Constructing Text: Wiki as a Toolkit for (Collaborative?) Learning

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Abstract

Writing a book from which others can learn is itself a powerful learning experience. Based on this proposition, we have launched *Science Online*, a wiki to support learning in high school science classrooms through the collaborative production of an online science resource. Our approach to designing educational uses of technology is based on an approach to education called constructionism, which advocates learning by working on personally meaningful projects. Our research examines the ways that constructionism connects to collective models of knowledge production and learning such as Knowledge Building. In this paper, we explore ways that collaboration using wiki tools fits into the constructionist approach, we examine learning goals for youth growing up in a read-write culture, and we discuss preliminary findings in an ongoing year-long study of *Science Online* in the classroom. Despite the radically open collaboration afforded by wiki, we observe that many factors conspired to stymie collaborative writing on the site. We expected to find cultural barriers to wiki adoption in schools. Unexpectedly, we are also finding that the design of the wiki tool itself contributed barriers to collaborative writing in the classroom.

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1. Growing Up in a Wiki World

In a read/write world, information literacy means more than knowing where to find information or how to interpret messages from advertisers, government agencies, educational institutions and other publishers. Literacy involves both becoming able to interpret information and becoming an adept participant in the construction of new knowledge. Distributed models of cognition and intelligence have become increasingly prevalent both in scholarly [18, 34] and, more recently, popular literature [35] and have often been associated with educational approaches that underscore the importance of collaborative problem solving and group work (i.e. [31, 32]). The production of media is a critical component of knowledge work. Educational experiences should prepare students to become skilled collaborators and producers of knowledge, not mere consumers. But to what extent can we expect students to take on such roles of cognitive and social responsibility?

The idea of turning over responsibility for knowledge production to students is sometimes met with confusion and resistance. Surely we cannot imagine that students will participate in the production of, for example, a real information resource, lesson plans for other students, or other useful educational materials. They are, after all, still learning. The design of learning materials and the experience of learning are commonly perceived as two distinct endeavors; one space is inhabited by teachers and more knowledgeable elders, the other inhabited by compliant neophytes. John Dewey suggested that education should be seen as a vital form of participation in the intellectual life of the word: "Education is a social process; education is growth; education is not a preparation for life but is life itself" [10]. Contemporary educational leaders like Marlene Scardamalia, Carl Bereiter, Jean Lave, and Etienne Wenger have long argued that the dissociation of educational experiences from real-world communities of practice is not only detrimental to learning, but also undervalues learners' potential to contribute legitimately to the intellectual work of the world [20, 32]. As technologies like wikis and blogs are adopted to support creative projects for both work and play, intellectual work is happening more and more frequently and with ever broader participation in collaborative spaces online. Students can easily contribute to meaningful intellectual projects. The stage is set and the barriers are low.

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We stated that literacy in a read/write world involves both becoming able to interpret information and becoming an adept participant in the construction of new knowledge. These are our goals for introducing wiki to the science classroom: to establish a public place for engaging in collaborative knowledge construction where students can not only learn about science, but also become better, more critical consumers of information and begin to see themselves as genuine participants in the process of knowledge production.

2. Social Constructionism

If we want to use wikis successfully in schools to begin engaging students in public knowledge building activities, we must understand how these activities support learning. In this paper, we use the lens of constructionism to bring into focus opportunities for learning in wiki worlds.

Constructionism is an approach to learning that emphasizes the production of public artifacts as a way of engaging with and learning about the world. From its roots in the logo programming language for children, to its inspiration of projects like One Laptop Per Child (OLPC), constructionism has had a profound effect on the way many researchers think about technology and education. Seymour Papert illustrated the basic idea of constructionism by suggesting that the kind of pride, creativity, persistence and sociality that surrounds the creation of soap-sculptures in a junior high school art class could also exist in other areas of learning—for example, mathematics [26]. Papert's vision of constructionism assumes that, given a chance to pursue their interests in a creative fashion, learners are capable, curious and tenacious. Constructionism as a way of thinking about education carries with it an ideology of empowerment and choice. Ideally, learners choose what it is they want to do and learn through the process of engaging in open-ended, unstructured, playful but productive construction activities.

The defining feature of any constructionist learning environment is the construction kit, or the materials that learners use to construct their artifacts [29]. Different construction kits facilitate different learning outcomes because they allow for the exploration of some ideas and constrain the exploration of others. For example, one can think of the archetypal model rocket as a construction kit that facilitates exploration of concepts like aerodynamics and force. Viewed from the constructionist perspective, Kay and Goldberg's classic characterization of computers as a "metamedium," or medium that can support the creation of all other media [19], frames computers as the mother of all construction kits. In fact, most of the work that has been done to define the constructionist ideology has been done using computational construction kits ranging from modeling and simulation environments [27], to simple robot construction [28], to software design [16] and text-based virtual worlds [7].

All of these construction kits allow learners to create some public artifact, and, in doing so, engage with some particular set of problems. For example, in the case of MOOSE Crossing, a text-based virtual world, the construction kit was plain text. In MOOSE Crossing, participants co-constructed a fantasy world not only by engaging in creative writing activities to describe its features, but also by using the scripting language MOOSE to bring that world "to life." Wiki also provides a textual construction kit, albeit of a different nature. In wikis, participants also use text to collaboratively construct a shared, public artifact, but with different sets of technological affordances and constraints. Different wiki platforms have been adapted to support diverse goals, and therefore provide somewhat different construction kits that support and constrain writing activities in unique ways, but all of them support collaborative construction of text.

Constructing texts is a powerful learning experience. Research on writing-to-learn has identified cognitive aspects of writing that result in students learning about the topic at hand as they become better authors. In her influential treatise on "Writing as a Mode of Learning," Emig observed that writing "requires the establishment of systematic connections and relationships. Clear writing by definition is that writing which signals without ambiguity the nature of conceptual relationships, whether they be coordinate, subordinate, superordinate, causal, or something other" [11 p.126]. In other words, through writing, one comes to understanding. Scardamalia and Bereiter operationalized that process in The Psychology of Written Composition, wherein they described a trajectory from novice writing strategies that simply recount information to more sophisticated, expert strategies that result in a transformation of knowledge [2]. Of course, the term "writing" refers to an extensive array of activities: taking notes during a lecture, making a diary entry, writing a literature review, capturing a sunset in poetry, instant messaging a friend, and scrawling graffiti on a bathroom wall. Occasional restroom epiphanies notwithstanding, these experiences are not equivalent in terms of learning and knowledge production. This raises several questions. What kinds of writing do wikis support well? Are they aligned with the kinds of textual construction that we expect to lead to learning and knowledge building, and are there ways to improve wiki construction kits to better facilitate writing-to-learn?

We have illustrated elsewhere how the construction of encyclopedia articles in Wikipedia represents a learning opportunity for participants [12]; however, MediaWiki, like most wikis, was not designed to explicitly support writing as a learning activity. It is a wiki platform that was

developed to support the construction of encyclopedia articles. Salient characteristics of an encyclopedia are expressed as features of the wiki environment. For example, separating an article into several sections automatically generates a hyperlinked outline of contents at the top of the page. Note that this feature does not constrain the construction of articles in any way. It does not prevent writers from creating one long string of text; however, it simplifies the practice of segmenting articles into relevant sections. Arguably, encouraging article segmentation may also encourage reflection on what those sections should be and how the article could best be organized. This is one example of how a textual construction kit might bring about specific kinds of productive learning activities like reflection on the organization of text.

Wikis explicitly facilitate *collaborative* text production. The early work with programming that led Seymour Papert to articulate the constructionist approach was first conceived as a way to support individual learning [25]. From these initial efforts grew projects that explicitly support constructionist learning through opportunities for social interaction [6]. Social theories of learning have found favor among many educational researchers. In part, this is because such theories provide insight about the situated nature of learning and can help us begin to explain relationships among multiple agents in complex learning environments. One particularly relevant example is Scardamalia and Bereiter's Knowledge Building. Knowledge Building (capitalized) is not used here as a generic description of a social or cognitive process of creating new knowledge. It refers to a specific approach to education that shares with constructionism a deep respect for learners and support for public artifact construction, but also emphasizes the collective nature of knowledge construction. (see [32]) Perhaps one of the most obvious ways that wiki can be leveraged in formal educational environments is not just as a construction kit for writing-to-learn, but a construction kit that supports public Knowledge Building activities in schools.

Together, the theoretical substrate of social constructionist learning, our early research findings, and the goal of engaging young people in the public collaborative production of new knowledge suggest a specialized wiki construction kit. If we want to prepare young people to participate in public, collaborative production of knowledge by using wikis, we must provide construction kits that support the writing practices we want to encourage. Furthermore, if we hope to support such activities in a formal learning environment, teachers' practices also need to be taken into account. Before we describe our efforts to build a wiki construction kit for high school science writing and the results of integrating it in a classroom, we will examine the literature to date on using wikis in educational contexts.

3. A History of Wiki in Education

The promise of wiki to support learning activities in formal education has been explored primarily in post-secondary contexts. In recent years, wikis have also been appearing more frequently in secondary schools (high schools). Publications on wikis in education range from descriptive efforts to characterize wiki learning activities and cultures, prescriptive efforts to establish guidelines for implementing wiki learning activities, and a few design reports that document technological innovations to support classroom use. To date, very little work has been done to measure learning outcomes explicitly and connect them with learners' wiki experiences.

The earliest documented uses of wiki in education were at the college level. In late 1997, researchers at Georgia Institute of Technology built the initial version of CoWeb, a variation on Ward Cunningham's original WikiWikiWeb, but implemented in Squeak Smalltalk [21]. Since then, CoWeb has been refined and used to support hundreds of courses at Georgia Tech. Instead of designing activities for instructors, researchers primarily supported wiki use in courses by simply making it available and responding to instructors' needs. By observing the resultant profusion of wiki activity, researchers were able to characterize patterns of and barriers to adoption among instructors and students [30]. In some cases, a learning culture that emphasized individual accomplishment and competition presented a barrier to adopting radically collaborative activities [14]. Still, the extreme flexibility and lightweight nature of the technology also led to inventive and successful new uses of the wiki among many instructors [15]. In some cases, instructors simply took advantage of the easily editable website to disseminate information, in other cases they used it as a place for individual peer review and critique, and in some cases instructors invented ways to use the wiki as a construction kit to engage students in collaborative, creative construction activities.

While wiki use was steadily becoming part of the standard academic toolkit for many Georgia Tech courses, researchers and instructors at other institutions also began experimenting with CoWeb and other flavors of wiki. Not surprisingly, many of the documented early explorations of wiki uses in higher education played out in computer science (CS) courses. The first wiki, Ward Cunningham's Portland Pattern Repository, was created to support the collection of computer programming design patterns [21], so it is not surprising that computer scientists were among the first to notice and appropriate wikis more broadly. In addition, technological resources and expertise in CS schools supported early adoption. At University of Colorado, CoWeb was adopted in 2001 to support Knowledge Building activities among students working on open source programming projects. Scharff found that

students used the wiki extensively to coordinate their activities and adopted it as a space to construct group project deliverables. Furthermore, they used it far more frequently than the traditional and more familiar course mailing list [33]. (For more examples of wiki uses in CS/Information Technology education, see [3, 4, 5, 24].)

Over the past few years, Wikipedia has more broadly popularized the idea of wiki and brought it to the attention of educators. The number of wiki-in-education related projects and publications has increased dramatically: a search for the term "wiki" in the Educational Resources Information Center (ERIC) returns one publication in 2003, two in 2004, three in 2005 and thirteen in 2006. Educators have been quick to respond to the wiki trend. Experience reports and personal observations of wiki use in the classroom have also proliferated as teachers begin experimenting and sharing their practices [23]. As wiki use in education has become more visible, wikis have also begun appearing at secondary school levels around the world in subjects ranging from computer science to language arts, to social studies to physics. Easily accessible wiki and community hosting services that target school communities create easy opportunities for teachers to experiment with wiki writing assignments. (See pbwiki.com, schools.wikia.com for examples.)

With the move from wiki use in colleges and universities to secondary schools, we see increased concern for understanding how structure and freedom can be balanced in learning activities. Lund and Smørdal describe wiki learning activities in a secondary school in Norway in which students in an English as a Foreign Language (EFL) class used MediaWiki to support collective Knowledge Building activities while practicing their language skills [22]. In these EFL classes, they explicitly examine the role of the teacher in Knowledge Building activities and describe how teacher intervention and guidance support the collective construction of knowledge. They find that teacher intervention is mainly located outside the wiki through in-class comments and feedback and suggest that wiki tools for education could better facilitate teacher intervention in the online environment.

The relationship between teacher and student is a central issue for any educational research agenda. Research on novel technologies in the classroom often highlights the ways that teacher-student relationships are altered when new communication technologies become part of the learning context. Generally these changes are framed by researchers as beneficial to the student. From early work using chat in the 1980s [1] to recent work on Knowledge Building communities [32], technologies that shift control from the teacher to the student have been understood as having a positive effect on learning. Still, teachers may not always be comfortable with that shift or understand how to best appropriate new technologies. As Lund and Smørdal point out, "an inherent part of being a teacher is to plan learning activities. The nature of these plans may be challenged by the emergent use of wikis as reported in the literature and as we have observed" [22] p43. Fortunately, wikis are also beginning to appear in teacher training and professional development.

Honegger describes how wikis are being adopted as part of teacher education at some German-speaking universities [17]. In Alcona, Italy, TWiki was adopted to support teacher professional development in order to allow local teachers to share best practices and teaching materials. Da Lio et. al. studied teachers' uses of the site and share a familiar story of initially limited success due to technological and cultural barriers. They observe that "[c]ollaboration is not a current practice in Italian schools. The widespread individualistic approach to teaching makes the development of a collective sense difficult for professionals to even contemplate" [8] p86.

Despite the frequently encountered cultural barriers in the teaching community, maverick early adopters are becoming involved in wiki projects to support knowledge sharing among education professionals. Many proponents of the open education movement have embraced wiki as a platform to support the collaborative production and wide distribution of free educational materials. Projects like Curriki (www.curriki.org) and Wikimedia's Wikibooks (www.wikibooks.org) and Wikiversity (www.wikiversity.org) are taking advantage of the peer production model to create textbooks, course materials, curricula, classroom activities and other documents that can be used to organize educational activities.

Cultural barriers to adoption in various forms are frequently documented in studies of wiki use in education. Technological barriers to adoption are also sometimes noted although they are not cited as primary barriers in post-secondary, secondary and teacher education. Still, even in cases where a wiki-based community appears to be thriving, usability issues such as the lack of a WYSIWYG editor can limit participation [36]. What might we expect to find if wikis are used with still younger students? Usability issues become increasingly salient with younger users who are less experienced both as writers and as computer users. Désilets et. al. tested a custom wiki platform called The Lizzy Wiki with eight and nine year olds in French-speaking Canada [9]. They found that usability issues associated with hyperlinking by far posed the most problems for the children and suggest that this is because the representation of hyperlinks in wikitext does not provide an adequate model of hypertext.

There has been little work done that explores technical modifications to wiki in response to observed cultural and technological barriers to successful adoption in formal

education. For example, Wang and Turner developed wiki extensions to address characteristics of wiki they deemed "undesirable" in the classroom context, such as students having the ability to edit any page and a lack of private spaces for writing [37]; however, it is unclear how the undesirability of such features was determined. In the next sections, we present the second iteration in a series of studies designed to explore and innovate both in terms of technological design of wiki tools and social organization of learning activities.

4. Science Online

In 2005 we proposed the creation of *Science Online*, a wiki-based learning environment where student authors construct articles about science topics. We are currently in the second design and research iteration of the project. After an initial pilot study using CoWeb to explore the desirable features of a wiki construction kit for writing-to-learn, we adopted the MediaWiki platform and built special extensions to support critical academic writing skills and classroom use. The design of the extensions was based partly on the results of a pilot study using wikis to support academic writing in a freshman-level American Government class (see [12]), partly on literature review, and partly on the writing practices we hoped to encourage in the science classroom.

4.1 Wiki Extensions for Academic Writing

As noted in the introductory section, we are interested in understanding how students think about information sources and raising levels of information literacy. In order to support critical use of information sources through careful citation, we built a bibliographic extension for MediaWiki called ReferenceTools. In the current version of MediaWiki, references are normally associated with one article. All the relevant information (author, title, etc) is entered using a special syntax in a reference tag in the wiki text, which is rendered as a footnote when the text is saved. References in MediaWiki are subordinate to specific articles. Because we want to support explicit, critical reflection on information sources and because citation plays a central role in the social construction of knowledge in the sciences, we wanted to embed critical citation practices in the design of the wiki authoring environment. ReferenceTools elevates references to first-class objects in the system.

The design of ReferenceTools was guided by examining features of commercial academic bibliographic tools and refined in consultation with a local high school science teacher. Usability tests were conducted to further improve user experience before in-situ field observations began. ReferenceTools allows students to enter their information sources as they edit a wiki page. An "insert reference" button calls a separate data entry window where the relevant citation data can be entered into a form. (See Figure 1.) When the student saves the reference (or selects an existing reference) a special reference tag is added to the wiki text. Upon saving, the tag is rendered as an in-text parenthetical reference and a list of works cited appears at the bottom of the page. It is important to note that references are saved in the database, so although each citation is initially associated with a specific article, the bibliography is shared across the wiki, so each information source need only be entered once and can be used to support multiple articles. If the reference tag is removed from all articles, the reference itself persists and can still be used. When a reference is entered into the database, a wiki page is automatically generated for that reference where its contents can be discussed or summarized. The reference page allows users to modify the reference information, see a history of all modifications, and revert changes if necessary. The reference page also provides a reverse citation index in that it lists all articles where the reference is currently cited.

In addition to ReferenceTools, we also created extensions to support classroom use: TeacherTools and StudentView. In our pilot study, we found that one of the aggravations associated with using wikis to support classroom work was information sprawl and a resulting inability of teachers and students to find one-another's work and understand who had done what [12]. The TeacherTools extension provides teachers with a central place to manage their classes, students, and assignments. StudentView provides essentially the same functionality for students—it automatically groups together pages that describe their assignments in one place, and lists their classmates so that they can contact one another easily. In addition, teachers and students have access to the SendMessage extension, which allows them to place a message on the talk pages of all class members or any subset of class members at once.

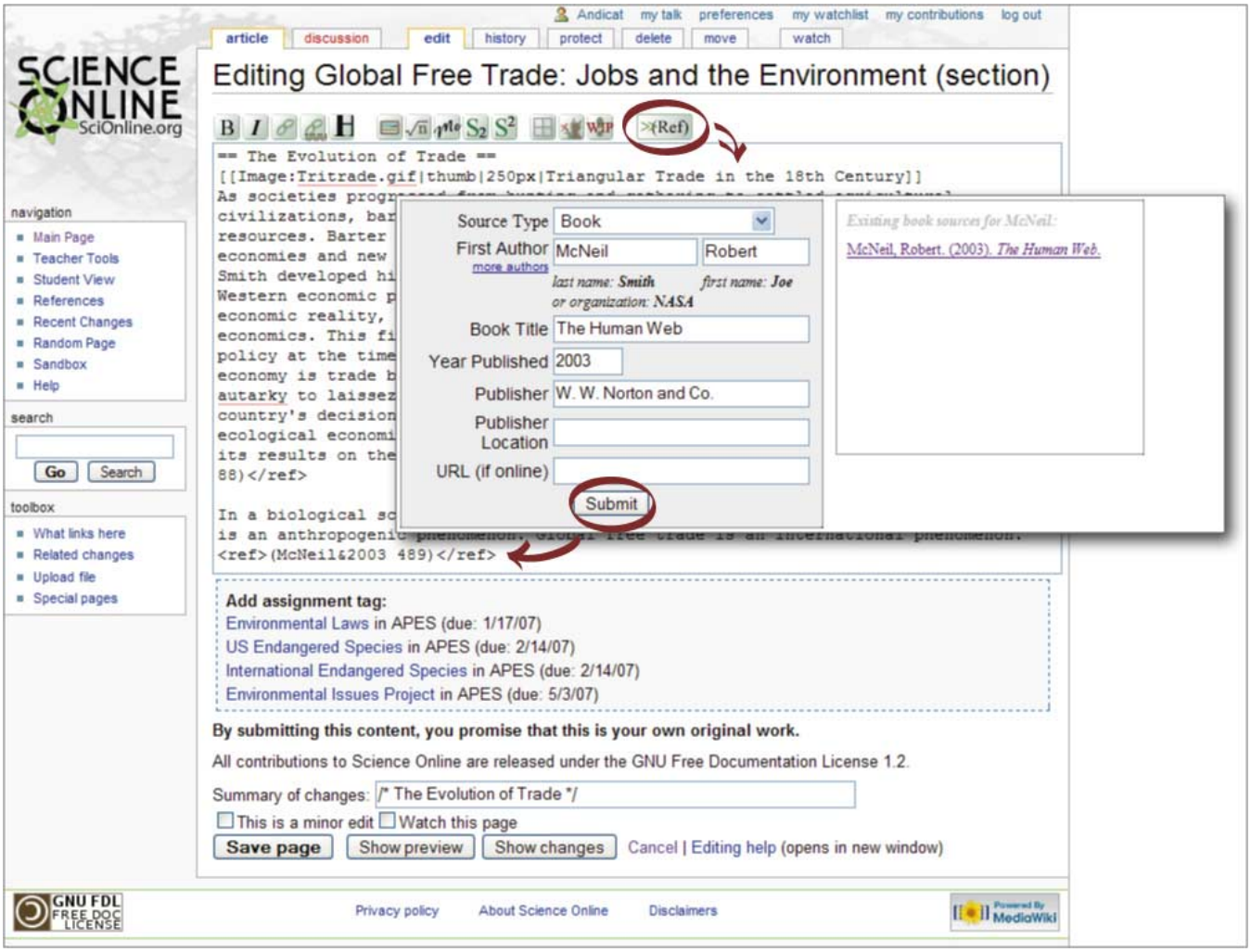

Figure 1: Using the ReferenceTools MediaWiki extension to insert a reference

4.2 *Science Online* in the Classroom

In the 2006-2007 school year, we invited two classes of high school environmental science students to write articles on *Science Online*. We spent one full academic year inspecting student and teacher experiences with the wiki. Our goals in examining classroom and online activity are threefold: 1) to understand the ways that the wiki construction kit creates a social landscape for classroom writing activities and possibilities for reflection, interaction and learning; 2) to contribute to the design dialogue in the wiki community and help further sensitize other researchers and developers to critical design issues in classrooms; and 3) to assess student learning.

4.2.1 Participants

The classes we invited to use the wiki were two Advanced Placement Environmental Science (APES) taught by the same teacher. We began the year in fall with one class of 15 students; in spring the teacher taught two sections of the class with 9 in each section. In total, 19 students both assented to participate and turned in signed consent forms from their parents. 10 of the study participants used the wiki for an entire school year; 4 used it in the first semester only, 5 it in the second semester only. All participants were either high school juniors or seniors.

4.2.2 Data Collection

To understand how the wiki was adopted by students and teachers in the class and how they made sense of the technology, the interactions it afforded, and the problems they encountered, we conducted in-class observations as well as interviews with students and the teacher at different points throughout the school year. A researcher was present in the classroom on 47 days throughout the year. On 20 of these days, students used computers in class to work on wikis or other assignments; on the other days they were doing labs, other collaborative work, presenting material to the class or having more traditional lecture/discussion days.

To assess student learning, we created document-based question pre- and post-tests that require students to use a set of information resources to answer an environmental science question in essay form. By observing differences in pre- and post-test sourcing practices, comparing these to students' writing practices on the wiki, and listening to student's accounts of their own sourcing practices, we intend to trace changes, if any, in students' use of science information resources over the course of the wiki assignments. Pre-tests showed that most students did not look at markers of information resource quality to understand science issues and resolve conflicts in information as they wrote.

Table 1: Study Participant Activity

*Names**	*Avg. Edits per Week***	*Total Edits*	*Unique Pages Edited****
Reagan	5	97	18
John	6	36	6
Sylvia	7	67	9
Heather	7	221	31
Paige	9	111	13
Ella	13	116	9
Amanda	13	231	18
Jill	14	382	27
Carrie	16	204	13
Ed	17	271	16
Carl	18	72	4
David	18	256	14
Anne	19	194	10
Brian	23	180	8
Larry	26	153	6
Gary	29	234	8
Kelly	30	384	13
Alex	45	404	9
Susan	49	779	16
Avg.	*19*	*231*	*13*
St. Dev.	*12*	*171*	*7*

* All names have been changed.

** Avg edits per week is used to control for the fact that some students participated for 10 weeks, some 17, and some 27.

*** Number includes articles, userpages and talk pages.

At the time of this writing, data collection is ongoing. Student work on the wiki was recently completed; post-testing and post-interviewing is not yet complete. The preliminary findings we present here are based primarily on in-class observations and interviews that took place throughout the school year with both the students and the teacher.

4.2.3 Overview of Assigned Wiki Writing Activities

Initially, we envisioned Science Online as a place for students to write what would traditionally be thought of as group research projects about science topics of their choice. Instead of writing a paper that dies on the teacher's desk, student research projects would become living documents and resources for others. Not surprisingly, the teacher who used the wiki adopted the site and appropriated it in new and unexpected ways in order to balance curricular demands, time constraints, and personal teaching style. Rather than use the wiki to support one primary collaborative article-writing project and an introductory assignment as initially envisioned, the teacher experimented over the course of the school year with seven varieties of discrete wiki assignments that varied in terms of length, collaboration, specific editing and sourcing requirements, and that were interleaved with different kinds of in-class activities. These assignments can be thought of as design iterations on wiki writing activities as the teacher adapted his expectations based on previous assignments. The assignments were:

Fall 2006

1. Create a User Page - October
This informal, individual assignment was designed by the researchers to be used as an introduction to the wiki. This was the only assignment that was not designed primarily by the teacher.

2. Biogeochemical Cycles Project - October
Students authored articles in groups of three. They created relatively short articles about a biogeochemical cycle and explained the information to the class in a 7-10 minute in-class presentation using the wiki as a visual aid.

3. Biomes Articles - November
Each student selected a biome from a list that was provided by the teacher and individually authored a wiki article about that biome. For this assignment, the teacher encouraged students to be creative and discuss where their biomes appeared in popular culture and literature in addition to providing information and images. During this project, some students began getting more creative and tried out advanced formatting techniques.

4. Human Population Dynamics - December
Each student selected a country or international organization and individually created an article that discussed its laws and cultural issues that affect human population growth. At the end of the wiki writing segment of the project, the class convened for an in-class debate about human population in which each represented the government or organization they had investigated.

Spring 2007

5. Environmental Laws - January
This was a short wiki assignment. Approximately 10 new students joined the class during the second semester. This individual assignment helped bring them up to speed. Each student created a short article that described a particular international, US, or state law that impacts the environment.

6. Endangered Species - February
Students found one American and one international threatened or endangered species of plant or animal and individually created an article about it. In order to facilitate studying for the end-of-year exam, the teacher asked if we could create a special template for making animal "trading cards." We created the template and added a "species box" button to the editing tool bar to make the template syntax easier for students to use.

7. Environmental Issues Project – March/April/May
The final project of the semester was longer and more involved than the previous ones. Each student selected a contemporary environmental issue to investigate in depth and had approximately six weeks to research the issue, assemble a bibliography, construct a wiki article, and prepare a power point or other form of presentation.

4.2.4 Preliminary Observations

Over the course of the school year, wiki activity varied widely from participant to participant. See Table 1 for numbers of edits per student. Although we have not yet completed data collection and analysis, a story of wiki appropriation and resistance is beginning to emerge from our observations and interviews. Most significantly, in this classroom context, instead of affording easy opportunities to collaboratively construct text, the wiki construction kit seemed to present several barriers to collaboration.

Before the school year began, researchers held several discussions with the teacher, Mr. Grant, who was enthusiastic about the idea of using wiki to support collaborative writing activities in high schools. He was particularly positive about wiki in comparison to blogs, which were becoming popular among teachers in his school district, but which he felt were not well suited as a platform for student writing assignments. We initially discussed the possibility of two wiki writing assignments, but as noted, he chose to introduce seven wiki assignments over the course of the year. As the school year progressed, Mr. Grant observed many limitations in the wiki toolkit as he attempted to appropriate it in ways that would support students in demonstrating proficiency on the advanced placement test at the end of the year.

In the first semester, students were introduced to the wiki during the first week of October. They created user pages and a researcher demonstrated the use of features like the "talk page" to leave one another messages.

One of the most notable features of the first-semester assignments was the collaboration. The first teacher-designed wiki assignment, Biogeochemical Cycles Project, was a project on which students collaborated in groups of three. Both students and teacher struggled with the collaborative aspects of the assignment. Students often worked in parallel during class and found that edit conflicts frequently slowed their progress. In interviews, several students commented on the awkwardness of having to rely on other students to complete a project, regardless of the technology used to write. Because it was the first substantial assignment, students were not yet comfortable with the wiki. They had difficulty recovering from errors and formatting their articles, which seemed to exacerbate their frustration with groupmates. Several students appealed to the teacher to grade them based on individual rather than collective effort.

Mr. Grant likewise had difficulty grading the collaborative assignment. He found parsing page histories laborious and uninformative and had difficulty understanding how each student had contributed to the collaboration. Although he had originally observed that the wiki would allow him to grade collaborative work more effectively, he found that it was too much work to understand patterns of collaboration and use them for assessment. After the Biogeochemical Cycles Project ended in October, the students were not asked to collaborate on articles again. They almost never touched one another's pages in later assignments.

In early interviews, students were positive about the wiki assignments but noted difficulty in uploading images, formatting and collaborating with other students. By the end of the semester, classroom observations indicate that most of the study participants had become proficient wiki editors. Many of them had begun using advanced formatting techniques by copy and pasting text from one of the researcher's user page. By December, early bugs caused by the reference extension had been mostly resolved and students only infrequently asked for assistance.

In the second semester, nine new students joined Mr. Grant's class; of these, five consented to participate in our study. Because half of his students were experienced wiki editors, the teacher provided less time for introduction to the wiki in the second semester. The user page assignment was not given and researchers gave less upfront instruction; that meant nine of the students received less instruction in using the wiki.

In the second semester, Mr. Grant became more emphatic about ways that the wiki construction kit was not quite

synchronized with his needs as a teacher. Some of his concerns centered on the openness of the site. He became increasingly concerned that students might be publishing things in a public place over which he had not had sufficient oversight. Design suggestions that emerged from these concerns included a privacy feature that would keep student work private until the students and the teacher had designated it as worthy of public consumption, possibly integrating it with a "rating" feature that could allow students and teachers to vote content into the public eye. He was apprehensive that students might write something publicly that would cause parents to complain. He frequently expressed concern that since students could see others' work, he could not ask several of them to write up the same topic to prepare for tests.

As he designed the second semester assignments, Mr. Grant also became increasingly concerned with designing ways of supporting the students in studying for the Advanced Placement (AP) exam at the end of the year.

Further data analysis and final assessment data will allow us to tell a more nuanced story of students' learning experiences and whether or not the wiki writing assignments have helped bring about the desired effects on sourcing practices and information literacy.

5. Looking Forward

Cultural and institutional factors influenced the adoption of wiki in this classroom as a primarily individual (albeit shared and public) toolkit for the construction of texts. Conflict between a culture of individual assessment and desired collaborative practices has emerged in many studies of wiki in education. (See [14, 22].) Just as Da Lio observed that Italian teachers were unprepared to adopt collective ways of thinking to make use of the wiki [8], Grant found in her case study of wiki adoption in a UK secondary school that students were socially unprepared to use the wiki in a collaborative fashion. She recognizes that "the social and cultural practices of collaborative working that need to accompany the use of the software in order to take advantage of the functional affordances of the tool were not in the students' repertoire of shared practices. Instead, they imported practices of individualized written assessment that they saw as important from the broader economy of education and the practices of the school community" [13 p.10].

Our students and teacher also employed familiar strategies for designing and completing assignments when collaboration proved challenging. We see this cultural mismatch as an opportunity for design. Tools are a fundamental component of any system of human activity. Constructionism as a way of thinking about human learning reminds us that well-designed tools have the potential to deeply affect the character of activity and the learning outcomes associated with it. We have observed elsewhere that MediaWiki readily supports collaborative text construction and Knowledge Building discourse in other contexts, such as Wikipedia [12]. Indeed, wiki publishing environments are being used to support thousands of online communities in the open "wilds" of the Internet. Often, wiki-based online communities are associated with a culture of openness and are radically permissive in their membership policies, requiring only that contributors do no harm and promote community goals, which themselves are often open to revision.

In stark contrast, wikis are also being adopted for closely circumscribed uses by communities with carefully restricted membership and firmly routinized existing practices such as schools and corporations. The social context for learning varies dramatically in these different cultural contexts and demands innovative designs. In our classroom, we saw evidence that not only did cultural and institutional barriers stymie collaboration, but the *design of the collaborative tool* itself contributed to resistance among students and from the teacher. If wiki is to become a readily adoptable construction kit that supports Knowledge Building communities in schools, the tools need to foster collaborative practices by making it easy for students to work together and for teachers to assess collaborative work. If teachers cannot assess collaborative wiki work, then we cannot expect wiki to be adopted for formal education, despite the potential learning gains for students.

As open models of content production become an increasingly familiar form of creating new knowledge, educational experiences should prepare students to become careful, critical, and competent participants in Knowledge Building activities both online and off. Moving forward, we are completing data analysis to examine learning outcomes for information literacy skills and are exploring directions for more sophisticated teacher tools to support assessment of collaborative student work. We are working to design wiki features to help close the gap between existing classroom practices and the "real world" practices of Knowledge Building communities.

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