Connected Biology: A Usability Study of Web 2.0 Tools

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Abstract: We incorporated traditional conceptual knowledge in an introductory Biology course into a Web2.0 learning environment, which we called Connected Biology. We subsequently investigated whether faculty and students using it for 15 weeks found it useful. We used Crazy Egg (a commercial tracking site) to track students' use of Connected Biology and their use of Web 2.0 tools. Students found Connected Biology useful (learnable, memorable, satisfying, and error-free) but not efficient. Although they accessed Connected Biology over 15 weeks, they tended to use it primarily to get feedback on their understanding of course content and not for exploratory activities. Interviews with faculty teaching introductory science courses indicated that most hold to a prescriptive learning model. The paper argues that we need to attend to the prevailing culture of introductory science courses (both student and teacher) before introducing Web 2.0 tools. Only then will the affordances of Web 2.0 tools be attained.

Keywords: web 2.0 tools, usability, data-mining, data-tracking

Introduction

Steve Hargadon (2009) summarizes the belief held by many educators that the expectation that computers would revolutionize education has not happened. Computers have made the delivery and assessment of learning easier; but if they were suddenly to disappear from our classrooms, teaching would not change by much. One reason for this, somewhat surprising conclusion, is that until recently, the technology used, Web 1.0, used a traditional one-way information flow, with content flowing from the source (educational media and teacher) to the students. In other words, it used a "push" technology with information being "dumped" on the student according to the goals and scheduling constraints determined by the educator. However, this has radically changed with the development of Web 2.0 (Brown, 2006). Web 2.0 technologies facilitate conversations around academic concepts, artifacts (images and videos), and data collections (databases and spreadsheets) in which the "Three R's have been supplanted by the "Three C's: Contributing, Collaborating, Creating" (Hargadon (2009, p8) through tools such as Facebook, Twitter, Wiki's, Voicethreads, etc.

Canole and Alevizou (2010) conducted a literature review of the use of Web 2.0 tools in Higher Education using both traditional and Web 2.0 methodologies. That is, in addition to accessing the usual academic sources (peer-reviewed journals articles and books), specialized databases (ERIC, Informaworld, etc.) and GoogleScholar, they conducted an "open review" using the Cloudswork site (http://cloudworks.ac.uk/). They define the open review process as one that "uses a social networking space to aggregate and collectively discuss an evolving body of literature around a set of core research questions" (Canole &Alevizou, 2010 p 6). They found that despite the affordances of Web 2.0 tools to promote radical transformation of learning, most students use technology for convenience (51%) and to facilitate course management (19%). The effective adoption of Web 2.0 tools into education practice by teachers also requires a change in the role of teachers and teaching. Overall, "only a minority of teachers, those with a research interest in the learning sciences, educational technology, or new media, have undertaken experimentation with new innovations in pedagogy" (Carole & Alevizou, 2010, p21). They cproposed several paradoxes to explain the low adoption of Web 2.0 tools by post-secondary faculty. They may fear that the the huge expansion of knowledge devalues expertise, that the fragmented, multi-located structure of networks destroys the integrity of domain knowledge structures, that the blurring of boundaries promotes plagerism, and that the social nature of learning networks harms individual learning at the expence of "group think".

Williams, Karousou, and Mackness (2011) contrast two learning environments: *emergent* and *prescriptive.* They associate the use of Web 2.0 tools with *emergent learning* networks and argue that both are required in an integrated learning ecology. The challenge becomes to design an effective balance between the two.

Many teachers, realizing the importance of incorporating active-learning participatory technologies into their teaching practices, do make the attempt; however, many, if not most, ultimately fail to sustain their efforts (Messina, Reeve & Scardamalia, 2003; Moreau, 2001). This has often been interpreted as a failure in their knowledge, effort, or available resources. However, an alternative interpretation is that features of the attempted implementation, per se, are at fault. That is, although the utility of the implementation is usually investigated, the usability of the implementation was not systematically tested. Usability in this context, is the degree to which an implementation meets the needs of the users (both teachers and students) by being learnable, efficient, memorable, satisfying, and error-free (Usability Professionals Association, 2009).

The goal of this paper is to investigate the usability of an implementation, herein called *Connected Biology*, incorporating Web 2.0 features.

Methods

This project used the methodology of a design-based research (Brown, 1992; Amiel & Reeves, 2008), to investigate the usability and utility of *Connected Biology*. Thus, we used ethnographic , questionnaire, and tracking methodologies. More specifically, we interviewed teachers, assessd students' perception of the usability of *Connected Biology*, and useed Crazy Egg (https://www.crazyegg.com) , a commercial tracking service similar to Google Analytics to track the number of visits and clicks made by students as well as where they clicke. Heat maps show where students stop scrolling and leave the page.

Participants

The participants were faculty and their students taking an introductory Biology course in a large urban community college. The students were 17-19 years old, in the pre-university science program, with an equal distribution of males and females (ie they're supposed to be digital natives.. Teachers were invited to participate in modifying and using *Connected Biology* in their courses.

Intervention

The intervention, *Connected Biology*, consisted of a web site which is acessed via a home page which includes a video, links to Science sites and an outline of the topics covered by the course. Each of the topics is linked to a topics page which includes the following elements: Pre-class Exercises (designed to prepare the students for the upcoming class), Classes (designed to outline the activities done in class), Consolidation exercises (designed to help students secure their learning), and the associated Learning Objectives (designed to guide students in their studying). The associated Web 2.0 tools associated with these elements are links to external sites, simulations, videos, images, a hot-linked glossary, on-line crossword puzzles, on-line concept mapping exercises, practice questions providing immediate feedback, links to on-line quizzes, and summaries of the content. Classes were held in an Active Learning Classroom, containing 6 tables, each with a Smartboard. There were 6-7 students per table. In addition, students used a class conference on First Class (a collaboration platform) to access their teacher's materials and communicate with each other and their teacher. The students were encouraged but not required to use any of these elements.

Analysis

Quantitative analysis

Questionnaires and tracking data were analyzed using descriptive and inferential statistics.

Qualitative analysis

Interviews with teachers were transcribed and coded into pre-existing categories that reflected the research interest.

Findings

Student survey of usability

We collected data on students' perception of the usability of *Connected Biology* after the unit on Cell Structure and Function, after the unit on Cell Division, and after the unit on Evolution. The maximum score on the survey was 25. Table 1 shows the changes in students' perception of usability over the three units.

There was a significant difference in students' perception of the usability of *Connected Biology* over the three sessions ($F = 10.57$ df $= 3,119$ $p = 0.0001$). Students rated the usability of *Connected Biology* lower for the unit on Cell Division (Mean = 16.0) than they did for the units on Cell Structure and Function (Mean = 18.1) and Evolution (Mean = 18.7).

Table 1: Descriptive statistics (mean and standard deviation) for students' perception of usability

	Cell Structure (N=32)		Cell Division (N=31)		Evolution (N=32)	
	mean	**sd**	**mean**	**sd**	**mean**	**sd**
Usability Score	18.1	3.2	16.0	0.93	18.7	3.6

The survey measured 5 aspects of usability; i.e., was the implementation Efficient, Free from Error, Learnable, Memorable, and Satisfying. Table 2 shows these aspects of usability over the three units.

Table 2:Descriptive statistics (means and standard deviation) for students' perception of aspects of usability.

Usability Aspect	Cell Structure (N=32)		Cell Division (N=31)		Evolution (N=32)	
	mean	**sd**	**mean**	**sd**	**mean**	**sd**
Efficient	3.6	0.82	2.9	0.43	3.3	0.93
Error Free	3.4	0.64	3.1	0.49	3.7	0.68
Learnable	3.9	0.81	3.3	0.35	4.0	0.85
Memorable	3.9	0.84	3.1	0.28	4.1	0.94
Satisfying	3.3	0.75	3.6	0.34	3.6	0.87

There was a significant difference in students' perception of the efficiency ($p = 0.002$), freedom from errors ($p = 0.002$), learnability ($p = 0.001$) and memorability ($p = 0.0001$) of *Connected Biology* over the three sessions ($F = 6.6$ $df = 10, 178$ $p = 0.0001$). Students rated these aspects of the usability of *Connected Biology* lower for the unit on Cell Division than they did for the units on Cell Structure and Function and Evolution. Moreover, their responses on the usability for the unit on Cell Division were much more consistent (see Figure 1).

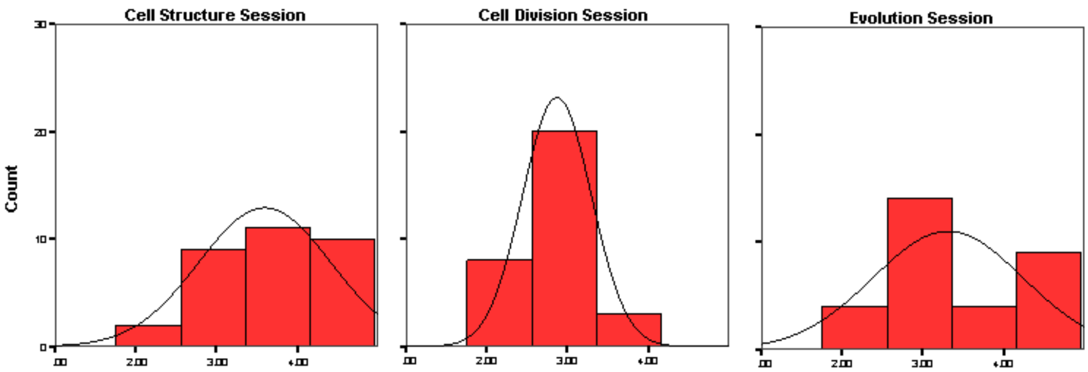
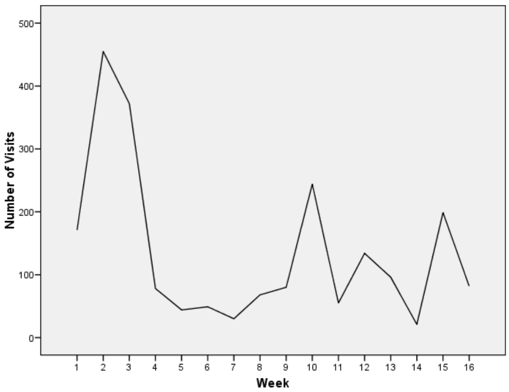


Figure 1. Distribution of students' responses to the efficiency of *Connected Biology*

Tracking of students use of *Connected Biology*

Students' visits, clicks, and scrolls were collected by Crazy Egg, a commercial tracking site (http://crazyegg.com). Figure 2 illustrates the number of visits to the home page of *Connected Biology* during the intervention.

Students visited *Connected Biology* between weeks 2 and 3, on week 12, and on week 15. There appears to be a novelty effect, in that students visited *Connected Biology* in large numbers at the beginning of the intervention; but less so as the semester progressed. Students may also have been tired at the end of the semester since their workload may have increased over the semester. The data suggests that students began to visit *Connected Biology* to prepare for the final exam on week 12 but stopped visiting it while they were preparing for their lab test and presentation of their research project (neither of which was covered by *Connected Biology)*.



- Cell Structure was covered in weeks 1 and 2
- The first class test was given in week 3
- Cell Division was covered in weeks 4 and 5
- The second class test was given in week 10
- Evolution was covered in weeks 11 and 12
- The final exam was given in week 16

Figure 2. Number of visits to *Connected Biology* by week.

Figure 3 shows the number of visits to each topic over the semester. Students visited Cell Structure and Function when the topic was covered in class and the week prior to the final exam. On the other hand, students visited Cell Division when the topic was covered in class and the week of the second class test in which their understanding of this material was assessed. They also visited this topic, week 12, perhaps when they received the results of their second test after the Easter break (week 11). They did not visit this page to review prior to the final exam. Students visited Evolution when the topic was covered in class and to review for the final exam.

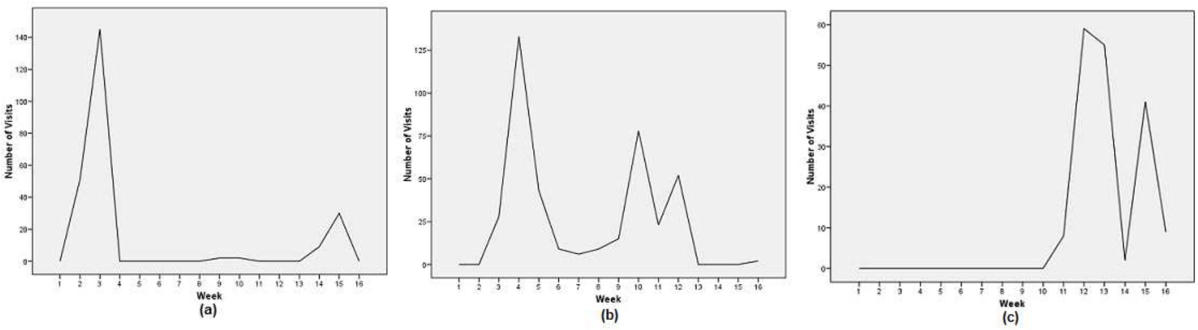


Figure 3. Number of visits to Cell Structure and Function (a), Cell Division (b) and Evolution (c) by week.

There were several elements across the three topics. Students' accessed *Connected Biology* via a home page which listed each topic and linked to topic pages for each unit. These topic pages included navigation links to preclass exercise, the classes, consolidation exercises, links to external tutorials, and activity frames with the objectives for each topic linked to a glossary. Each element had several Web 2.0 tools (e.g., on-line practice tests, immediate feedback questions, images/videos/animations, internal and external web activities, on-line crossword puzzles, on-line concept mapping activities, etc.).

Table 3 shows the number and percentage of visits to each element for each topic. The interactivity index (number of clicks/number of visits) for the Cell Structure and Function, Cell Division, and Evolution units were 0.96, 0.84, and 1.37 respectively. This indicates that students were using the topics page primarily to link to the elements. The students were surprisingly consistent in their visits to the elements. They rarely visited the linked tutorials (1.1%) which were featured on these pages.

Table 3: Number and student visits to *Connected Biology* elements.

	Cell Structure		**Cell Division**		**Evolution**		**Total**	
Element	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Objective/Glossary	38	16	134	34.1	54	14.7	226	22.6
Link to Tutorials	6	2.5	2	0.5	3	0.8	11	1.1
Preclass Exercises	82	34.5	112	28.5	131	35.6	325	32.5
Classes	53	22.3	48	12.2	55	14.9	156	15.6
Consolidation Exercises	47	19.7	84	21.4	109	29.6	240	24.0
Navigation Buttons	12	5.0	13	3.3	16	4.3	41	4.1

How did students use the Objectives and Glossary Element

The interactivity indices (number of clicks/number of visits) were 0.1 and 0.3 for the Cell Structure and Function and Cell Division units, respectively. Students visited these elements primarily to review the learning objectives. In total they clicked on terms linking to the glossary 18% of the time.

How did students use the Pre Class Exercises Element

Table 4 shows the number and percentage of visits to each tool in the preclass exercises element for each topic. The interactivity index (number of clicks/number of visits) for the Cell Structure and Function, Cell Division, and Evolution units were 4.9, 7.7, and 12.2 respectively. Thus, students used this element to interact with the material. They also increased their interactivity over the span of the intervention. They were consistent in their use of the Web 2.0 tools, primarily using the Pre Class Exercises element to click on the immediate feedback questions (60.3%) and the summary of the topics (32.7%). They accessed the images, animations, and videos rarely (5.1%), and almost never accessed the suggested activities (1.2%).

Table 4: Number and percentage of student visits to Web 2.0 tools in the Pre Class Exercises element.

	Cell Structure		Cell Division		Evolution		Total	
Tools	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Information	247	27.1	590	35.2	600	33.2	1437	32.7
Immediate Feedback Questions	598	65.6	884	52.7	1166	64.5	2648	60.3
Images/Animations/Videos	53	5.8	149	8.9	20	1.1	222	5.1
Activities	7	0.8	28	1.7	18	1.0	53	1.2
Navigation/Download buttons	7	0.8	25	1.5	3	0.2	35	0.2

How did students use the Class Element

We only collected data on how students used the Classes element for the Cell Structure and Function and Cell Division units. The interactivity indices were 0.4 and 1.6 respectively. Students visited these elements primarily to review the learning objectives. In total, they clicked on terms linking to the glossary 18% of the time.

How did students use the Consolidation Exercises

The interactivity index for the Cell Structure and Function, Cell Division, and Evolution units were 0.90, 0.80, and 0.65 respectively. Thus, students did not interact with this element. That is, they went to the page, read it, and left (using the back arrows). Table 5 shows the number and percentage of visits that students made to the tools on the consolidation element of the three topics. Thus, students used this element primarily to do practice quizzes on the topics. They rarely accessed the tutorials, and almost never accessed the on-line crossword or on-line concept mapping tools.

Table 5: Number and percentage of student visits to Web 2.0 tools in the Consolidation Exercises element.

Tools	**Cell Structure**		**Cell Division**		**Evolution**		**Total**	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Quizzes	91	98.9	116	93.5	7	100	214	96
On-line Crossword Puzzles	1	1.1	0		0	0	1	0.5
On-line Concept Map Tool	0		0		0	0	0	0
Link to Tutorials	0		8	6.5	0	0	8	3.5

Teacher views on integration of technology and Web 2.0 tools

Although 3 teachers (from a pool of 6 teachers teaching the Biology course) agreed to participate in the project, ultimately only 1 teacher did. Therefore, we could not conduct a usability study on teachers. Instead, we interviewed 5 teachers in order to understand the teacher culture that might prevent teachers from volunteering.

Teacher A believes that students need to see the relevance of the class content to their lives. He/ she spends a lot of time and resources collecting videos and research papers (suitable for students) and uses them in class to initiate interest and discussion. Teacher A directs students on what sections of the textbook to cover and makes use of the on-line learning activities packaged with the textbook. However, he/she does not require students to do any of the activities because not all students have access.

> Sometimes I bring in a YouTube documentary, but very short, and that starts the whole discussions. I think it gets them really stimulated when they see it. So I usually show them 5 minutes, and then that starts … a discussion on that topic.

Teacher B believes that it is important to put together a perfect course (notes, learning objectives, quizzes, etc.) and make them available to students at the beginning. He/she focuses on the course content and on "figuring out" what and how to deliver it. Teacher B directs students to what material they need to know, what readings they should do (that will not be covered in class) and gives them some practice questions. He/she believes there is not enough time to cover all the content in class.

> I am still trying to put together the perfect course, to master the information that I want to present, and … how I want to present it. And have all of my course materials ready to go, learning objectives, practice questions and all that stuff.

> I prepare [students] for the types of questions that I am going to ask them on class tests.

Teacher C focuses on the text book and he/she does not deviate from it. He/she uses the on-line materials (videos/activities/quizzes) packaged with the textbook in class because not all students have access to them. Teacher C allows students to bring their laptops to class and gives them questions/problems to discuss in small groups.

> The textbook pretty much does [it] all, the online activity, it's because we mainly focus on the content of the textbook, so we don't really diverge ways from textbook. Like they can search on their own for some of our topics but I didn't encourage them.

Teacher D believes that students learn by doing and has designed activities for them to do in groups. He/she also believes that students need to be directed to the concepts they need to master, they need to come prepared to class, and need to consolidate their learning. Teacher D uses the teacher resources packaged with the textbook to design assessment questions at a higher cognitive level (analysis/synthesis). Teacher D focuses on how students are learning and what misconceptions they may have.

> I've developed a lot of activities in class, educational activities, not just work sheets, but activities so that the students have to work together to do the research in the classroom to find, or discover the answer …. and then present it to the rest of the class.

> [The website) is for pre-class preparation and post-class follow up, [for use] during the class, because there were links to videos, and other websites

Teacher E uses a suite of graded e-learning and problem-based learning activities which students complete as groups. He/she also uses a web-page that has instructional videos (from YouTube), practice questions, and the on-line materials packaged with the textbook to cover the course content.

> We have a smart board [in the classroom] so I used that as a tool, and the way I used it, actually almost never pick up a real pen any more… so everything goes on the smart board, everything gets recorded, everything gets saved, everything gets then saved as a PDF, and everything gets posted for students to see. Then I created a … website for one of my courses, I have videos for theory, solutions, I have some assessment question and I have real questions, sort of quiz type questions, with objectives. And that's my whole course covering every major topic in the course.

Conclusions and implications

Although most students found *Connected Biology* satisfying, learnable, memorable, and error-free (but not efficient), they did not make much use of the embedded Web 2.0 tools. That is, they used the web-site as an electronic Study Guide. They used it when the topic was covered in class and prior to being tested on the content. They made little or no use of the enrichment tools (videos, activities, tutorials). Science students have a heavy workload, taking on average 3 science courses, a language course, a physical education course, a humanities course, and a complimentary course. They are very strategic in how they study. They made a great effort to complete the pre-class exercises, focusing on the acquisition of the content and testing their understanding. This had a positive effect on the class in that students came to class prepared. They were thus able to profit from the in-class activities and discussions. Thus, the prevalent student culture is: do the required work, participate in class, and prepare for tests. In other words they have a prescriptive model (Williams, Karousou, & Mackness, 2011) of learning biology where learning is predictable albeit complicated, the organization of knowledge is hierarchal, verification and correction is provided by the experts and not negotiable. This view may in fact reflect the reality of formal post-secondary science education, at least at the introductory level. That is, in most science domains knowledge is "created and applied to give control" (Williams, Karousou, & Mackness, 2011, p 43).

The teacher interviews also reveal a teacher-centered pedagogy in which most teachers "stuck" closely to the textbook and associated materials. For example, the common course outline specifies the pages in the text book that for which the students are responsible. All teachers, even those teachers that made use of Web 2.0 tools held a prescriptive learning model. This may reflect both the nature of science (as taught at the introductory level) and the assessment practices. Unless work is graded, students do not do the work. However, "the traditional interpretation [of assessment] becomes problematic [in emergent learning networks]" (Romer, 2002 quoted by Williams, Karousou, & Markess, 2011).

The Biology course is a multisection course with a common final which includes more than 85% multiple choice questions. This drives students to adopt a learning approach that discourages exploration and promotes focusing on practice questions. In addition, it discourages teachers from adopting more student-centered pedagogies. Given that this context is not likely to change, several questions arise: Is there a place for emergent learning in introductory science courses? If so, what is the optimal balance of emergent and prescriptive learning? Are there certain topics that are more suited to emergent learning and what are they? How do we "open up" assessment practices so that emergent learning is encouraged? How do we design emergent learning environments that are time-efficient for students? Many of these questions will have to be answered before the affordances of Web 2.0 tools can be realized in introductory science courses.

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