Chapter 8
Scaffolding Knowledge Communities in the Classroom: New Opportunities in the Web 2.0 Era

Vanessa L. Peters and James D. Slotta

Technology for the Twenty-First Century Classroom

Computer and information technologies have transformed nearly every dimension of society, including business, government, science, and engineering. The changes within these organizations reflect the emergence of a "Knowledge Society," where we come to rely on processes of knowledge creation and advancement over those of labor, industry, or mechanical production (Drucker, 1959; Bereiter & Scardamalia, 1996). Yet in spite of such twenty-first century movements, the education sector of society remains largely unchanged, with classrooms still closely resembling those of the mid-twentieth century (Becker, 1999). A number of scholars have remarked on the slow uptake of technology-enhanced methods in the classroom (e.g., Tyack & Cuban, 1995; Cuban, 2001). As diSessa (2000) observes, "Few can or should claim that computers have influenced the cultural practices of school the way they have other aspects of society, such as science or business. Just look at texts, tests, and assignments from core subjects. They really have changed little so far" (p. 3). The conservatism observed by these scholars has persisted despite efforts from the learning sciences community to transform classroom culture from one that is teacher dominated, to one where students assume autonomy over their own learning. Given the knowledge-oriented, technology-infused workplaces in which students will participate, it is important that schools integrate technology meaningfully into the curriculum, and develop new methods of instruction that emphasize collaborative knowledge construction.

However, any substantive change made to school curricula will require a corresponding significant change in teachers' practices. Integrating new, technology-based innovations into one's classroom practice is not easy. Teachers rely on familiar methods not because they lack incentive for improving student learning,

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V.L. Peters (✉) and J.D. Slotta
Ontario Institute for Studies in Education, University of Toronto, 252 Bloor Street West,
Toronto, Ontario M5S 1V6, Canada
e-mail: vlpeters@gmail.com

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but because these methods fit within the complex ecology of their classroom and school community. Teachers' methods must also accommodate the mandated curriculum subject content, which is usually assessed through conventional measures. Thus, the successful adoption of any newly designed curriculum will require a continued serious investment of time and intellectual energy from teachers, administrators, and other school personnel who are directly involved with student achievement (Cuban & Usdan, 2003). Ideally, teachers' involvement would begin in the early stages of the curriculum design process. Too often, teachers learn the details of new methods or materials at roughly the same time they are implementing them (Glenman & Melmed, 2000), leaving them little time to consider how to best integrate the innovations into their broader curriculum.

Many teachers do see technology as a means of supporting new pedagogical practices. However, even when they have access to educational technologies such as SMART Boards, Clickers, or Internet-enabled computers, they often lack knowledge of how these innovations can be effectively used for learning and instruction. Thus, teachers face a steep learning curve in adopting new technologies for curriculum or assessment within their classroom. Whereas on one hand they should not be expected to design such innovations on their own, on the other, there are generally few ways in which someone else could do it for them. In order for curriculum innovations to really succeed in a classroom, the teacher's must be involved in their design and customization for specific contexts. This requires research from the learning sciences, as well as targeted professional development programs that include in-service supports for teachers as they embark on the voyage of transforming classrooms into knowledge communities.

It has never been more important for educators to embrace new technologies, in order to help students learn the skills and practices required of knowledge workers (Scardamalia, 2000). This chapter will explore the implications of Web 2.0 technologies for supporting new forms of curriculum and assessment in classrooms, and the impact of a co-design method in engaging teachers in the process of transforming their curriculum. We begin with a short summary of the key features of Web 2.0, followed by a review of research from the learning sciences that could be relevant to educators who wish to apply these technologies. We then describe a theoretical model for designing curriculum that emphasizes collaborative knowledge construction, and a methodology of co-design. Two studies are then presented in which this model was applied in developing a high school biology curriculum, followed by a discussion of the outcomes of our curriculum. We close with a discussion of implications and next steps.

The Emergence of Web 2.0

Following the economic collapse of the dot-com bubble in 2001, several pioneers of the Internet, including Tim O'Reilly (2007), observed that far from collapsing, the Web was becoming even more important to society. In 2003, they coined the term "Web 2.0" to refer to a new generation of Internet-based applications that were functionally distinct from those of the previous era. These are technologies that push the boundaries of how we think about collaboration and communication, and are perhaps best exemplified in the way in which web content is produced and consumed. Whereas earlier web applications emphasized individual production and mass consumption (i.e., an individual creates a web site which is then read by many), Web 2.0 emphasizes mass production and mass consumption (i.e., users are both producers and consumers – see Alexander, 2006).

Interactivity and social networking are typical of Web 2.0 resources, with millions of people around the globe connecting through social networking applications such as MySpace and Facebook. Another recent social networking service that allows users to aggregate photo, video, and chat applications is called Tagged (http://www.tagged.com). Social elements of Internet applications have allowed the transformation of our online experience. Many people now maintain "blogs," a periodic narrative typically authored by a single individual but with comments on blog entries given by the community of subscribers. Podcasts serve a similar function, but are presented in an audio or audio-visual format instead of simple text. Using a simple syndication service (RSS), users can subscribe to blogs, podcasts, or other web sites and receive automated notification whenever content has been added or updated. Google now offers a "reader" service that allows individuals to subscribe to any number of such publications (see http://reader.google.com). Thus, a fundamental feature of Web 2.0 is the connection of individuals into social networks. Even now, new features are being added, such as enabling the interconnection of cell phone and other hand held computers within such networks, as exemplified by the social messaging application called Twitter (see http://www.twitter.com) which has spurred a global conversation with the question: "What are you doing?"

Another important characteristic of Web 2.0 applications is their support of collaborative editing. Wikis, including the well-known Wikipedia, are ongoing artifacts that are written, edited, and maintained by any number of contributors. Many wiki applications are available free of charge on Web sites, enabling any group or organization to engage in collaborative writing and thereby harnessing the combined contributions and insights of all members. Some of the earliest research into wiki usage was conducted in educational settings. As an extension of Ward Cunningham's "WikiWikiWeb," Guzdial (1998) developed "CoWeb," an educational wiki-based collaboration tool for use by students, educators and researchers. The open-authoring capabilities of CoWeb supports a number of important pedagogical objectives, as students develop their own knowledge through creating public artifacts (Papert & Harel, 1991), and increase their level of student agency (Scardamalia & Bereiter, 1991). Thus, another essential aspect of Web 2.0 is the aggregation of contributions from the distributed audience. Rather than rely on a single source authority to create the content that is consumed by the masses, Web 2.0 relies on "The Wisdom of Crowds" (Surowiecki, 2004).

Many web applications have been created that draw on the aggregated input of their visitors. Amazon bookseller (http://www.amazon.com) was one of the first web sites to demonstrate the power of aggregated visits through its use of recommender systems: what other books you would like. Based on your selection of a book to purchase, Amazon is able to quickly correlate your choice with those of others who chose the same book (as well as your own past history of purchases) and recommend a set of other books that you might enjoy. This illustrates how patterns of use and preference can be another form of aggregation (not just aggregated content). The YouTube video sharing community demonstrates this capability through its "popularity" index – where the most viewed videos are recommended in the display, and a new set of videos is recommended based on patterns of popularity and coselection. News aggregators such as Digg (http://www.digg.com) simply report all of the most popular news items, as rated by viewers. In this way, Web 2.0 applications employ a social feedback mechanism to actually provide an essential aspect of their functionality.

A final related characteristic of Web 2.0 is that of social tagging and "folksonomies" – collaborative and dynamic categorizations of web sites. Anyone who has used an electronic subject index is acquainted with the idea of searching through resources using tags or keywords. However, unlike traditional indexing, the keywords (or "tags") in a folksonomy are not defined by information specialists or librarians, but by users themselves. There is no hierarchal organization of tags in a folksonomy. Users are free to assign them into overlapping categories of their choice, and have the option of sharing their repository of keywords with other users (Alexander, 2006). Folksonomies are extensively used in social bookmaking services such as Delicious and BibSonomy – applications that provide tools that help users semantically organize their favorite web sites. Tag activity within a folksonomy can also be represented with "tag clouds" – visual structures that arrange search terms according to defined categories or frequency of use. Folksonomies are used extensively in photo management applications such as Flickr and Picasa, and are a standard feature in many new and emerging web applications such as photosynth (http://www.photosynth.net/) and taggraph (http://www.taggraph.com), which employ folksonomies to achieve remarkable user experiences.

New Opportunities for Teaching and Learning

The knowledge-oriented media associated with Web 2.0 present exciting new opportunities for educational research (Ullrich et al., 2008). Indeed, scholars have begun exploring how Web 2.0 can be productively used for learning and instruction. Wikis, for example, provide a collaborative structure that enables students to learn from both their individual and collaborative efforts. When coauthoring a document, students' individual contributions are a first step toward social collaboration (Aguiton & Cardon, 2007). Students working in a wiki cannot predict how their contributions will be received, nor can they predict how the coauthored document will evolve. Negotiating the content for a collaborative document can prompt the type of peer exchange that has been shown to foster student learning (e.g., Webb & Palincsar, 1996; Palincsar, 1998). Bryant, Forte, and Bruckman (2005) demonstrated that participants adopt new goals as they become more involved in the authoring process, shifting their focus from one of personal contribution to one of growing concern for the shared artifact. Students can also socially tag their wiki entries, resulting in folksonomies that make them accessible to a wider audience, which can encourage students to make more thoughtful and conscientious contributions (Wheeler, Yeomans, & Wheeler, 2008). Thus, wikis can provide educators with a powerful tool for fostering new philosophical outlooks and accepted forms of practice within the classroom (Papert, 2000).

The studies mentioned above are just the beginning of what will likely become an interesting new thread within the research literature. At the 2008 meeting of the International Society of the Learning Sciences, we convened a panel (Peters & Slotta, 2008) to address the new affordances of Web 2.0 technologies for research. Just as students and teachers can benefit from the opportunities provided by collaborative technologies, researchers can also gain new opportunities to support complex models of learning and instruction. There is still much to discover about how emerging technologies can be leveraged in ways that are compatible with theories of learning. In response to society's increasing dependence on knowledge and technical innovation, educational researchers can help to determine effective pedagogical approaches that support collaborative knowledge construction in the classroom. In the next section, we review research from the learning sciences that is relevant to our own theoretical perspective, ending with a description of a new pedagogical model that guides our designs of innovative Web 2.0 curriculum.

Scaffolding Knowledge Communities and Inquiry

Fostering a Knowledge Community

One strand of the learning science research literature that is clearly relevant to the successful integration of Web 2.0 approaches is the one concerned with "knowledge communities." In this research tradition, students collaborate with their peers and teachers to develop a shared understanding of their goals for learning and the process by which they will meet those goals (Brown & Campione, 1996; Scardamalia & Bereiter, 2003; Hakkarainen, 2004). For example, in the research program called Fostering Community of Learners (FCL), Brown and Campione (1996) carefully choreographed an elementary classroom, selectively presenting materials to small groups of students with different areas of expertise, so that the students and teachers within the classroom grew as a "knowledge community." The key components of FCL – student driven research, jigsawed information sharing, and performance of consequential tasks – provide structure and support for students' collaborations within the learning community. When combined, these components form a potent pedagogical strategy that fosters critical reflection and deep understanding of disciplinary content. An important theoretical contribution of FCL is the notion of diverse expertise. In their classroom implementations of

FCL, Brown and Campione (1996) found that students came to highly value the contributions of their peers. These contributions were not always about content, but were often related to using the computers or managing the group (Collins, Joseph, & Bielaczyc, 2004). A related innovation called crosstalk involves students presenting their preliminary findings to the entire class, producing a peer-review of ideas that often resulted in students developing a new line of inquiry (Bielaczyc, 2006).

A related approach known as knowledge building emphasizes the production and improvement of ideas that are shared within a community (Scardamalia & Bereiter, 1991, 2003; Brown & Palincsar, 1989). Students are given exclusive responsibility for the high-level processes of knowledge construction: generating new ideas, building on classmates' ideas, and synthesizing ideas into higher-level concepts. Unlike a traditional cognitive view of learning, which is concerned with individual cognitive development, knowledge building results in the creation or modification of public knowledge. Public, in this sense, means that the knowledge is available to other group members to be worked upon and improved. At times, knowledge building may involve disagreement in terms of what constitutes advancement of an idea, and how the limits of understanding should be defined. In a knowledge-building environment, such issues are dealt with jointly by group members, and not arbitrated by any external authority.

Through maintaining a shared and sustained focus, members of knowledge communities work jointly to arrive at new meanings and understandings. In this way, ideas are subject to multiple revisions and refinements that ultimately result in an improvement of the original. One of the most important measures of success in a knowledge community approach is whether students are working toward a common goal. This feature separates knowledge communities from other approaches such as project-based learning, guided discovery, or scaffolded inquiry (discussed next), which may rely on collaborative activities and real-world content to encourage the social construction of knowledge, but have a tendency to result in what Scardamalia and Bereiter (2003) call "shallow constructivism" (p. 1370). In a knowledge community approach, students work collaboratively in developing a community-owned knowledge base. In turn, this process supports individual students to develop as autonomous learners (Bereiter & Scardamalia, 1989). The teacher is considered a learning partner and facilitator, not an expert who is the principal source of knowledge. Rather, students develop expertise by asking questions and negotiating personal understandings through their own line of inquiry.

In general, it is quite challenging for teachers or researchers to coordinate a knowledge community approach in any classroom. As Kling and Courtright (2003) observe, "developing a group into a community is a major accomplishment that requires special processes and practices, and the experience is often both frustrating and satisfying for many of the participants" (p. 221). Thus, while this research tradition has earned great respect among scholars, it has been difficult to extend into K-12 classrooms where there is such a strong focus on the coverage of curriculum standards. This is particularly true of secondary science, where teachers are faced with substantial content expectations and traditional assessments, and are thus reluctant to embrace the wholesale changes required to enact a knowledge community model (Rico & Shulman, 2004; Whitcomb, 2004; Gardner, 2004). Teachers in these settings are typically under great pressure to ensure that the students develop an understanding of a wide range of topics, presenting unfavorable conditions for a knowledge community approach (Slotta & Peters, 2008). Thus, despite the acclaim given to the knowledge community approach in research reviews (e.g., Bransford, Brown, & Cocking, 2000), the instructional method has not been widely adopted by teachers, particularly at the secondary level.

Scaffolded Inquiry

Another strand of learning science research is that of scaffolded inquiry, where students learn by interacting with carefully designed "scaffolded" learning materials and negotiating ideas with their classmates. A number of prominent pedagogical approaches have been developed for scaffolded inquiry, most of which are deeply committed to incorporating collaborative activities (e.g., Krajcik, Blumenfeld, Marx, & Soloway, 1994; Edelson, Gordin, & Pea, 1999; Linn & Hsi, 2000; Quintana et al., 2004; Slotta & Linn, 2009). However, while scaffolded inquiry may be deeply collaborative, the perspective of learning remains focused on the individual learner. Guided by cognitive and constructivist frameworks, scaffolded inquiry materials are carefully scripted to guide students from one reflective activity to the next. All student work in such activities is collected by researchers for purposes of analysis of students' understanding. Specific research studies typically investigate questions related to the effectiveness of different curriculum designs, and how they enable students to develop a deep personal understanding (Linn & Eylon, 2006; Slotta & Linn, 2009).

Great progress has been made in the approach of scaffolded inquiry, perhaps because many more studies have examined this approach than that of knowledge communities. Indeed, it is relatively straightforward to design and enact a well-controlled investigation of scaffolded inquiry. One feature that is quite common to such investigations is the use of scaffolding technologies that guide students through the curriculum sequence, prompt for reflections, and provide rich multimedia materials. Several scaffolding environments have been developed over the past decades for science inquiry, including BioKIDS (Songer, 2006), BGuILE (Reiser et al., 2001), Inquiry Island (White et al., 2002), Knowledge Integration Environment (KIE) (Bell, Davis, & Linn, 1995) and WISE (Slotta, 2004). These environments were designed to enable teachers to more easily enact complex forms of inquiry instruction, demonstrating the powerful enabling role of technologies (e.g., see Roschelle, Knudsen, & Hegedus, this volume). Such work has given rise to several general frameworks for scaffolded inquiry, such as those of Quintana et al. (2004) and Linn and Eylon (2006).

Still, despite the relative success of such approaches in classroom studies, there has been little uptake of these innovations by teachers in regular classrooms

(Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000; Borko & Putnam, 1995; Cuban, 2001). While they may be more straightforward than a knowledge community approach, scaffolded inquiry methods are still quite challenging for teachers to adopt (Slotta & Linn, 2009). They generally demand a deeper treatment of topics, and thus more curriculum time for any given topic than most teachers are allowed – particularly in secondary science. In general, rich new models of collaboration and inquiry are challenging for teachers, who must tailor their course curriculum to provide room for some topics to be covered in greater depth than others. This tailoring process requires teachers to fully understand the nuances of the innovative materials (including any scaffolding technologies) to ensure that they are properly enacted. However, because researchers generally develop these materials, teachers may not find them straightforward to interpret or adapt.

The Knowledge Community and Inquiry Model

In order for teachers to adopt inquiry and knowledge community approaches, we must find a way to include them in the design of the curriculum, ensuring that a balance is held between implementing specific pedagogical models and covering the required content. Science textbooks cover more topics than any other subject, resulting in a curriculum that can be described as being "a mile wide and an inch deep" (Schmidt, McKnight, & Raizen, 1997, p. 62). Science teachers are required to cover specific content matter (e.g., cellular function, collision theory, organic compounds), making it difficult to design learning activities where students can pursue a deep understanding of science topics as a community of learners. Any science lesson or unit must be able to fit within a tight schedule of content coverage, with outcomes that are assessable by conventional measures. Teachers must feel that that every class period is used productively, and that their lessons are in alignment with the science topics outlined in the curriculum expectations (Penuel, Fishman, Gallagher, Korbak, & Prado-Lopez, 2008).

How can we help teachers adopt innovative, research-based approaches into their secondary science classrooms? Although research has explored avenues for adding inquiry-based and collaborative knowledge construction to the curriculum, teachers have not readily embraced either of these approaches. Inquiry has often been too rigidly designed and inflexible, requiring specific practices and materials that may not fit with the existing curriculum. Collaborative knowledge construction is often too open-ended, making it difficult for teachers to target specific learning outcomes. What is needed is a way to help teachers design and adopt rich inquiry-oriented curriculum that connects deeply to science content expectations, and supports teachers and students in their enactment of new methods.

In an effort to make headway on these problems, Slotta and his colleagues have developed the Knowledge Community and Inquiry (KCI) model that combines collaborative knowledge construction with scripted inquiry activities to target specific curriculum learning objectives (Slotta, 2007; Slotta & Peters, 2008). The model produces curriculum designs that begin with a collaborative knowledge construction phase where students explore and investigate their own ideas as a community of learners and create knowledge artifacts that are aggregated into a knowledge base. This community knowledge base then serves as a resource for subsequent scaffolded inquiry activities, where students are engaged in collaboration and reflection. To adhere to the spirit of knowledge communities, such inquiry activities should not be completely predetermined (i.e., before the knowledge construction phase), as the ideas and interests of the students should help to determine the focus of any inquiry (Scardamalia & Bereiter, 1996). Common themes, ideas or interests should emerge, reflecting the "voice" of the community. The instructor must listen to this voice and respond by designing activities that reflect students' interests. The latter process is critical, but also pedagogically challenging to execute, since the inquiry activities must also address the content expectations and learning goals of the curriculum.

It is no easy task to design activities that responds to community interests while addressing learning goals and adhering to time constraints. In the KCI model, scaffolded inquiry activities are co-designed by teachers and researchers only after the knowledge construction phase is well underway, building upon the themes they identify within the knowledge base. Students then draw upon the elements from their community knowledge base to complete the scaffolded inquiry tasks that are directly connected to assessable content-learning outcomes. KCI curricula can only be developed through close collaboration between researchers and teachers to ensure a carefully controlled flow of collaborative knowledge construction and scaffolded inquiry activities that are specifically designed to address specific learning objectives (Slotta & Peters, 2008).

A Co-design Community for Curriculum Development

The success of any research-based curriculum will critically depend on the teacher's understanding of the theoretical basis of that curriculum. Teachers would be unlikely to succeed in implementing any complex forms of curriculum for which they were not involved in the design. Moreover, it would be impossible for any researcher to create truly engaging curriculum materials without continuous input from the teacher(s) that will be enacting that curriculum. In order to design curriculum that meets the researchers' objectives while fulfilling the teacher's curriculum requirements, a collaborative model of development must be pursued.

One approach where all learning materials and pedagogical activities are developed collaboratively by researchers and teachers is that of co-design. Roschelle, Penuel, and Shechtmen (2006) employed a co-design method for a study in which they worked closely with stakeholder groups to produce an innovative curriculum for secondary school science. They describe co-design as "a highly facilitated, team-based process in which teachers, researchers, and developers work together in defined roles to design an educational innovation, realize the design in one or more prototypes, and evaluate each prototype's significance for addressing a concrete educational need" (p. 606). Co-design has a number of features that are common with other user-oriented design methods such as participatory design and user-centered design, which also emphasize the importance of input from the stakeholders of the design innovation. Like design-based research (Brown, 1992; Collins, 1999), co-design involves the continuous refinement of a design innovation that addresses an educational objective. Co-design, however, is more specified as it involves a number of well-defined process steps that are necessary for implementation.

Penuel, Rochelle, and Shechtman (2007) discuss tensions that are typical of a co-design approach. The process of delineating a new curriculum brings to light an individual's assumptions and expectations not only about their own role in the design process, but also those of other team members. Each stakeholder group, including teachers, researchers, and technology developers, often use their own specific terminologies to describe their intentions for the innovation. Also, each member of the co-design team may be relatively unfamiliar with the challenges and perspectives of the other members, which can lead to appearances of insensitivity or lack of appreciation for their efforts. For example, a teacher who is unaware the logistics behind software development may appear demanding and unrealistic when requesting a new technology feature from a programmer. Prior to commencing the project, Penuel et al. (2007) recommend that the design team review the process steps and objectives of co-design, including identifying a concrete innovation challenge, negotiating a flexible curricular objective and establishing defined roles for all members of the co-design team.

Study 1: Physiology of Human Diseases

To conduct this research, we established a partnership with the science department of an urban high school in a large Canadian city. A number of meetings were held with school administrators and science teachers to discuss our collaboration, and two biology teachers expressed interest in co-designing a technology-enhanced curriculum. The following two studies detail the KCI curriculum that resulted from this collaboration, including classroom trials and evaluation. The goal of this research is to investigate the KCI model in terms of its capability to engage students in a knowledge community while also supporting scaffolded inquiry that targets specific learning goals.

Design Research

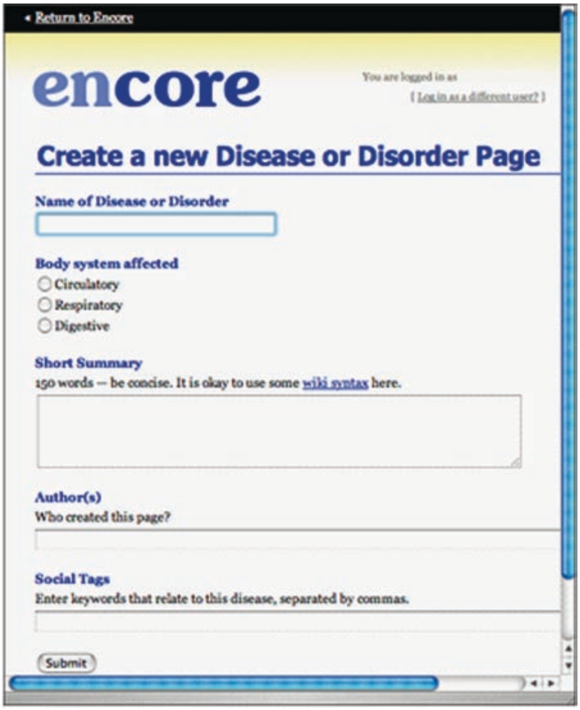
We chose a design research approach, with the expectation that we would conduct our research within a classroom context to evaluate our curriculum's fit to the KCI model. Collins (1999) discusses a number of issues in design research that distinguish it methodologically from traditional experimental studies. One important distinction concerns the role of the researcher. In experimental studies, the researcher makes all the decisions regarding the design and analysis of the study. Design experiments, on the other hand, entail close collaborations between the researcher and the various stakeholder groups involved in the study, which in the current study included teachers, students and school administrators. In addition, research variables cannot always be controlled in design experiments, particularly since the intervention itself changes over the course of the study. Still another challenge is the voluminous datasets that are typically collected, usually from both qualitative and quantitative methods. It has been argued that because of these challenges, design studies lack a strong theoretical foundation and do not generate findings for the purpose of extending a theory (diSessa & Cobb, 2004). Other scholars (e.g., Edelson, 2002; Bell, 2004; Hoadley, 2004) suggest that design-oriented research can be conducted with empirical rigor, resulting in credible arguments and evidence-based claims. The design research method is appropriate for this case, as it is well-suited to co-design of materials, and is focused on the evaluation and improvement of the curriculum in order to achieve the KCI model.

Embedding Technology Scaffolds

In this study, a wiki-based environment provided technological functionality for collaborative knowledge construction as it enabled students to easily access and edit one another's ideas, reorganize pages to capture emerging themes, and link pages to establish connections between related ideas. We designed a new hybrid wiki environment to improve control over student accounts, editing permissions, and other features. Although it was important to preserve the open-ended feeling of collaborative editing that typifies wikis, it was equally important to have a simple and structured way for students to create wiki pages as a knowledge resource. The result was the development of a special web form (using the Ruby on Rails technology environment) to create new wiki pages, including the collection of metadata. Whenever students wished to create a new wiki page for a certain purpose, we created a web form that allowed them to type the name and overview of the page, as well as to provide basic metadata. This form then generated a new wiki page that was properly linked, with prespecified headers and the required authoring and access permissions. For example, in creating wiki pages about human diseases (our first topic), students would click on a link called "Add New Disease Page" that would pop up a web form as shown in Fig. 8.1. Once completed, this web form would generate a new wiki page that students could then proceed to edit in the usual fashion (i.e., using the normal wiki editing).

Participants

The co-design team included two biology teachers from the participating high school, two researchers, and occasional participation from the school principal, vice principal of curriculum, as well as the school technology coordinators. Student



Create a new Disease or Disorder Page

Name of Disease or Disorder

Body system affected
○ Circulatory
○ Respiratory
○ Digestive

Short Summary
150 words – be concise. It is okay to use some wiki syntax here.

Author(s)
Who created this page?

Social Tags
Enter keywords that relate to this disease, separated by commas.

Fig. 8.1 "New Disease Page" script

participants included 102 grade-ten students who were distributed into four sections of an intermediate-level biology class (two sections per teacher).

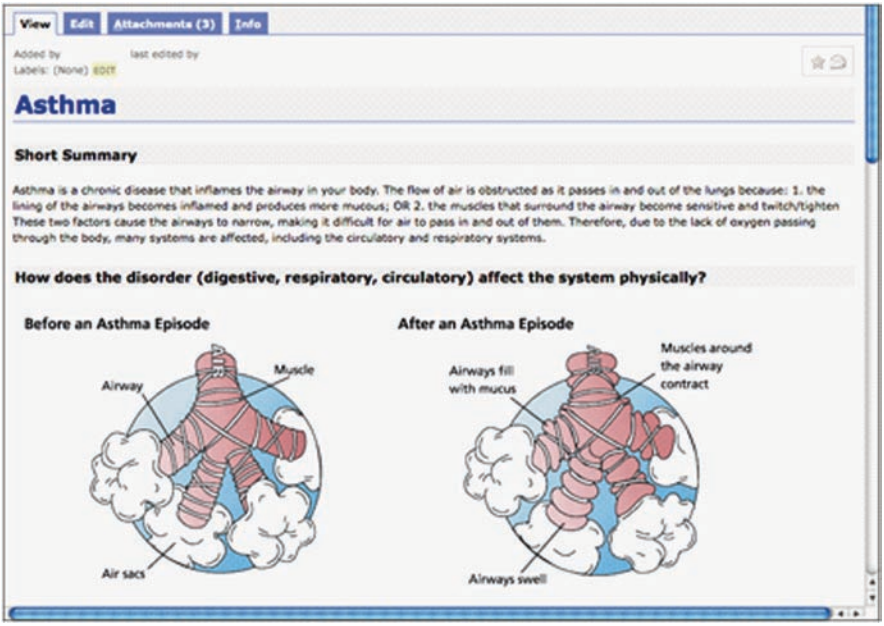
Design

Our co-design team held weekly meetings over a period of 4 months to develop the curriculum. During these meetings, we used our own wiki space to record minutes and document the evolving curriculum. Along the way, the teachers learned about the various theoretical ideas underlying KCI, and the researchers learned about the specific content and assessment requirements for the grade-ten biology curriculum. The result was a 1-week lesson on human diseases that fit within a larger unit on internal systems and regulation. The course syllabus allocated 40 h of class time to this unit; approximately 20 of these hours were spent covering the KCI curriculum.

All four biology classes completed the human disease lesson, which began with a knowledge construction activity where students were sorted into three groups for different human body systems (circulatory, respiratory, and digestive). Students could choose to specialize in any disease or disorder that interested them, provided it was within their assigned system. Students then formed small groups based on their shared interests in a disease or disorder, discussing amongst themselves what they already knew or had heard about their disease. Using wireless laptops (one for every two students), these same groups then created a wiki-based “Disease page” using our customized New Page script, which was presented to students as a web link within the wiki.

After the new page had been created using the New Page script (e.g., the “Pleural Effusion” disease of the respiratory system), it was accessible to all students from all four sections of the class. These disease pages comprised the knowledge base that would be used in later inquiry activities. Figure 8.2 displays the top portion of the Pleural Effusion page. Because there were four class sections of students working on these pages, they were ultimately quite well-developed with links to many outside web sites, images, and resources.

If students from the second class section (i.e., ones that met after the first class had already started creating disease pages) wanted to specialize in a disease or disorder that was already in the wiki, they were instructed to continue working on the same page rather than start a new one. This avoided redundant entries in the wiki, and helped cultivate a sense of community among the four classes. Students in the third and fourth classes contributed to the wiki in the same fashion, resulting in a single knowledge repository that would later be used by all 102 students. In this way, students from the four class sections were able to divide up the



Asthma

Short Summary

Asthma is a chronic disease that inflames the airway in your body. The flow of air is obstructed as it passes in and out of the lungs because: 1. the lining of the airways becomes inflamed and produces more mucous; OR 2. the muscles that surround the airway become sensitive and twitch/tighten These two factors cause the airways to narrow, making it difficult for air to pass in and out of them. Therefore, due to the lack of oxygen passing through the body, many systems are affected, including the circulatory and respiratory systems.

How does the disorder (digestive, respiratory, circulatory) affect the system physically?

Fig. 8.2 A respiratory disease page

knowledge base into three main areas (respiratory, circulatory, and digestive diseases) for which they created and jointly edited all the major diseases. Of course, this meant that students who had specialized in one of the disease areas would not be familiar with diseases from the other two, but this was an intentional element of the design, and presumed to be one of its strengths. The teachers instructed students that they would need to "do a good job creating their disease pages, and to trust that their peers were doing the same," as they would need to rely on one another's work in subsequent activities.

After the knowledge base was constructed, we engaged students in a scaffolded inquiry activity where they were encouraged to use their peers' work in an authentic and purposeful way. This activity took the form of a "Challenge Case," which involved creating a fictitious case study of a patient who presents a number of symptoms to their physician for a diagnosis. Students created challenge cases for the same disease or disorder they had worked on when creating the knowledge base, but then solved the challenge cases created by their peers. To engage students with the wider community resource, they were instructed to choose a case that was not in the same area as the disease for which they had created a wiki page (i.e., if a student created a wiki page about a respiratory disease, they had to solve a challenge case involving either the circulatory or digestive systems).

Analysis and Findings

In evaluating the validity of the curriculum, in terms of adhering to the KCI model, we asked the following questions: Did students actively participate in constructing a community knowledge resource? Did students rely on the knowledge base to conduct the scaffolded inquiry activities? Did the curriculum cover the required biology content? Did students engage deeply in the activities, and did they demonstrate conceptual understanding of the science topics? We were also interested in students' and teachers' experiences with the curriculum, including the teachers' perceptions of the co-design process.

We found that the curriculum was successful in engaging students in coauthoring a community knowledge resource. Between the four classes, students created 23 comprehensive wiki pages about diseases of the three body systems, with an average of four authors and 15 revisions per page (see Fig. 8.3). Each of these pages was run through Copyscape©, a web-based utility that compares web pages to check for instances of plagiarism. From all 102 students and nearly 500-page revisions, there were four instances of plagiarism that warranted concern. When solving their challenge cases, students did indeed use their peers' disease pages as the primary resource. The researchers had wondered whether students might prefer to use just Google when solving the challenge cases, but classroom observations and web logs revealed that they almost universally relied upon their community resource base – presumably because it was so directly relevant to the inquiry domain.

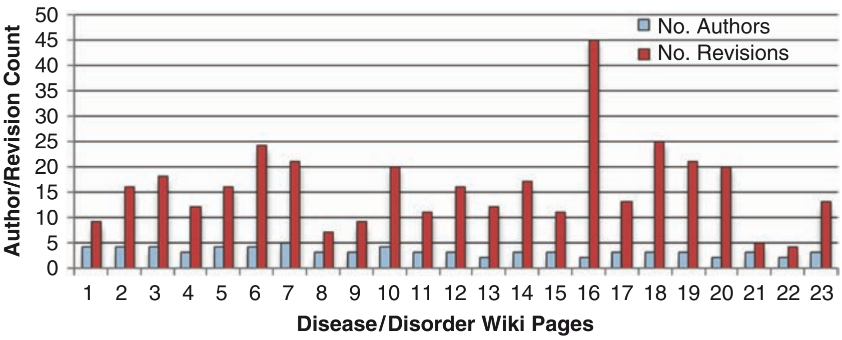


Fig. 8.3 Disease/disorder wiki pages: authors and revisions

Both of the teachers felt the wiki lesson helped students develop deeper understandings of how the three internal systems interconnect, which was an important learning objective in the curriculum. On the final exam, students were able to make connections between diseases of the three body systems (such as why hemophiliacs are more susceptible to respiratory illness). One of the teachers, Patricia, described how the curriculum addressed the content standards: "When I was doing my marking, I was actually pretty surprised… with this lesson they definitely covered the [Canadian Education] Ministry content, and they ended up learning a lot more about how the different physiological systems interact." One student, Cynthia, described her understanding of blood clots in a poststudy interview:

> Well, I thought it was interesting to learn how many different diseases are connected to the blood – from sickle cell anemia to missing proteins that cause hemophilia since the blood can't clot properly. The wiki stuff we did showed me how fragile our body is, but also how well it can adapt to problems.

To gauge student achievement, we compared the students' exam scores with those of students from the previous 2 years, who received the regular human disease curriculum that consisted of lectures and a lab (Table 8.1). To control for differencs in teaching style, we only used classes that had the same teacher for each of the three academic years. We compared the performance of these three groups on the physiology section of the final exam, which used similar open-ended questions in all 3 years (e.g., a question might ask students to describe how a disease in one body system affected the biological processes of another). An analysis of variance was conducted to compare the mean scores among the three groups. Those who participated in the wiki lesson had higher physiology scores than students who had been taught with the regular curriculum (Fig. 8.4). This difference was significant, with a value of $F(2,96)=7.236$, $p=0.001$, $\eta^2=0.13$. The scores on the remainder of the final exam (i.e., with the physiology section excluded) did not differ significantly across the 3 years. This suggests that there were no baseline differences, for example, in the student populations, or the difficulty of exams overall.

Table 8.1 Means and standard deviations of final exam scores for physiology curriculum

Biology final exam	Mean	SD
2004–2005		
Physiology section	82.65	12.86
Rest of exam	68.18	7.58
2005–2006		
Physiology section	83.35	13.84
Rest of exam	66.54	5.95
2006–2007		
Physiology section	91.60	8.58
Rest of exam	67.24	6.68

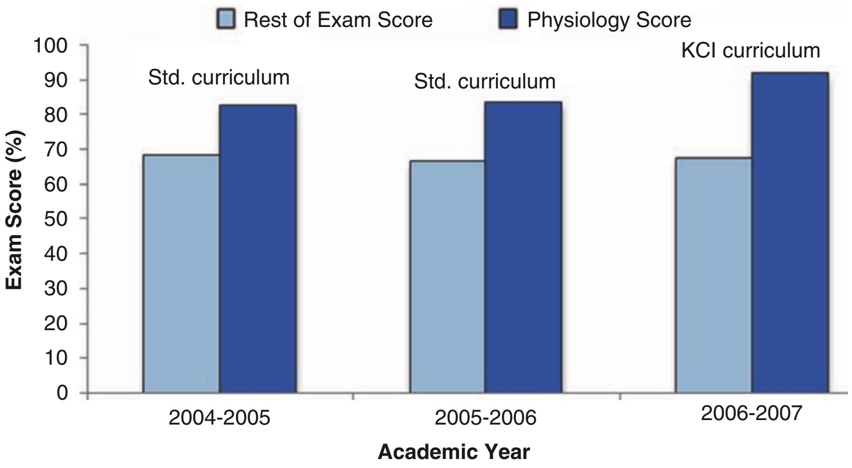


Fig. 8.4 Students' final exam scores

When interviewed, both teachers indicated that they felt positive about the experience, which had been time-consuming, but that the workload had not been too overwhelming. However, Laura did admit feeling apprehensive before beginning the unit, and expressed her concern about not covering all the required material:

> We weren't going to do [the activity] just for the sake of doing it. We're very much classroom teachers. If it's not going to help the kids learn really well, we're not interested in it. But it worked. I mean, we put a lot of time into negotiating things, but I think it ended up being a really good quality lesson.

Overall, the teachers felt the KCI human disease curriculum was a good use of class time, they were able to obtain the required assessments, and addressed all subject content expectations. The co-design team agreed to plan another unit for grade-ten students the following year, which would be our second iteration of the curriculum.

Evaluating Our Success with KCI

Although the first implementation of the KCI curriculum was encouraging, a number of problems became apparent after reviewing the students' work. During the challenge case activity, students used their community resource (the repository of wiki pages) to solve their case studies. However, when doing so, they did not engage with the material with any depth. Students consulted each other's disease pages to arrive at a diagnosis, but they did not extend the ideas any further, nor did they synthesize the material. Thus, the lesson did not fully achieve an important objective of the KCI model: to engage students in making interconnections between their ideas in the scaffolded inquiry activities and the content of the community knowledge base. We suspected that future versions of the curriculum would need to make such connections more explicit by scaffolding students' collaborative processes, and engaging them more deeply with their peers' work.

The assessment of the curriculum was also a concern for students. In a poststudy interview, a number of students expressed disappointment that the disease pages were not formally graded, and felt that their efforts should have been rewarded. Several students also expressed annoyance at not receiving more explicit and direct instructions when creating their disease pages. In the words of one student:

> I thought we were going to get a rubric for this assignment that we did, why didn't we get a rubric? All we got were a few comments about what to include in the wiki – how are we supposed to know what to write without a rubric? And the whole wiki thing was worth 5% of our final grade – that's a lot, considering we were only given two class periods to work on it.

Collectively, the findings from the first implementation of the KCI model illustrated areas in which the curriculum needed improvement. A number of refinements were required to meet the researchers' objectives, including more integration with the activities into the existing curriculum. To achieve this, the next iteration of the curriculum would need to be longer, with activities that could be formally assessed.

Study 2: Canadian Biodiversity

Encouraged by the results of the first study, the co-design team developed a new KCI curriculum in the following school term with a new cohort of 114 grade-ten biology students, in four separate classes. The co-design team remained the same, with one additional science teacher joining the group (one of the teachers from the first study taught two classes, the other two teachers each taught one). The school principal and vice principal also attended a small number of the co-design meetings; they felt our research partnership complemented the strategic vision for the school, which included more integration of technology into the curriculum. The topic of this second curriculum was Canadian Biodiversity, and included a section on Practices for Sustainable Living. The KCI portion of the curriculum was approximately 60 h, or 8 weeks of class time, interspersed over the duration of the broader 14-week unit.

Design

The teacher of each of the four biology classes began the unit by placing students into one of eight Canadian biome groups. Working in these groups, students were free to choose a geographical region from Canada for which they would create a wiki "Ecozone Page" (Fig. 8.5). A New Page script, similar to the one used in the previous iteration, was designed to create ecozone pages with a structure that linked to the curriculum standards (e.g., with headers for the eubacteria and archeabacteria in the ecozone). Students across the four classes contributed to this wiki repository, adding to and editing their peers' ecozone pages. Again, the four classes created a single knowledge repository that would be used by all 114 students for subsequent activities. Over the 8-week unit, students were given a total of six full class periods to complete their ecozone pages, with unfinished pages assigned as homework.

In small groups, students then created a "Biodiversity Issue" page, which described a problem or issue that was threatening their ecozone. Students were able to draw on the expertise they had gained from building their ecozone page to create a detailed description of the causes and implications of the issue. We designed another New Page script (Fig. 8.6), that specified the expected content, in the form of headers with small, italicized instructional prompts, to be included in the Biodiversity Issue page (e.g., discussing the protista, fungi, and plantae of an ecozone). Since ecozones overlap geographically, students were asked to make

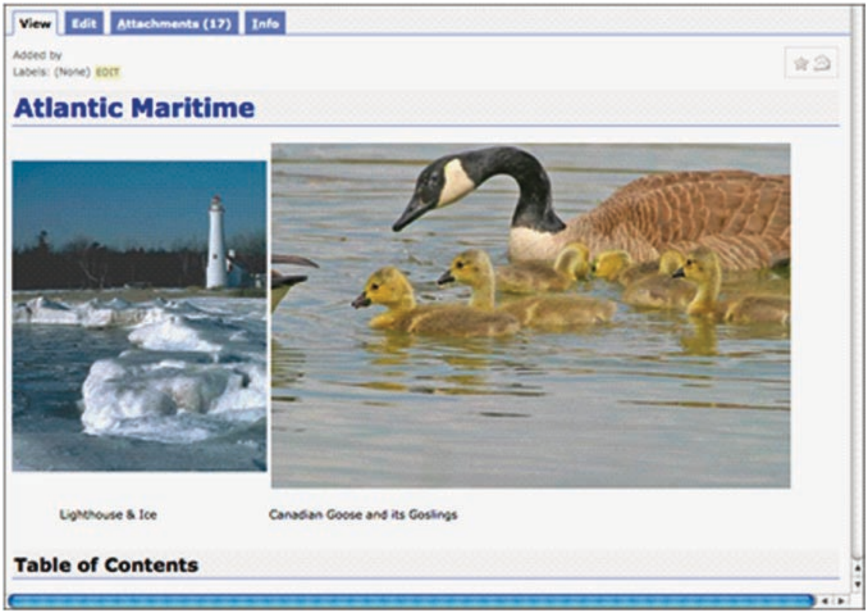


Fig. 8.5 Temperate forest ecozone page

Biological organization

Delete this line and the following italicized line(s), replacing with your response.
Discuss archae bacterial, eubacteria, prostista, fungi, plantae, and animalia.

Physical location

Delete this line and the following italicized line(s), replacing with your response.
In which provinces/territories would you find this ecozone? What other biomes are affected?

Biodiversity overview

Delete this line and the following italicized line(s), replacing with your replies.
Discuss the biodiversity in this Ecozone. Focus on relationships within biological organizations.

Fig. 8.6 Specified biology content in a New Page script

connections between regions, including how the biological factors of one ecozone can influence the biology of another. Students were also asked to include links to their peers' wiki pages that they referenced, embedded in a description of how the content was related.

In the second iteration, an increased effort was given to ensure the activities reflected the voice of the student community. To this end, a "critical juncture" phase was added to capture students' interests and incorporate them into the KCI curriculum. After the Biodiversity Issue pages were completed, the researchers and teachers met to review the content and identify students' interests as represented in their wiki pages. The team identified five major themes: habitat loss and destruction, invasive species, climate change, pollution, and the demands of growing urban populations. These five themes became the topic for the final phase of the curriculum: a scaffolded inquiry activity where students produced an individual research proposal.

The purpose of the individual research proposal was to encourage students to make real-world connections among the ideas and concepts presented in the knowledge base (the ecozone and biodiversity issue pages), including the implications for Canada and their local school community. The teachers asserted that the activity would need to be an individual one so students would have the opportunity to receive an individual grade within the biodiversity unit. In their research proposal, students were asked to outline a current environmental problem in Canada, including a detailed plan of how to address and remedy the situation. Students were asked to connect their proposals to as many ecozone and biodiversity issue pages as possible, including links to all referenced pages. A final New Page script was developed to specify the aspects that should be included in their proposal: project summary, biodiversity impacts, biodiversity specifications, and possible root cause of the problem.

Analysis and Findings

Once again, we evaluated our curriculum in terms of its success in implementing the KCI model. Did students create a rich community knowledge base? Was the knowledge base important to their inquiry tasks? Was the inquiry guided by the emergent themes within the knowledge base? Similar sources of data were available for this iteration as for the previous one: student wiki pages, final research projects, and performance on the final exams, as well as interviews of students and teachers.

The second KCI curriculum was successful in engaging students in the creation of a coauthored resource base. Altogether, students created 36 biome and ecozone pages, the majority of these had three or four contributing authors (Fig. 8.7). Although students actively edited their disease pages in the physiology curriculum, they were much more engaged with revisions in the Biodiversity unit. More class time dedicated to the wiki and a longer unit overall resulted in more edits to the wiki. Interested to find out what kind of edits students were making, we created an algorithm that calculated changes made to the text of a wiki page (i.e., words that were either added, deleted, or changed). For each page revision (each time a page was opened and saved), there was an average of 74 word edits. A significant positive correlation between the number of word edits and page revisions ($r(35) = 0.90$, $p < 0.0001$) suggests that students were actively authoring content throughout the

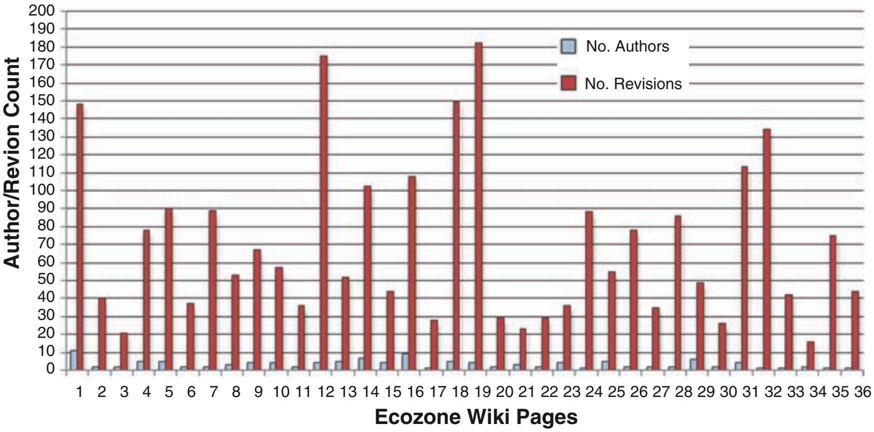


Fig. 8.7 Ecozone pages: authors and revisions

Biodiversity unit, rather than just formatting their wiki or working on the aesthetics. Asked, mid-study, about her thoughts on creating a wiki as part of her Biodiversity unit, Lily, commented:

> It was just a more interactive, more fun way to do [the unit] instead of just getting the notes. Because that's what we usually do for pretty much every unit. We have the projector up and it's just notes that we copy down.

Unlike the disease pages from first study, students were told that their ecozone pages would be formally evaluated. Although this likely provided students with some added incentive, it also appeared to be a cause of frustration, especially since they were not provided with a detailed grading rubric beforehand. One student, Teresa explained her frustration as follows:

> There should have been a restriction on length. If the wiki had to be a certain length, say 5 pages or something, then everybody would do 5 pages and it would have been fine. But since nobody knew how much to do, well, the overachievers went and did like 10 pages, and then everybody else freaked and did 10 pages, then the overachievers would do, like, 10 more pages. So no matter how hard you work, you were never done!

Still, the efforts students put into their ecozone pages appeared to have positive effects on their learning. Using the same teacher's two classes, we performed a correlation test on the relationship between students' exam scores and their ecozone page evaluation score. Student work on the ecozone pages were evaluated in terms of the specific biology content that was included in the wiki. Ecozone pages that included the content specified in the New Page script were awarded higher grades. The teacher also assessed the pages for accuracy and completeness. We found a significant positive correlation between the Ecozone Page scores and the biodiversity exam scores ($r(49)=0.39$, $p<0.0036$).

As we did in the first study, we compared students' final exam scores with those of students from the previous 2 years. Again, we compared only students who had the same teacher in all 3 years (Table 8.2). Again, there was a significant difference among all 3 years between the mean scores of the biodiversity section of the final exam $F(2,113)=7.133$, $p=0.001$, $\eta^2=0.11$ (Fig. 8.8). The scores on the remainder of the final exam (i.e., with the biodiversity section excluded) did not improve across the 3-year span.

Table 8.2 Means and standard deviations of final exam scores for biodiversity curriculum

Biology final exam	Mean	SD
2005–2006		
Biodiversity section	85.57	9.37
Rest of exam	81.55	9.19
2006–2007		
Biodiversity section	83.83	17.28
Rest of exam	83.44	6.94
2007–2008		
Biodiversity section	92.93	7.98
Rest of exam	79.69	8.80

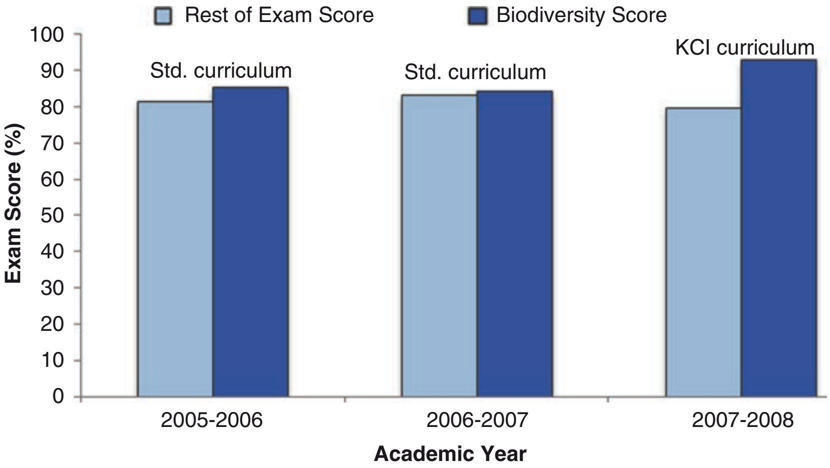


Fig. 8.8 Students' biodiversity exam scores

In the final interviews, we were interested in learning about students' perspectives of the learning process with the KCI curriculum, particularly in terms of the wiki component. Although some students expressed a sense of competition when working on their ecozone pages, others enjoyed being able to see what their peers had produced. In Alice's words:

> I kinda liked looking at other peoples' wiki pages, I thought that was a good exercise because it kind of trained you to assess how other people convey their information and you kind of just got more ideas about how you could improve your page as well, and it was good to just be able to think about it and give people constructive criticism. I don't know, I just thought that part was neat.

Another student, Jocelyn, described her ecozone page as an ongoing artifact, even though she had finished her assignments for the Biodiversity unit. Instead, she described how she felt compelled to keep updating her work. She explains:

> I don't think the wiki was a one-time thing where you're like, 'oh, I'm finished and I can stop working on it.' Like, I know for me, I'd have to go back and edit it once and a while because I'd come across some new piece of information or I'd read something and I'm like, 'oh well, I have to edit something back on my page,' or something like that. So it ended up being a really long-term thing – I even worked on it way after it was due.

We also interviewed the school vice principal, who oversees curriculum development in consultation with the subject department heads. For the researchers, part of the value of the KCI model is its flexibility in terms of subject matter and teacher enactment. Since the co-design approach ensures that teachers are deeply involved in the design of the materials, they can essentially take over when time comes to enact the curriculum. As teachers become more involved in co-design, their understanding of and familiarity with the researcher's pedagogical model (in this case, KCI) becomes more secure. It was this aspect of co-design that the school vice principal alluded to in his interview:

> The important thing for me is if we're going to introduce a new intervention or technology, then it needs to be sustainable. Because in the beginning I think the researchers have more expertise in terms of the technology, but now our teachers are getting there, too. They're more confident and comfortable using it, and now they're enabled to a point where they can do a new curriculum and sustain it, and share it with their colleagues. If this falls apart because it's totally dependent on the researchers to make it work, then there's not much value in it for us.

Design Challenges and Recommendations

After completing the second iteration, we had the opportunity to reflect on the different implementations of the KCI curriculum. We noticed there were a number of difficulties with the Biodiversity curriculum that we did not have in the first study with the Human Physiology unit. For example, the extended knowledge construction activity from the 8-week curriculum was somewhat problematic. In the Physiology unit, students' work on the disease pages was limited to two class periods over the course of a week. In the Biodiversity unit, students worked on their ecozone and biodiversity issue pages for over 8 weeks, with some students working over the December break. These knowledge construction activities dominated the second curriculum considerably, leaving comparatively little time for the final activity, the individual research proposal. Many students felt overburdened with the amount of time it took to create their community resource. Since there was a considerable amount of detailed information in their wiki pages, students were also worried about having to memorize the content for their final exam. The teachers quelled their concerns by posting messages on the class list serve, but they too had apprehensions about the wiki pages, in terms of the time it would take to grade them. To address these issues, the next iteration of the curriculum will combine the Biodiversity Issue activity with the Individual Research Proposal to alleviate some of the wiki work and lessen the time constraints for both teachers and students. In general, KCI curriculum designs must guard against demanding too much authoring from students, and must be cautious about the amount of curriculum time they demand of teachers.

We also noted the potential for improving the designs of scaffolded inquiry. In the Biodiversity curriculum, we provided students with a starter page with some appropriate headers and hints for their research proposal. However, it would be more desirable to engage students with a series of steps for reflecting about their proposal topic, searching for resources, exchanging ideas with peers, and developing several versions of the proposal. This sequence of activities could involve a number of distinct inquiry steps and various tools, including concept mapping tools and collaborative groups. Of course, this would further add to the complexity of the design and would need to be balanced in terms of the workload for students and teachers.

We noticed the co-design approach was more challenging during the second iteration of the curriculum. This was largely due to the number of co-design meetings that were required throughout the design process, which proved to be too much for the teachers. Although we had the experience of the Human Physiology curriculum behind us, the Biodiversity unit still required ongoing co-design meetings through its implementation. Adding a third teacher only contributed to the difficulty of scheduling meetings during the school term. Since the teachers had varied school schedules, it was difficult to find meeting times during the day when no teacher was in a classroom. Meetings that took place over the lunch hour were often interrupted by students, or were truncated so that teachers could use the time for grading or preparing for their next class. In a poststudy interview, one of the teachers, Laura, described her experience of the co-design meetings as follows:

> It was really hard to make the meetings. Really hard. There had to be an outside force telling me we need to meet. And it had to be me saying if we don't meet, I'm shafting somebody's research. And so many times I was dragging my heels thinking, 'I have so many more important things to do.' But those meeting were really important. And they were essential to making this work.

In both iterations of the KCI curriculum, researchers as well as teachers had hoped to make productive use of the wiki data logs (i.e., for analysis and assessment). One of the advantages of a wiki is that it preserves all saved versions in a historical archive. Any previous version can easily be restored, along with users' editing activity. Such functionality has the potential for providing teachers with a powerful tool for assessing group work, and is the kind of tool our teachers expressed an interest in employing. In previous studies, researchers have used data logs to create visualizations for quantifying students' individual wiki contributions (Kay, Yacef, & Reimann, 2007) and for facilitating navigation and content flow (Ullman & Kay, 2007). Still, the voluminous data generated by web logs can be quite daunting, and more research is required before teachers can use such sources to assess the quality of students' wiki contributions. We are currently engaged in efforts to design analytic tools for such purposes.

Conclusion

This chapter provides the first empirical support for the Knowledge Community and Inquiry model. The work reported here demonstrates that the model can result in effective designs that engage students in a knowledge community, while also enabling structured inquiry activities that address content expectations. The co-design process was also confirmed as an effective approach, as it provided an engaging experience for the researchers and teachers, and resulted in two iterations of successful design. It is worth noting that this kind of curriculum is a rare event in research or classroom practice, where four students in different sections of a class collaborate together to create a useful knowledge resource, and then separately work on technology-enhanced inquiry projects that draw upon that resource. It was felt by the teachers and researchers that this project had positive outcomes, and that students had learned in ways that none of us had experienced before.

The teachers' commitment to the KCI curriculum was essential for ensuring that students were engaged with the materials and actively participating. This commitment also enabled them to adopt new methods of knowledge construction and collaborative inquiry, which were supported by a technology (i.e., the wiki) that was new to the teachers. These teachers responded enthusiastically to the new methods, and are currently engaged in designing a new global climate curriculum that is yet another iteration of the model. Further, they continue to enact the physiology and biodiversity units, which are now a core part of their curriculum. This study demonstrates that knowledge community methods can be successfully designed for high school science classrooms, and provides support for the KCI model as an effective mechanism for embedding such methods into curriculum activities. This work thus responds to an ongoing challenge of how to make community-based learning activities and scaffolded inquiry more relevant for secondary teachers, and opens up possible avenues for future research and theoretical models.

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