Co-Designing Curricula to Promote Collaborative Knowledge Construction in Secondary School Science

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Abstract: We describe a two-year study of a rich secondary science curriculum that was co-designed in close partnership with teachers, technology specialists and even school administrators. The goal of the research was to provide empirical support for a recent model of learning and instruction that blends the two perspectives of knowledge communities and scaffolded inquiry. A design-oriented method was employed, where the first iteration of the curriculum was evaluated in terms of its fit to the model, as well as its impact on student learning. Based on a set of design recommendations, a much more substantive curriculum was developed for the second iteration, leading to rich measures of student collaboration and deep understanding of the targeted science concepts. This paper describes our co-design process, which allowed teachers to lead the curriculum design and classroom enactment while researchers contributed design guidelines according to the theoretical model.

Introduction

It is not easy for teachers to experiment with new instructional approaches. Unlike scientists and business people who are generally motivated to embrace new practices, teachers are more cautious about change. In part, this is because the stakes are high in teaching: If something goes wrong in the classroom and things get out of control, this can have lasting consequences that make it difficult or impossible for the teacher to regain that control. Additionally, the demands of research-based approaches are often unrealistic, requiring a radical change in teachers' practices. Traditional methods such as lectures, labs and problem sets are more familiar to teachers, who understandably try to remain within their comfort zone. This is particularly the case in content-rich subject areas like science, where teachers feel a tremendous pressure to address all content expectations. Methods that engage students in high levels of open collaboration can be unconventional for teachers, who usually require time to experiment with the new methods before using them in their classrooms.

Although research has explored new ways to add inquiry-based and collaborative knowledge construction to the curriculum, these approaches are not easily embraced by teachers. For example, inquiry methods (e.g., Linn & Hsi, 2000; Edelson, Pea, & Gomez, 1996) have often been too heavily scripted and inflexible, requiring specific practices and materials that may not fit in with the teacher's existing curriculum. Another leading approach from research is that of collaborative knowledge construction (Brown & Campione, 1996; Scardamalia & Bereiter, 1996) which can be 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 addresses specific science learning goals, and supports teachers and students in becoming a knowledge community.

This paper begins by considering the rich research traditions of scaffolded inquiry and knowledge communities, as well as a recent model (see Slotta, 2007; Slotta & Peters, 2008) that describes how they can be blended to create powerful new curriculum that is well suited for secondary science. We also discuss the important innovation of co-design (Roschelle, Penuel, & Sechtman, 2006), which offers a means of creating such curriculum in a way that it meets teachers' expectations while assuring adherence to the model. We discuss a two-year design study with two iterations where co-design was employed to create a technology-enhanced curriculum that was designed around the model. For each design iteration, we evaluate how well the curriculum conformed to the model, and measure the success of the activities in terms of helping students achieve a deep understanding of science in collaboration with peers.

Moving Research-Based Innovations into the Classroom

It can be challenging to implement innovations developed by "outsiders" into traditional classrooms. This is especially the case for high school science, where a high volume of curriculum content and traditional assessments make it difficult for teachers to embrace the kinds of rich inquiry and constructivist models that are advocated by researchers. Science textbooks in particular cover more topics than any other subject, resulting in textbooks that have been described as being "a mile wide and an inch deep" (Schmidt, McKnight & Raizen, 1997, p. 62). Teachers are responsible for addressing well-specified sequences of subject matter (e.g., cellular biology, genetics, human physiology), making it difficult to design learning activities where students pursue a deep understanding of science through open collaboration. Curriculum expectations more than fill up the time allotted to most science courses, leaving teachers little or no time to engage their students in discussions of "big-picture" questions or personally relevant projects. All lessons or units must fit within a tight class schedule, with outcomes that are assessable by conventional measures. Instructors must feel they are using each class period productively, and that their students are learning the science topics set forth by their national or local educational agencies. For any new curriculum to be successfully implemented, the teachers must perceive an alignment between the new materials and the mandated curriculum (Penuel, Fishman, Gallagher, Korbak, & Lopez-Prado, 2008).

Powerful Learning Innovations

There are a number of promising approaches that provide mechanisms for engaging students in rich and engaging collaborative inquiry. One common thread among these approaches is the goal of fostering knowledge creation by engaging students in collaborative activities within a community of peers. 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." Scardamalia and Bereiter (1996, 2002) have investigated a knowledge building approach where 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. These and other innovations have the potential to transform classrooms into knowledge communities where students work on collaborative activities within their peer community. Yet, most secondary science teachers are unable or unwilling to implement such an approach in their classrooms. Methods such as FCL and knowledge building require substantial changes in teachers' instructional practices, and it can be difficult for them to make these changes while still addressing the required subject matter.

Another common theme in the research literature is that of scaffolded inquiry. Researchers have developed a number of prominent pedagogical approaches that provide students with rich collaborative inquiry activities, which often includes technology-enhanced tools and materials (e.g., Linn & Hsi, 2000; Slotta, 2004; Songer, 2006). Despite widespread enthusiasm, these approaches have yet to make any strong headway in science classrooms, as researchers have yet to determine how they can promote new cultures of learning while remaining sensitive to curriculum standards: What types of pedagogical and technological innovations are required to transform classrooms into learning communities? How can these innovations be designed? What supports do teachers need to enact new approaches in a manner that does not undermine the theoretical commitments of the design? These are all questions that need to be addressed before inquiry-oriented instruction can pervade secondary school science curricula.

Toward a New Model for Knowledge Community and Inquiry

In an effort to make headway on these problems, Slotta (2007) developed the Knowledge Community and Inquiry (KCI) model, which combines collaborative knowledge construction with scaffolded inquiry activities to target specific curriculum learning objectives (see also Slotta & Peters, 2008). The model begins with a collaborative knowledge construction activity where students explore and investigate their own ideas as a community of learners, creating knowledge artifacts that are aggregated into a communal knowledge base. An important component of collaborative knowledge construction is that learning activities (such as inquiry-type investigations) must be guided by the community itself through the knowledge construction process (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 design of any activity must also address the subject matter and learning goals of the curriculum.

It is no easy task to design curriculum that responds to community interests while addressing learning objectives and adhering to time constraints. In the KCI model, the scaffolded inquiry activities are co-designed by teachers and researchers only after the knowledge construction phase is complete, resulting in dynamic, emergent activities that build upon the themes that were identified within the knowledge base. Students then work independently or collaboratively on these activities, drawing on knowledge elements from the community knowledge base, producing new contributions to that knowledge base, and completing inquiry tasks that are directly connected to assessable learning outcomes.

Co-design: A Powerful Innovation for Classroom-based Research

How can we create instructional materials that encompass research objectives while still complementing a teacher's curriculum? The success of any research-based curriculum will critically depend on the teacher's understanding and enactment of the materials and approaches. Technology can provide scaffolding, but any new and complex method requires a complete buy-in of the participating teachers. This can be accomplished through a process known as co-design (Roschelle, Penuel, & Shechtman, 2006; Penuel, Rochelle, & Shechtman, 2007) where all instructional materials and designs are developed in close collaboration between researchers and teachers. Roschelle et al. (2006) developed co-design 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. Both these approaches emphasize the importance of input from the end users of the design innovation. However, co-design almost always involves extensive negotiations and trade-offs before any final design decisions can be made. The reliance that co-design places on teachers' input also makes it highly compatible with design-based research.

Methodology

This study takes the form of a design-research experiment for the purpose of developing a collaborative, inquiry-based curriculum through iteration. Design research was developed by Brown (1992) and Collins (1992) in response to the recognition of the need for studying learning in context. Brown (1992) stresses that to fully appreciate the complexity of students' learning, the researcher must study the classroom holistically. Curriculum development, assessment and the role of the teacher are all interconnected and cannot be examined independently without disturbing the synergy that is part of regular working classrooms. Contributing to a theory of learning that informs practice can only be achieved if the innovation can realistically be enacted in everyday classroom settings (Brown, 1992). Thus, design experiments have been said to "fill a niche in the array of experimental methods that is needed to improve educational practices" (Collins, Joseph, & Bielaczyc, 2004, p. 21).

Embedded Technology Scaffolds

We employed a wiki-based technology environment to support the design and delivery of all research materials. A wiki provided the ideal functionality for collaborative knowledge construction, since students could easily access and edit one another's ideas, reorganize pages to capture emerging themes, and link pages to establish connections between related ideas. A new hybrid wiki environment improved 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, structured way for students to create wiki pages to their treatment of science concepts. The result was the development of a special web form (developed in the Ruby on Rails language) to collect metadata (using check boxes and text fields), which then generated a new wiki page that was properly linked, including pre-specified headers and the required authoring and access permissions. This web form was used in the research to create a "New Page" script (see Figure 1) that included headers and scaffolded students about specific science content to include in their wiki pages. Another advantage of the web form is that it enabled students to start working on the content right away, and gave a consistent look and feel to the wiki.

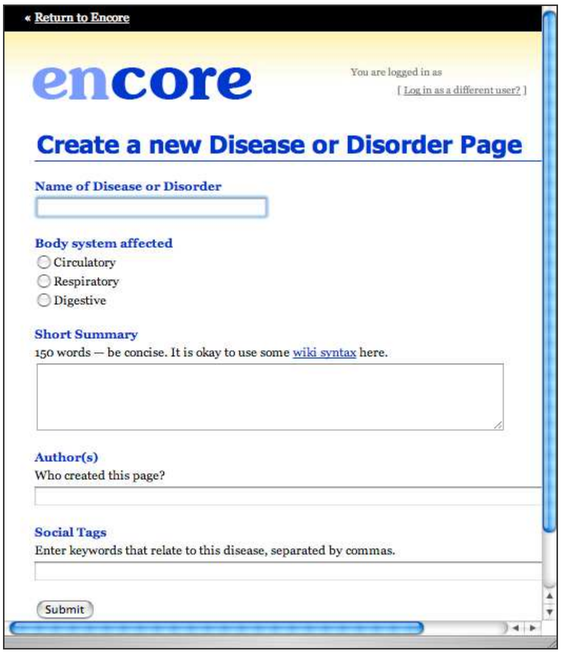

Figure 1. Example of a "New Page" Script for Human Physiology

Iteration 1: Human Physiology and Diseases

Prior to the first iteration, the researchers established a working relationship with two science teachers from a local high school. A number of meetings were held to discuss the initiation of a research partnership. In October of 2006, one of the researchers conducted field visits to observe the culture and practice of the classroom. Eight full-class periods were observed over the following three months. Beginning January 2007, the researchers and teachers met to plan a curriculum for grade ten biology students that was designed around the KCI model. Seventeen co-design meetings were held between January and May of 2007. To limit the extra workload on teachers, the co-design meetings often took place at the school at times that were convenient for the teachers. The curriculum that resulted from these meetings, the Human Physiology unit, began in May of 2007 and was one week in duration.

Participants

Participants included 102 grade ten biology students and two experienced science teachers. The co-educational school involved in this study provides specialized curriculum for high-achieving students in grades 7 through 12. Initially created as a laboratory school, this unique institution prides itself on new and innovative classroom practices. Admission to the school is competitive and based on students' score on the Secondary School Admission Test (SSAT), with 98% of new admissions being accepted from grade 6 students. The school population is ethnically diverse, with the majority of students coming from middle to upper-middle class homes. The school has a strong commitment to the liberal arts and sciences curriculum, and students are expected to fully engage in their academic program. There is a strong emphasis on community, and individual acceleration and early course specialization are discouraged. Assessment is ongoing throughout the school year and consists of formal progress reports and performance improvement plans.

Phase 1: Developing a Knowledge Base

Students began the lesson by participating in a knowledge construction activity where they first brainstormed about different diseases that affect the human body. The teacher then placed students into one of three categories of human body systems: circulatory, respiratory or digestive. In small groups, students could choose to create a wiki page about any disease of their choice, provided it was in their assigned body system. Using the New Page script, students created a "Disease Page" about their chosen system disease (see Figure 2 for an example Disease Page). This script specified some of the content that students had to include in their wiki pages (e.g. how their disease affects other systems in the human body). Students across all four class periods contributed to this same wiki repository, editing and revising each other's wiki disease pages. Each class was given two full periods to complete their disease pages, unfinished pages were assigned as homework.

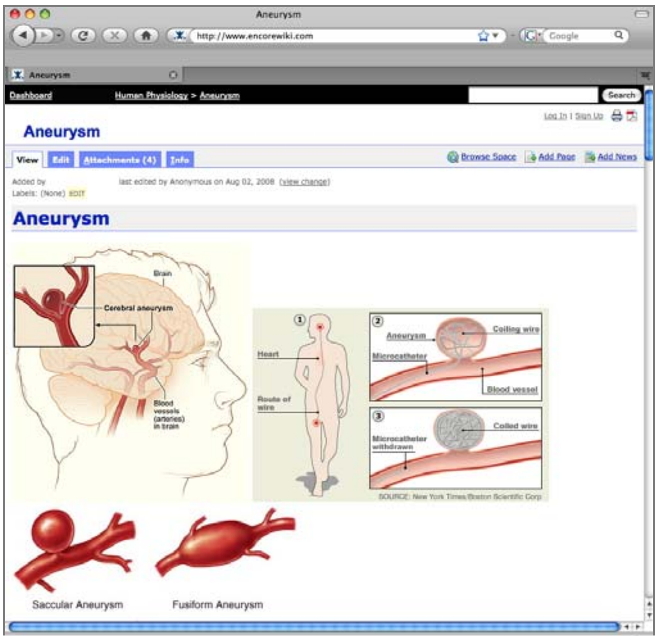

Figure 2. Example of a Circulatory Disease Page

Phase 2: Scaffolded Inquiry

In small groups, students then created a "Challenge Case" about their disease, which involved a fictitious case study about an individual who presents a number of symptoms to their physician. To engage students with the wider community knowledge base, they were instructed to solve a challenge case that was not in the same system as their wiki Disease Page (i.e. if a student created a wiki page about a circulatory disease, then they had to solve a challenge case that involved either the respiratory or digestive system).

Analysis and Findings

The curriculum was evaluated in terms of the following dimensions: its adherence to the KCI model, student learning outcomes, and students' experiences with the curriculum. The new curriculum was successful in creating a community knowledge base. Between the four classes, students created 23 comprehensive disease pages across the three systems. Each disease page was run through Copyscape©, a web-based utility that compares web pages to check for instances of plagiarism. Of all 102 students, there were four instances of plagiarism that warranted concern. When solving the challenge cases, students used their peers' disease pages as a resource. The researchers anticipated that students would use Google, but instead they consulted their community resource base. The challenge cases were solved in-class, giving the researchers the opportunity to observe students' activities.

We also compared the students' exam scores with the same teachers grade ten biology students from the previous two years, who received the traditional curriculum consisting of lectures and a lab. Only classes that had been taught by the same teacher in all three years were included in the comparison. We compared the performance of the three groups on the physiology sections of the final exam, which used similar open-ended questions for all three years (e.g., a question might ask students to describe how a disease in one body system affected the biological processes of another). An independent-measures ANOVA revealed a significant difference in students' scores. Those who participated in the wiki lesson were found to have higher scores than students from the previous two years who were taught with the regular curriculum. This difference was significant, with a value of $F(2, 96) = 7.236$, $p = .001$ (see Figure 3).

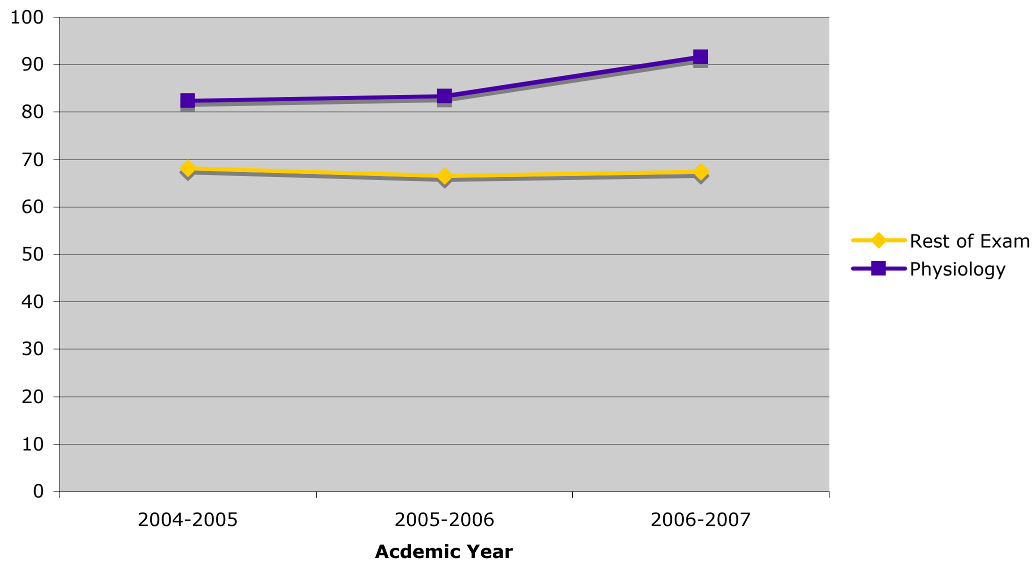

Figure 3. Students' Exam Scores

In their interviews, both teachers indicated feeling positive and enthusiastic about the new curriculum. Both teachers agreed that designing the activities were time-consuming, but that the workload was not too overwhelming. One of the teachers, Laura, admitted feeling apprehensive before beginning the unit, and expressed her concern about 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.

In terms of student understanding, the teachers felt that the curriculum helped students develop deeper understandings of how the three physiological systems interact together. The teachers were very satisfied with students' understanding of the material as evidenced by their responses on the final exam. The students were able to make connections between the different diseases of the body systems (e.g. how a low red blood cell count from one disease could make a person more susceptible to a disease in a different system). The second teacher, Joanna, described how the curriculum was able to address 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 body systems interact." One student demonstrated such understanding in a post-study interview:

> "If there's a problem with the production of red blood cells in one system, oxygen won't be transported around the body very well, and CO_2 will not be removed as efficiently. The disease wiki showed me that there's a direct link between the processes of organelles and how they work in our body – like the mitochondrion O_2 go through the Krebs cycle, and red blood cells bring the O_2 to the other cells for use in cellular respiration."

Design Challenges and Recommendations

Although the first iteration of the curriculum was encouraging, a number of problems became apparent during its enactment. During the scaffolded activity, students were successful in using their community resource (i.e. the repository of disease pages) to solve their challenge cases. However, when doing so, they did not engage deeply with the material. Students only needed to consult their peers' wiki pages briefly to solve the cases, there was no cause for them to make connections to the material or extend it. Because of this, the design did not meet the definition of the KCI model, which requires a deep interconnection between the scaffolded inquiry activities and the knowledge base created by the students. Future iterations would need to make such connections more explicit by scaffolding them. Additionally, a number of students expressed disappointment in their interviews that the disease pages were not formally graded, and felt they should have been rewarded for their efforts. Many students also expressed annoyance at not receiving more explicit and direct instructions about creating a disease page. 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? How are we supposed to know what to include? 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."

Taken together, the data from the first iteration illustrated areas in which the curriculum needed improvement. A number of refinements were needed to meet more of the researchers' objectives (e.g. having students make deeper connections to the community resource). The curriculum also appeared to require longer activities for which the teachers could assign grades.

Iteration 2: Canada's Biodiversity

The second iteration of the KCI curriculum was implemented in the fall of 2007 with a new cohort of 114 grade ten biology students. The co-design team remained the same, with one additional science teacher joining the group. The school principal and vice principal also attended a small number of these meetings. The curriculum content for Iteration 2 was Canadian Biodiversity, and included a section on practices for sustainable living. The KCI curriculum in the second iteration was interspersed over a much longer period of eight weeks.

Phase 1: Developing a Knowledge Base

The teacher began the Biodiversity lesson 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". A small number of groups wrote a wiki page about a biome instead of an ecozone. A New Page script was also used in the second iteration, and specified content that was outlined in the curriculum standards (e.g. eubacteria and archeabacteria in ecozones). Once again, students across the four classes contributed to this same wiki repository, adding to and editing their peers' ecozone pages. Over the eight-week unit, students were given a total of six full class periods to complete their disease pages, with unfinished pages assigned as homework.

Phase 2: Enriching the Knowledge Base

In pairs, students then created a "Biodiversity Issue" page. A biodiversity issue page described a problem or issue that was threatening one of Canada's ecozones. Students were able to utilize their expertise by choosing a biodiversity issue that involved the same region for which they had created an Ecozone Page. Similar to the Human Physiology lesson, a wiki template specified content to be included in the Biodiversity Issue pages (e.g. the importance of reestablishing or preserving the biodiversity of an ecozone). Since ecozones and biomes overlap geographically, students were asked to make 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 any of their classmates' wiki pages that they referenced.

Phase 3: Identifying Emergent Themes within the Knowledge Base

Efforts were made in the second iteration to ensure the curriculum reflected the voice of the 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, with the purpose of incorporating these interests into a subsequent activity. Five major themes were identified: (a) habitat loss and destruction, (b) invasive species, (c) climate change, (d) pollution, and (e) demands of growing urban populations. These five themes were used to guide the design of the final phase of the curriculum: a scaffolded inquiry activity where students wrote an individual research proposal.

Phase 4: Scaffolded Inquiry – The Individual Research Proposal

The purpose of the individual research proposal was to engage students in making connections between the ideas and concepts in their community knowledge base (the ecozone and biodiversity issue pages), and pressing real-world problems, including the implications for Canada and their local school community. Teachers asserted that the activity needed to be an individual to allow for the assignment of an individual grade within the biodiversity unit. In this activity, students were asked to write a research proposal that outlined 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 pages as possible, including links to all referenced pages. A New Page script specified aspects to be included in their proposal: project summary, biodiversity impacts, biodiversity specifications and possible root cause.

Analysis and Findings

Similar data were collected in the Biodiversity curriculum as that collected for Human Physiology, with the addition of web logs of students' wiki activity. Across the four classes, students created 34 ecozone and biome pages, and 47 biodiversity issue pages, and were actively engaged in revising the wiki entries of their knowledge resource. Figure 4 illustrates the number of page revisions for each ecozone (i.e., each time a page was opened and saved) vs. the average number of words that were edited in each revision. We created an algorithm that parsed the wiki data for text that had been added, deleted or revised, excluding any text found in wiki mark-up, image tags or title headers. We found a significant positive correlation between the number of word edits and the number of page revisions ($r(35) = .90$, $p < .0001$) suggesting that students were actively authoring throughout the Biodiversity unit, rather than continuously formatting their wiki or working on aesthetics.

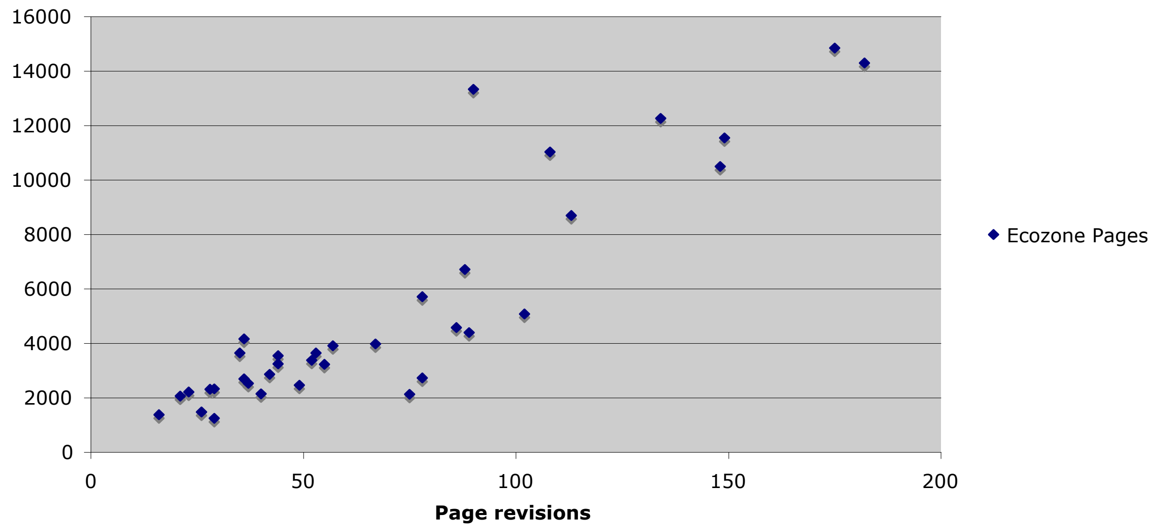

Figure 4. Ecozone Page Revisions by Average Number of Words Edited

Student work during the knowledge construction activity also appeared to have a positive effect on learning outcomes. Using the two classes that were taught by the same teacher, a correlation test was performed 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 in terms of accuracy and completeness. There was a significant positive correlation between the Ecozone Page scores and the biodiversity exam scores ($r(49) = .38$, $p < .0056$), including much overlap between students' scores (Figure 5).

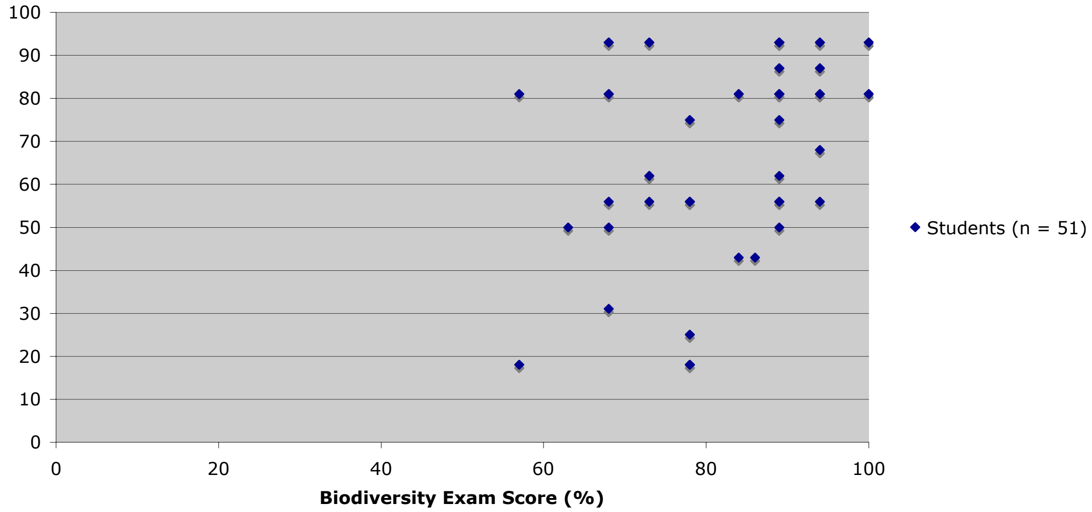

Figure 5. Students' Biodiversity Exam Scores vs. Ecozone Page Scores

During their interviews, students revealed mixed reactions towards the KCI curriculum in terms of its presentation and structure. While some students appeared to enjoy the open-ended format, others felt it interfered with what they described as "regular" learning. Lila described her perspective as follows:

> "[The new curriculum] isn't fair because some people don't work well like this. They work well when they're given a lot of questions and they have to basically learn the material first and then be tested on that and everything. And also, I think regular learning is better because then you have a direction to go into, like you know what you want to look up. And then once you have the background information on the topic and everything I think it's easier for you to think of more questions and, like, analyze the whole situation."

Other students were more positive about the open-ended aspect. For example, Jonah enjoyed being able to discern his own topic instead of being "just told what to do all the time". Ingrid felt similarly, but she also explained that she enjoyed the inquiry of learning about ecozones and other environmental issues. In Ingrid's own words:

> "Let's say you're starting off with a question, like why are forests in British Columbia decreasing right now, right? From that you could go on and you discover a whole bunch of other questions. And then from that main question you can maybe go on to investigate the disappearance of the spotted owl or something. Which is linked to the forests. So it's kind of like a linkage process instead of just being like tested on one set goal, and it's also more interesting to find you own way."

Part of the value of the KCI model is its flexibility in terms of subject matter and teacher enactment. Since co-design ensures that teachers are deeply involved in the design of the materials, the researcher can remain hands-off when it comes time to enact the curriculum. As teachers become more involved in co-design, their understanding of and familiarity with the KCI model will increase. An interview with the school vice-principal revealed his position on the research-based innovation within his school:

> "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 with 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

A number of challenges arose in the Biodiversity curriculum that were not present in the first iteration. Although the one-week duration of the Human Physiology curriculum appeared to be too brief, the eight-week period of the Biodiversity curriculum was too long. In particular, the number of co-design meetings required throughout the design process proved to be too much for the teachers, even though the researchers were very obliging. Adding a third teacher only contributed to the difficulty of planning meetings throughout the term. Since the teachers had varied school schedules, it was not possible to meet during class time. Meetings that took place over the lunch hour were often interrupted by students, or were truncated so teachers could use the time for marking or class preparation. One of the teachers, Laura, described her experience of the second iteration 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."

The eight-week curriculum also extended the length of the knowledge construction phase, which ended up being problematic. In the first iteration, students' work on the disease pages was limited to two class periods over the course of a week. In the Biodiversity curriculum, the combination of Ecozone pages and Biodiversity Issue pages resulted in too much "busy work". Both students and teachers felt overwhelmed with the amount of content that was generated in the wiki. Future iterations of the KCI model will need to find the middle ground in terms of the ideal length for a knowledge construction activity.

Conclusion

This research provides support for the Knowledge Community and Inquiry model, in which scaffolded inquiry activities provide students with incentive and opportunity to make use of their community knowledge base. The co-design method was effective, and essential for helping teachers feel committed to the curriculum. This commitment from teachers was necessary to ensure that students were engaged with the materials and actively participating in the activities. The KCI model also enabled the teachers to adopt new methods of knowledge construction and collaborative inquiry, which were described by the researchers but could only be enacted by the teachers. We see our growing partnership with the teachers as step towards the "hybrid" culture described by Bereiter (2002), in which the culture of researchers and teachers come together to address educational concerns that require the expertise of both groups. In our research, the teachers responded enthusiastically to the new methods, and are currently engaged in designing a new global climate change unit that is a further extension of the KCI model. Moreover, they continue to enact the physiology and biodiversity units, which have become a staple part of the biodiversity curriculum.

This study demonstrates that knowledge community methods, when developed in collaboration with teachers, can be successfully designed for high school science classrooms. Although still ongoing, this research lends support to the KCI model as a powerful mechanism for embedding collaborative knowledge construction 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 pedagogical models.

References

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *Journal of the Learning Sciences, 2*(2), 141-178.

Brown, A. L., & Campione, J. (1996). Psychological theory and the design of innovative learning environments: On procedures, principles, and systems. In L. Schauble & R. Glaser (Eds.), *Innovations in learning: New environments for education*, (pp. 289-325). Mahwah, NJ: Erlbaum.

Bereiter, C. (2002). *Education and mind in the knowledge age* (pp. 382-418). Mahwah, NJ: Lawrence Erlbaum Associates.

Collins, A. (1992). Toward a design science of education. In E. Scanlon & T. O'Shea (Eds.), *New directions in Educational Technology* (pp. 15–22). New York: Springer-Verlag.

Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. *International Journal of the Learning Sciences, 13*(1), 15-42.

Edelson, D. C., Pea, R. D., & Gomez, L. (1996). Constructivism in the collaboratory. In B. G. Wilson (Ed.), Constructivist learning environments: Case studies in instructional design (pp. 151–164). Englewood Cliffs, NJ: Educational Technology Publications.

Linn, M. C. & Eylon, B. S. (2006). Science education: Integrating views of learning and instruction. In P. A.

Alexander & P. H. Winne (Eds.), *Handbook of Educational Psychology, 2nd ed*. (pp. 511-544). Mahwah, NJ : Lawrence.
Linn, M. C., & Hsi, S. (2000). Computers, Teachers, Peers: Science Learning Partners. Mahwah, NJ: Lawrence Erlbaum Associates.Linn, M. C. & Songer, N. B. (1991). Cognitive and conceptual change in adolescence. *American Journal of Education, 99*(4), 379–417.
Linn, M. C. & Songer, N. B. (1991). Cognitive and conceptual change in adolescence. *American Journal of Education, 99*(4), 379–417.
Palincsar, A., & Brown, A. L. (1984). Reciprocal teaching of comprehension-fostering and comprehension-Monitoring activities. *Cognition and Instruction, 1*(2), 117-175.
Pea, R. D., & Gomez, L. (1993). Distributed multimedia learning environments: The Collaborative Visualization Project. *Communications of the ACM, 36*(5), 60-63.
Penuel, W. R., Roschelle, J., & Shechtman, N. (2007). Designing formative assessment software with teachers: An analysis of the co-design process. *Research and Practice in Technology Enhanced Learning, 2*(1), 51-74.
Penuel, W. R., Fishman, B. J., Gallagher, L. P., Korbak, C., & Lopez-Prado, B. (2008). The mediating role of coherence in curriculum implementation. *Proceedings of the Biennial International Conference of the Learning Sciences (ICLS).* Utrecht, The Netherlands. ISSN: 1819-0138.
Peters, V., & Slotta, J. D. (2007, August). Co-designing a knowledge building activity with secondary school teachers. Paper presented at the annual meeting of the *Institute for Knowledge Innovation and Technology*, Toronto, ON.
Roschelle, J., Penuel, W. R., & Schechtman, N. (2006). Co-design of innovations with teachers: Definition and dynamics. *Proceedings of the International Conference of the Learning Sciences*, Bloomington, IN.
Scardamalia, M., & Bereiter, C. (1996). Adaptation and understanding: A case for new cultures of schooling. In S. Vosniadou, E. de Corte, R. Glaser, & H. Mandl (Eds.), *International perspectives on the design of technology: Supported learning environments* (pp. 149-163). Mahwah, NJ: Lawrence Erlbaum.
Scardamalia, M., & Bereiter, C. (2002). Knowledge Building. In *Encyclopedia of Education, Second Edition.* New York: Macmillan Reference.
Schmidt, W. H., McKnight, C. C., & Raizen, S. A. (1997). *A splintered vision: An investigation of U.S. science and mathematics education*. Norwell, MA: Kluwer Academic Publishers.
Slotta, J. D. (2004). The web-based inquiry science environment (WISE): Scaffolding knowledge integration in the science classroom. In M. C. Linn, P. Bell, & E. Davis (Eds.) *Internet Environments for Science Education* (pp. 202-231). Mahwah, NJ: Erlbaum.
Slotta, J. D. (2007, June). Supporting collaborative inquiry: New architectures, new opportunities. In J. Gobert (Chair), Fostering peer collaboration with technology. Symposium conducted at the annual Computer Supported Collaborative Learning (CSCL) conference, Rutgers, NJ.
Slotta, J. D., & Peters, V. L. (2008). A blended model for knowledge communities: Embedding scaffolded inquiry. In the proceedings of the *Biennial Meeting of the International Conference of the Learning Sciences (ICLS)*. Utrecht, The Netherlands. ISSN: 1819-0138.
Songer, N. B. (2006). BioKIDS: An Animated Conversation on the Development of Curricular Activity Structures for Inquiry Science. In R. Keith Sawyer (Ed.), *Cambridge Handbook of the Learning Sciences* (pp. 355-369). New York: Cambridge University Press.

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