ONLINE ARTICLE

Do Online Labs Work?

An Assessment of an Online Lab on Cell Division

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Distance education appears to be an increasingly popular option for students here at Coastal Carolina University, a public, mainly undergraduate institution with about 7,000 students. We offer one online section of our Introduction to Biological Science course for majors (BIOL 121), however, we have not tried doing the co-requisite lab online. In an effort to determine whether online labs are worth considering, this study compares student learning and attitudes when performing an online *versus* a traditional in-class version of a lab exercise on cell division.

Studies have shown that online content delivery can work as well as more traditional classroom work (Johnson, 2002; King & Hildreth, 2001; O'Connell, 2001). So called "hybrid" courses, where there is some face-to-face contact, and some online work can also be effective (Riffell & Sibley, 2003; Prothero, 2000; Tuckman, 2002; Reed, 1998). The latter is not surprising in light of the reports from the National Research Council suggesting that science knowledge is most effectively gained when students apply a range of cognitive processes (National Research Council, 1996a;b). There is controversy, however, with fears that online instruction may eliminate valuable peer interactions, and some students have a clear preference for an instructor-oriented environment (Dewhurst et al., 2000). Generally, computer-assisted learning can be helpful, but only if the instructor really knows how to integrate it well (Cepni et al., 2004; Chang, 2001).

Most of these studies have been done with K-12 students and non-science majors, and perhaps most scientists would agree that students really miss something if they don't have a real lab experience. Does it affect their learning though? As coordinator of a multi-section lab course, I found there are situations where an online lab could be helpful. If classes are canceled for a holiday or weather event for just one day, lab students that day will fall behind those meeting the rest of the week. The options are to cancel lab for the whole week (or to "redirect" as our administrators prefer we say), or to find some take-home exercise the affected students can do instead of the traditional lab. Also when a student has to miss a lab for legitimate reasons, being able to offer her/him a make-up that does not involve physically trying to set up a lab exercise can be helpful when space, equipment, and time are tight. Can students learn science effectively this way though, or are they short-changed? This study looks at the effectiveness of an online lab exercise for traditional freshmen science majors in our BIOL 121 course.

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Materials & Methods

The cell division laboratory exercise used here is "Chromsomes and Cell Division" from *Laboratory Investigations for Biology* (Dickey, 2003). An online version of this lab exercise was assembled as a WebCT page. WebCT is an electronic course management system that allows faculty to create what its authors call a "Virtual Course Environment" (WebCT 4.1, 2004). Downloadable instructions, links, and e-mail to the instructor can easily be accessed by the students. It is also possible to include survey (or quiz) questions that the students can answer online. The advantage of this system over a simple Web page is that it's reasonably user-friendly for students and faculty, and the content is password protected so there are few issues with copyrights.

The activities of the two labs are summarized in Table 1, including the Web sites to which the online students were directed. The students doing the online lab were asked to refer to their lab manual so they could read the same background information associated with each activity as the in-class students. They were also asked to draw the various phases of mitosis and meiosis based on what they found online, just as the students in the class drew based on their inspection of slides and work with pop beads. In short, an effort was made to make the two versions of the lab as similar as possible.

A pilot version of this experiment was conducted with the author's two lab sections in fall 2003. The sample size was 26, approximately evenly split between sections so one section did the online version and one section did the lab in class. It was found that the students who did the online version of the exercise performed significantly worse on the post-exercise content quiz, however, this particular group of students did worse than the other section nearly every week. Based on their surveys, they also strongly disliked doing the online lab, however that was their apparent attitude in class as well. It was therefore decided that the online exercise was sufficiently user-friendly for the students to do, but for assessment, a

Table 1. A Comparison of Activities In-Class and Online.

	IN-CLASS (FROM DICKEY, 2003)	ONLINE
TITLE	Chromosomes and Cell Division	Chromosomes and Cell Division
Exercise 1: Activity A	Extracting DNA from Cells	Not included
Exercise 1: Activity B	Karyotypes	Interactive Online Site: Genetic Science Learning Center (2005) http://gslc.genetics.utah.edu/units/disorders/karyotype/karyotype.cfm
Exercise 2: Activity A	Process of Mitosis: Pop Bead Simulation of Mitosis	Interactive Online Site: Cells Alive! (Sullivan, 2004) http://www.cellsalive.com/mitosis.htm
Exercise 2: Activity B	Viewing Mitosis in Onion Root Cells: Uses prepared slides	Interactive Online Site: Online Onion Root Tips from The Biology Project (2004) www.biololgy.arizona.edu/cell_bio/activities/cell_cycle/cell_cycle.html
Exercise 3: Activity A	Process of Meiosis: Pop Bead Simulation of Meiosis	Interactive Online Site: How Cells Divide (Groleau, 2001) www.pbs.org/wgbh/nova/baby/divide.html
Exercise 3: Activity B	Viewing Meiosis in Organisms: prepared slides	Same site as for Exercise 3, Activity A

different and larger sample was necessary. The Tuesday labs which fell on Election Day in fall 2004 could not be held in class because CCU was closed. This presented a good opportunity to try the experiment again.

Three lab instructors participated in the study with 54 of their students completing the lab exercise in class and 52 doing the online version. Students self-selected lab sections, but as first semester freshmen, they did this based only on the time the labs were offered, so it is assumed that these were random groups. There were no obvious grading patterns between sections as existed in the pilot study. The overwhelming majority of the lab students in this study were traditional, approximately 60% female, and lacking in ethnic diversity. Students' scores on a quiz on the lab content were compared. For all students, the quiz was done in class the week following the lab exercise. The quiz questions are shown in Table 2. Statistical comparisons of quiz scores were made with a two-factor analysis of variance (ANOVA) comparing lab form (online or in-class) blocked by instructor, using SYSTAT 10 (SYSTAT Software, Inc., Point Richmond, CA). In addition, there was a voluntary online survey in association with the online lab in order to assess student effort and attitude toward the online exercise. There were five questions where students had a choice of answers and one that allowed for written responses. The five questions are shown in Table 3. The question to which they were asked to respond in writing was:

> *Please write a few comments about this experience. Should we continue to develop online labs or not? Why or why not? What did you like or not like about this exercise?*

Results & Discussion

The students who performed the lab exercise online performed significantly better on the content quiz the following week (P=0.004), although the difference was small: 12.1 +/- 4.5 SD *versus* 10.8 +/- 6.4 SD out of a possible 15 points. No significant difference was found among instructors (P=0.349). There was a significant interaction between instructor and lab form (P=0.003), however, this interaction was a result of students in Instructor B's section performing better than the students in the other sections on the in-class quiz, but worse on the online inquiry. These data are summarized in Figure 1. Pursuing possible reasons for this instructor difference would

Table 2. Cell Division Lab Follow-Up Quiz Questions.

NO.		QUESTION AND POINT VALUE (TOTAL OF 15 POINTS POSSIBLE)
1.	a	How many chromosomes would you see in a regular human karyotype? 1pt
	b	Would the karyotype be from a diploid or haploid cell? 1pt
2.		According to your calculations on the onion root tip cells, which phase of mitosis lasts the longest? 1pt
3.	a	Gametes in humans are produced in the ovaries and testes. Are they produced by meiosis or mitosis? 1pt
	b	Does the process you chose occur anywhere else in a human body? If so, where? 1pt
4.	a	In which phase of cell division do the chromosomes duplicate themselves? 1pt
	b	Does this happen in both mitosis and meiosis? 1pt
5.		Once you're an adult do your cells still undergo mitosis? Why or why not? 2pt
6.		Draw a cell with 2 chromosomes in anaphase I in meiosis. 1pt
7.		How is the end result of mitosis different from the end result of meiosis (be sure to include differences in the number of chromosomes in your explanation)? Why is this difference important (what is the purpose of these two types of division)? 2pt
8.		You have homologous pairs of chromosomes because you got one member of each pair from each parent. Are the chromosomes passed generation to generation exactly the same? In other words, is your maternal chromosome #1 just like your mom's chromosome #1? Explain your answer and why this is important. 3pt

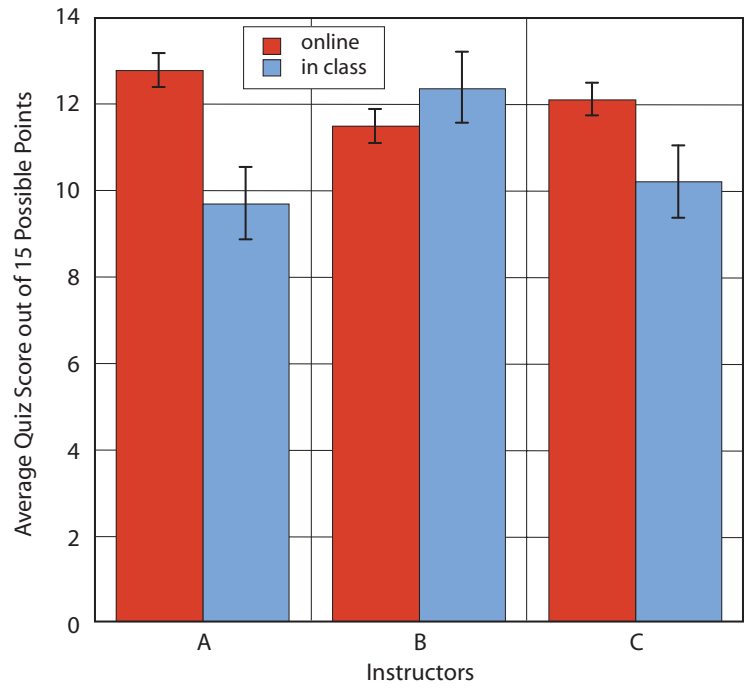
be interesting. Was she a more thorough teacher in some way, or did she "give away" the quiz topics? Or does this suggest that the different lab sections weren't as random as assumed: Do certain types of students or learners favor certain time slots for labs?

Thirty-seven students (71% of those who did the lab online) responded to the survey and showed a mixed reaction to the online experience. Table 3 shows the questions and dominant responses. Not surprisingly, most students spent less time on this lab than they would have in class where the lab normally takes students from two to two-and-a-half hours. Sixty-four percent of respondents spent 30-90 minutes online, however, 15% did say it took them longer than two hours. They did not seem to wait until the last minute to complete the exercise. The majority also worked with just one other person, rather than with a three- or four-person team as is typical in the lab setting. Apparently, then, these students got just as much content knowledge out of the lab in a much shorter time, and with minimal interaction.

Table 3. Questions and Most Frequent Answers to the Online Survey About the Online Lab Exercise.

QUESTION	MOST FREQUENT ANSWER (N = 37; percent answering this way is in parenthesis)
How long did it take you to complete this lab exercise?	30-60 minutes (36%) 60-90 minutes (28%)
When did you complete this lab exercise?	The same week as our regular lab meeting (36%) The weekend prior to our lab (26%)
Did you work on this lab by yourself of with someone else?	With one other person—not my regular lab partner (76%)
Where did you work on this lab exercise?	My dorm/home (72%)
Overall, did you like doing lab this way?	Approx. equal numbers "yes" and "no"

Figure 1. Quiz Performance Following the Cell-Division Lab Exercise.



Thirty-three students responded with written comments. Twelve students were unequivocally positive:

- *I think that this way is better because it gives us a chance to really look at what we are doing ... a chance to do it alone without our lab group.*
- *I liked how the animations were right there ...*
- *... an online lab every now and then would be fine.*
- *I really enjoyed the online lab. The models were very concise and the websites were much better than just looking in the book.*
- *I believe that online labs are great because we can fit it into our free time ... I can concentrate better on what I am doing.*

Fifteen students did not like doing the online lab at all:

- *I hated this way of doing a lab ...They are way harder than the in class labs because you do not have other people to help you understand it.*
- *I did not like this at all. I like the hands on kind of learning and this was not that at all.*
- *This was awful. I would much rather do the lab in class. I feel as though I didn't learn anything and will probably fail the quiz.*
- *I think that it was pretty difficult due to the fact that the students were not able to communicate with their lab partners or either the professor one on one.*
- *I really enjoy working in the lab more. I think I get more out of the lab when it is actual hands on. Not to mention I was really looking forward to seeing DNA in person this semester.*

The remaining survey responses were mixed. Generally the students thought the lab was okay to do online but wouldn't want to do all their labs that way. This response was typical:

> *Although I thought this lab was ok, I would rather be taught in class. It's easier to understand things when it is explained to you by a teacher. However, one online lab in a whole semester isn't too much to ask for!*

Conclusions

Those of us who favor the hands-on science experience may take heart in the fact that several of the online students commented that they missed the hands-on, collaborative work they would have performed in the lab room. They had been encouraged to work with other students if they wished, and many worked in pairs, but the group dynamic was lacking.

In addition, six students specifically commented on the lack of access to an instructor. The instructor e-mail is linked to WebCT, and it is also possible to set up online discussions. Encouraging the students to use these to interact and contact the instructor might help mitigate this problem. Particularly disturbing was the final negative comment listed previously where the student had actually been looking forward to a specific lab activity and missed out on it due to his/her participation in the online lab. That's very unfortunate.

Overall, though, the data show that the students' understanding of the lab content following their work was slightly better when they did the lab exercise online. That is encouraging because it suggests that we are not short-changing students who need to do online versions of labs for one reason or another. These online labs are quite convenient for facilitating make-up labs for individual students or for situations when a one-day cancellation of classes (due to holidays or weather) disrupts the weekly lab schedule. The online lab is a different experience for the student, but not necessarily a lesser one.

Does this suggest we should consider offering more lab exercises online? Perhaps, but with the caveat that it may depend on the subject and objectives of the lab. One might get a very different result if the lab exercise involved actual live specimens for students to investigate and manipulate. In this particular case, the cell division exercise was an essentially "dry lab," the objective of which is for the students to learn what occurs in the stages of mitosis and meiosis, with an emphasis on the differences and reasons for the differences between the two. This is illustrated in the content of the quiz questions shown in Table 3. Many students could easily read and learn this type of content. The students in class did some work with "real" slides and microscopes, and undoubtedly learned something from this process not measured by the quiz, but it's also certain that the quality of the images they saw was inferior to what was online. In addition, the in-class students seem to gain confidence in their understanding of the stages of cell division by doing the hands-on pop bead portion of the exercise. They frequently comment that they understand their lecture notes much better after this exercise. A student could do that on his/her own though, and there would likely be no great benefit for a non-tactile learner. In summary, while this lab exercise and our objectives were a good "fit" for online learning, more inquiry-oriented, open ended exercises, emphasizing experimental design or lab technique, might be much more difficult to accomplish online.

It would be interesting to do a similar comparison of an online *versus* in-class lab exercise and collect data on the learning styles of the students involved (Siebert & McIntosh, 2001). Students who learn science effectively without hands-on work would probably do fine with online labs. It's encouraging that a random selection of students can do okay too, but if you allow students the option of online labs, there is probably a population who would thrive. It would be important that students making decisions about distance learning be aware of their preferred learning style, however. And they also ought to be aware of what they might miss out on. You can't actually touch DNA on a computer screen.

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