledge contributions were valuable to the learning of others. An epistemic aim that requires further investigation is the establishment of shared understandings within the knowledge community. Regarding “Epistemic Value,” a pre/post Likert survey administered before and after the Zoo Field Trip revealed that students who engaged in the EvoRoom curriculum showed significant gains in their perceived value of knowledge communities in comparison to students who did not participate in the EvoRoom curriculum.

The findings related to the “Structure of Knowledge” dimension revealed that collective responsibility was lowest in cases where a “divide and conquer” (cooperative) approach was used to delegate student tasks. Further, knowledge gaps were amplified in cases where the social incentives to complete the task were low (e.g. the Borneo Timeline
assignment on the OLP) or in higher-order reasoning tasks for which access to the knowledge base was unavailable (e.g. the pencil-and-paper groups for Question 3 of the Evolution Activity).

“Sources of Knowledge” findings revealed a shift in students’ epistemic cognitions, with sources predominantly coming from authority in the pre-survey, towards a greater balance of authority, peers, and the self in the post-survey. Consistent with the findings of the design analysis, weaknesses in the “Justification of Knowledge” and “Epistemic Stance” were identified in the Online Learning Portfolio, the Evolution Activity and, to some extent, the Biodiversity Activity. Students’ justification of knowledge was strongest in the Zydeco Zoo claims assignment, as this was built into the design of the app. However, when students used this same app in the Biodiversity Activity to develop claims in a collaborative context, the use of evidential and non-evidential justification was lacking in favour of consensus within the group.

The achievement of the epistemic virtues in the enacted curriculum was inferred from other findings in the EC framework, such as the attainment of the epistemic aims. However, the epistemic vice that requires further investigation is the extent to which students satisficed their epistemic stance throughout the curriculum activities. Although there was some evidence of satisficing occurring within the Biodiversity Activity, instruments to measure students’ epistemic stance was not included in this design iteration.

The reliability of the enacted learning processes was also inferred from the findings for “Epistemic Aims.” However, and additional measure revealed that the majority of students (62%) felt they were likely to remember more of the EvoRoom curriculum content the following year compared to other units of the course. These students reported that the EvoRoom curriculum entailed more active learning and a greater application of knowledge compared to the passive learning and memorization they experienced in other units of the course.
CHAPTER 6: CONCLUSIONS

As detailed in section 2.6.3, the KCI model consists of five principles, each consisting of a set of epistemological commitments, pedagogical affordances and technological elements. At the time of this research, the five principles and three sub-components constitute the finest level of detail available concerning the KCI model, and hence serve as the topic of design and analysis. While the inclusion of epistemic elements has been regarded as vital within KCI, there has been a greater overall emphasis on structural and curricular aspects of the model, such as content connections and assessable outcomes. The two-stage MBDR (model-based design research) analysis of EvoRoom aimed to evaluate and enrich the epistemic commitments of KCI as they were manifest in the design and enactment of the EvoRoom curriculum. These analyses (Chapters 4 and 5) revealed the complex interconnections amongst the epistemological, pedagogical and technological components of the model. As a result, this study was able to produce a set of informed design ‘priorities’ that may influence subsequent KCI curricula, and may even feed into the detailed definitions and principles of the model itself.

The mapping of the epistemic commitments of KCI to Chinn et al.’s (2011) EC framework revealed epistemic gaps in two key areas: the “justification of knowledge” and “epistemic stance.” With the exception of the curriculum activities that used the Zydeco software application, (i.e. the Zoo field trip and the Biodiversity Activity) for where the affordance for justification was explicitly reinforced by elements of the software interface (Kuhn et al., 2010; Zhang and Quintana, 2012), the design of the EvoRoom curriculum did not include any instructions or scaffolds to facilitate students’ justification of knowledge within the shared community knowledge base. Consequently, during the enactment of the curriculum, knowledge negotiations either occurred verbally and were not captured by the technology environment, or otherwise did not occur at all. The justification of knowledge was also hindered in cases where knowledge contributions were largely factual (e.g. within the wiki pages of the Online Learning Portfolio) or simply entailed the reporting of observational data (e.g. within the EvoRoom Evolution Activity).

Within the Zydeco app, which provided scaffolding for the justification of knowledge, the enactment analysis revealed a distinct contrast between the way knowledge
justifications occurred for individual knowledge claims (i.e. the Zoo Field Trip Activity) versus group knowledge claims (i.e. the Biodiversity Activity). Although the technological scaffolds within Zydeco were identical in both cases, these two activities were pedagogically quite distinct. The “claims statements” that students generated for the Zoo Field Trip Activity were in response to open-ended questions related to a driving question about the unity of biodiversity. Conversely, the claims statements within the Biodiversity activity were in response to a closed-ended, right-or-wrong question (asking which of the four walls of the EvoRoom depicted a particular climatic scenario). Here, group consensus was favoured over justificatory rigor, and the addition of evidence to claims statements commonly occurred after a group decision had already been reached. As a result, 58% of students were “falsely certain” that their claim was correct (i.e. their group had reached a consensus, however their claim statement was ultimately incorrect). This lack of evidentiary justification to support group claims statements is indicative of the satisficing of epistemic stances within the group. However, as indicated in section 5.2.3.3, groups who used more evidence to support their claims statement were more likely to reach “true certainty” (i.e. where their group had reached a consensus and their claim statement was correct).

In light of these findings, the following design priorities are recommended with respect to “justification” and “epistemic stance”:

1. Technological scaffolds that support evidentiary and non-evidentiary justification should be built into the design of the community knowledge base.

2. Knowledge negotiations amongst members of the knowledge community should be captured by the technology environment – not only to prevent student satisficing, but also to serve as artifacts that support the negotiation process, and for subsequent idea-growth.

3. To support the justification of knowledge in collaborative contexts, inquiry questions should be open-ended and should promote explanatory coherence over ‘correctness.’

4. From a pedagogical perspective, activities should be designed that help students to understand the importance of justificatory rigor and how the satisficing of their epistemic stance might compromise the integrity of the inquiry.
The “structure of knowledge” findings within the EvoRoom enactment analysis provided insights related to collective responsibility and social incentives for contributing to the shared knowledge base. In cases where a cooperative “divide-and-conquer” approach was used to delegate tasks (e.g. within the wiki pages of the Online Learning Portfolio), students’ sense of collective responsibility for filling gaps in the knowledge base was low. It is possible that during these instances, where students were working individually to complete their assigned tasks, their perception of a broader collectivity within the knowledge community may have been temporarily clouded. Gaps in the knowledge base were amplified in cases where the consequentiality of students’ contributions was not apparent. For example, with the Borneo Field Guide assignment students were aware that their contributions would be submitted to the “Encyclopedia of Life” website, and as a result the number of gaps in the knowledge base was relatively low. However, the Borneo Timeline assignment was not contributed to Science 2.0, and as a result the majority of the knowledge base for this activity remained incomplete. Although students were told that their OLP contributions would be part of the broader EvoRoom narrative in both cases, it is possible that students may have lacked clarity as to what would specifically become of their contributions in this assignment or why these contributions would be valuable to the knowledge community throughout subsequent inquiry. These outcomes suggest that the connection between collaborative activities and cooperative activities within a knowledge community curriculum needs to be made more explicit so that students can better understand the value and consequence of their contributions in both contexts. As such, the following design priorities are recommended:

1. From a pedagogical perspective, students should be aware of the broader curriculum narrative and should understand the consequences of their contributions at each stage. For tasks that are completed cooperatively (i.e. individually, as in “divide and conquer”), students should be reminded of how their contributions will be used to support future collective or collaborative tasks.

2. Technology elements should enable students to track their contributions, including the number of reads or uses of a particular knowledge artifact within the shared knowledge base. This type of feedback would allow students to follow the growth of their ideas throughout the broader curriculum arc and would indicate how others in
the knowledge community have relied upon their contributions (and, consequently, that their contributions have value).

In addition to the above design priorities, the outcome of the MBDR analysis also provided insights that may be used to fortify the five overarching principles of the KCI model. Recognizing the interplay between the technological, pedagogical, and epistemic elements of the model, the five KCI principles and their corresponding MBDR insights are provided below:

**Principle 1:** Students work collectively as a knowledge community, creating a knowledge base that serves as a resource for their ongoing inquiry within a specific science domain.

**MBDR insight:** In working collectively as a knowledge community, students will participate in both collaborative and cooperative tasks. However, as noted above, their contributions to the knowledge base in each situation must be recognized as part of a larger curriculum arc within which their contributions have both value and consequentiality. The technology supports within KCI should provide students with feedback related to their knowledge contributions, including the ways that they were used by the knowledge community to support idea growth throughout the collective inquiry.

**Principle 2:** The knowledge base is accessible for use as a resource as well as for editing and improvement by all members.

**MBDR Insight:** Knowledge negotiations should be captured and made visible within the knowledge base to increase the justificatory rigor of the inquiry and to prevent students from satisficing their epistemic stances. Technological scaffolds to support evidentiary and non-evidentiary justification should be provided within the knowledge base to facilitate idea improvement. An aggregate display that provided a constant source of reference throughout collaborative inquiry activities would serve to make progress within the knowledge base visually apparent, and facilitate higher-order reasoning as a referent for discourse and inquiry decisions.
**Principle 3:** Collaborative inquiry activities are designed to address the targeted science learning goals, including assessable outcomes.

**MBDR Insight:** Students must identify shared learning goals within the knowledge community throughout each of the inquiry activities such that their understanding of the targeted science curriculum expectations is not restricted to the specific topics that they themselves researched. As a consequence of these shared learning goals, students should be supported to recognize the knowledge community as being valuable to their understanding of the targeted science expectations, even though the culminating curricular tasks may be evaluated on an individual basis.

**Principle 4:** Inquiry activities are designed to engage students with the knowledge base as a resource, and to add new ideas and elements to the knowledge base.

**MBDR Insight:** As in the notes for Principle 2 above, the knowledge base should include scaffolds or supports for evidentiary and non-evidentiary justification of contributions. Further, there should be a mechanism to differentiate between contributions that are factual from those that are explanatory, as the justificatory standards would be different for each contribution type. The technology environment should capture knowledge negotiations such that “ideas in progress” may serve as artifacts for future inquiry and improvement.

**Principle 5:** The teacher plays a specific role defined within the inquiry script, but also a general orchestrational role, scaffolded by the technology environment.

**MBDR Insight:** In addition to orchestrating activity sequences, the teacher should serve as both the navigator and narrator of the curriculum arc. As a navigator, she should enable students to identify where they are at each stage of the inquiry and to motivate discussions about where they need to go in order to progress as a knowledge community. As a narrator, she should articulate the consequentiality of students’ contributions at each stage of the inquiry, demonstrating how these fit in to the broader curriculum narrative. She should also be aware of her role in supporting students’ epistemic cognitions, helping make the virtues and vices explicit, and reflecting on appropriate examples.
In conclusion, the role of students’ epistemic cognitions must be understood in order to design effective inquiry activities that engage students and teachers in new forms of learning, and that make ideas and interactions both visible and emergent from student-contributed content. The two-stage MBDR analysis of the EvoRoom curriculum presented in this thesis first revealed gaps in the epistemological commitments of the KCI model as framed through Chinn et al.’s 2011 expanded EC framework – specifically in the areas of “justification” and “epistemic stance.” The design analysis then identified how these gaps were carried forward into the curriculum design. The enactment analysis evaluated the curriculum in terms of its fidelity to the design, and revealed additional epistemic cognitions to be accounted for in subsequent design iterations. The findings from this analysis were used to generate a series of design priorities for future KCI curricula, as well as a series of insights that could be applied to the KCI model at the principle-level.

While this thesis applied a particular theoretical framework for epistemic cognition to a particular model of learning, it should be recognized that an MBDR analysis of KCI that employed a different EC framework or epistemological perspective would yield a different set of recommendations. Similarly, while the epistemic gaps identified throughout this analysis were reported from a KCI perspective, the application of this EC framework to a different learning model would lead to a different set of insights and design priorities. Although there are inherent limitations in evaluating a curriculum design from a particular theoretical perspective, the MBDR analysis conducted in this thesis was applied to only one of several iterations of the EvoRoom design that have occurred over the course of its development. Moreover, additional analyses are currently underway to explore the nature of student interactions with peers, teacher, and materials, as well as learning and reasoning outcomes (see Lui and Slotta, 2013). These analyses, as well as possible future design iterations may contribute further perspectives concerning the nature of epistemic cognition in a collective inquiry curriculum.
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APPENDIX A: PRE/POST LIKERT QUESTIONNAIRE

1.) When I learn something new, it is important for me to share this knowledge with my peers.

   strongly disagree 1 2 3 4 5 6 7 strongly agree

2.) The knowledge that my peers share does not help me understand concepts any better than if I had learned them independently.

   strongly disagree 1 2 3 4 5 6 7 strongly agree

3.) Sharing my knowledge with my peers is intrinsically rewarding (i.e. it is beneficial for its own sake).

   strongly disagree 1 2 3 4 5 6 7 strongly agree

4.) Sharing my knowledge with my peers is extrinsically rewarding (e.g. I receive recognition and/or marks based on my contributions).

   strongly disagree 1 2 3 4 5 6 7 strongly agree

5.) When performing an investigation, pooling my data with my classmates leads to better experimental results than if I had worked by myself.

   strongly disagree 1 2 3 4 5 6 7 strongly agree

6.) When performing an investigation, pooling my data with my classmates helps me acquire more knowledge than if I had worked by myself.

   strongly disagree 1 2 3 4 5 6 7 strongly agree

7.) When performing an investigation, pooling my data with my classmates makes it more difficult to detect (and correct) errors.

   strongly disagree 1 2 3 4 5 6 7 strongly agree

8.) When peers share their knowledge with each other, the total knowledge of the group as a whole is greater than the knowledge of any one individual.

   strongly disagree 1 2 3 4 5 6 7 strongly agree

9.) Peers who pool their knowledge together are less effective at solving problems than individuals working independently.

   strongly disagree 1 2 3 4 5 6 7 strongly agree

10.) Peers who pool their knowledge together are more innovative than individuals working independently.

    strongly disagree 1 2 3 4 5 6 7 strongly agree
APPENDIX B: EVOROOM EC PRE-SURVEY

1. What are the main sources of knowledge in school science?
2. What are the main sources of knowledge in ‘real world’ science?
3. What are some ways that you learn new things in school science?
4. What are some of the ways that scientists make new discoveries about the world?
5. How do you know if something is true in science class?
6. How does a scientist know if something is true?
7. If you didn’t believe something was true, what kind of proof or justification would it take for you to change your mind?
8. When a scientist makes a discovery, how does this benefit the scientific community?
9. When a scientist makes a discovery, how does this benefit society?
10. If you learn something new in school science, do your classmates benefit at all? (If so, how?)
11. Recently, science has become increasingly social as scientists collaborate to develop large, shared constructs such as the human genome project and galaxy mapping. How might students in a science class work together to develop their own improved understandings of science topics?
APPENDIX C: EVOROOM EC POST-SURVEY

1. What are some of the teaching methods or learning strategies that help you learn best in science?

2. Do you think that the EvoRoom activities and Zoo field trip were more focused on advancing your own individual learning, or advancing the knowledge of the class as a whole?

3. What were the main sources of knowledge throughout the EvoRoom activities and Zoo field trip?

4. Describe an example in either of the EvoRoom activities or Zoo field trip where the whole class was working towards a common/shared goal.

5. When you were on the Zoo field trip, describe the approach your group took to collecting evidence.

6. The evidence that everyone collected from the Zoo field trip was all contributed to a shared evidence base. How much did you rely on other people’s evidence when generating your claims?

7. How much do you feel that your contributions to the evidence base helped the learning of others?

8. In the most recent EvoRoom Biodiversity activity, describe the strategy your group used to determine which of the four ecosystems represented your ‘scenario’ (high/low temperature, earthquake, low rainfall).
   a. Was there a consensus in your group about which scenario was yours? If not, how did you negotiate this decision?

9. Much of what you did within the EvoRoom was not for marks. In general, do you think students will put effort into something if it’s not for marks?

10. Do you believe that a student’s marks are a true reflection of his/her understanding of the course material?

11. What are some of the study strategies you will use to help prepare for the final exam?

12. Compared to the other units in the course, how much of the material from the Evolution and Biodiversity units are you likely to remember next year?