Integrating Information Technology into Biology Courses

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Information technology is successfully integrated into biology courses through a variety of mechanisms. Class e-mail distribution lists are used to answer student questions outside of regular class/laboratory time. The World Wide Web (WWW) is used for posting interactive course syllabi, posting student-generated data, and as a research tool. Ninety eight percent of students surveyed (n = 42) indicated that integrating the Internet and the WWW into four different biology courses was useful, and 74% of respondents believe the WWW should be incorporated into additional courses.

Key Words: IT, WWW, web pages, cyberspace, e-mail, hypertext, links, browsers

Introduction
The three most popular letters in the world today are without a doubt WWW. It seems that one can’t watch a television program or commercial without those ubiquitous symbols appearing in the epilogue. Newspapers, magazines, and radio programs all advertise their presence in cyberspace. Telephones are becoming obsolete as phone software becomes more available. A few years back it was fashionable to hand out business cards with your name, physical address, telephone number, and fax number. In today’s world, those same cards won’t leave an impression without a cyber-address (email and homepage). It appears then, that all forms of communication are converging on the WWW, or, at the very least, each desires a presence on the WWW. As biology educators, we need to take advantage of this burgeoning field of Information Technology and integrate it into our courses.

The Internet is a world-wide network of interconnected computers that communicate with each other through various protocols. The simplest information sharing protocol allows exchange of data and text, and the most complicated systems allow transmission of images, video, and sound through a hypertext interface known as the World Wide Web. Hypertext is a format for documents that are accessed on the WWW. Some words, phrases, or graphics in a hypertext document are highlighted or underlined (or both), and these words, phrases, or graphics are hypertext links (links or hyperlinks for short) to other documents. A Web page allows you to use a computer mouse to click on a highlighted word or graphic and link seamlessly with parts of other documents, whether the documents are stored on the same computer or on separate machines in distant places around the world. Web pages are made available by computer running special software called servers. Hypertext files are viewed by users through use of special software programs called browsers (e.g., Netscape, Microsoft Explorer). Although the Internet has been in existence since the 1960s, the WWW did not come on-line until 1990 and did not become popular until the National Center for Supercomputing Applications (NCSA) released Mosaic (Web browsing software) in 1993 (Leiner et al., 1997). Since 1993, growth of the WWW has surpassed every other mode of online communications, increasing exponentially with a current doubling time of less than six months. Gray (1996) estimates that approximately 9.5 million computers with Internet addresses existed in January 1996, and that in July 1996 there were 230,000 servers serving web pages to the WWW. Each server typically makes hundreds to hundreds of thousands of Web pages available to browsers of the WWW. Therefore, it is highly probable that there are millions of web pages available at any time (although the exact number will never be known because there is no central registry for Web pages). Finding information in this morass of cyberspace is at best a daunting and frustrating task. Fortunately, there are search engines that facilitate information retrieval, but the nature of these software programs and the WWW does not allow the level of sophisticated searching typically associated with online catalogues at libraries or other Boolean Logic tools used in searching online databases such as Medline® (U.S. National Library of Medicine, 1997). Nonetheless the WWW can be successfully integrated into and used to enrich many different biology courses.

How can Information Technology be integrated into biology courses? Electronic mail (e-mail) is a simple, yet effective, communication tool that can be easily adapted for use in any course. I establish electronic distribution lists that allow me to simultaneously send the same message to
all students in a class. This is especially helpful when a student poses a question on Thursday that I can't answer without consulting a reference in my office. Instead of waiting to share the answer with the class five days later on the following Tuesday, I send it to everyone via e-mail within a few hours of when the class ended. Also, many students formulate questions while studying late at night. Instead of telephoning at such late hours, they e-mail questions which I answer the following morning. Our librarians have established a similar service entitled ASKUS, in which students are encouraged to submit questions via e-mail that are answered within 24 hours. I also require students to subscribe to e-mail discussion groups. These discussion groups can be very enlightening, or they can be disastrous. One learns the difference very quickly. Finding discussion groups is relatively easy. Search engines such as Yahoo (Yahoo, 1997) or directories such as LISZT (Southwick, 1997) are good places to start searching for relevant discussion groups.

The WWW is used in my classes for three different purposes: 1) posting interactive syllabi, 2) locating resources, and 3) posting student generated data. I do not provide a copy of the course syllabus on the first day of class, or at any time during the semester. Instead, I make the syllabi available through the Biology Department homepage (Hoagland, 1997a); students are introduced to the WWW and the Internet during the first class. Each syllabus includes the following standard information: meeting times and places, office hours, contact information, course description, assessment, and schedule of laboratory and lecture topics. Additionally, hypertext links allow students to access weekly objective files which include study questions, aids for writing scientific papers, WWW resources, and results of laboratory experiments. Because new ways of understanding traditional biological concepts frequently arise during class discussions and laboratory experiments, I update the study questions each week. I also frequently revise the WWW links on my syllabi because of the dynamic nature of the web. Syllabi for my classes; Genetics I, Biological Concepts, Vertebrate Physiology, Mammalogy, and Biology in Cyberspace are posted.

♦ The MIT Biology Hypertextbook (MIT Experimental Study Group, 1996) is a good resource for learning cell and molecular biology, and the Department of Biochemistry & Molecular Biology at the University of Leeds has a terrific tutorial for glycolysis (Maber, 1996).

♦ 3-D animations of many cellular metabolic pathways can be accessed through the Center for Biophysics and Computational Biology at the University of Illinois at Urbana Champaign (Crofts, 1996).

♦ The National Museum of Natural History at the Smithsonian Institution maintains a searchable database of all currently recognized species of the world's mammals (Wilson and Reeder, 1993).

♦ David and Wayne Madisson (1996) at the University of Arizona have developed the Tree of Life Website in which they present the most comprehensive phylogeny available anywhere.

♦ The Human Genome Project Website (U.S. DOE, 1997) provides access to the human genome database, and OMIM — Online Mendelian Inheritance in Man — (NCBI, 1997) is a superb searchable human genetics database.

♦ The U.S. Census Bureau (U.S. Census Bureau, 1997) provides a searchable database which allows visitors to access current and projected population statistics for the United States and the World, monitor the spread of HIV infection, and obtain related demographic, social, and economic information with the click of a mouse button.

There are also many resources available that provide assistance in developing web pages, including

♦ A Beginner's Guide to HTML (NCSA, 1996),
♦ Online HTML Tutorial (Maricopa Center for Learning & Instruction, 1996),
♦ Web Tutorial (Global SchoolNet Foundation, 1996)
Table 1. Responses to surveys administered to biology classes making extensive use of the World Wide Web and electronic mail. (see text for further details)

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
<th>NA</th>
<th>Maybe</th>
<th>Blank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Did you find the use of the Internet and the World Wide Web useful?</td>
<td>41</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Did you find the use of the Internet and the World Wide Web interesting?</td>
<td>40</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Did you like having the syllabus on the World Wide Web?</td>
<td>38</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Did you like having the instructor send you e-mail messages?</td>
<td>36</td>
<td>4</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Did you like using e-mail?</td>
<td>36</td>
<td>5</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Would you like other courses to have their syllabi on the World Wide Web?</td>
<td>31</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>If so, which ones?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Was any of the information on the Biology homepage helpful to you? If so, please list those resources you found most helpful.</td>
<td>27</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>8. Do you intend to take any more biology courses?</td>
<td>23</td>
<td>13</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Did you use e-mail and the World Wide Web before you took this class?</td>
<td>18</td>
<td>24</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Will you use e-mail and the World Wide Web in the future?</td>
<td>41</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Searching the WWW can be very time consuming and frustrating, therefore I also maintain a list of resources that are of general interest to biology majors. This list (Hoagland, 1997e) currently contains greater than 300 hyperlinks and is much too extensive to include in this paper. However, brief descriptions of a few sites will serve to demonstrate the value of the WWW as a teaching resource.

**Student Labs**

One of the most valuable uses of the WWW is for posting the results of student experiments. This is especially useful for courses with multiple lab sections because data from each section can be posted on the web at the conclusion of the experiment, and multiple data sets can be pooled for a more statistically rigorous analysis. Additionally, data sets from previous years can be included in analyses or used for comparison. I have found this aspect of integrating the WWW into biology courses one of the most positive for students. For example, for many years students at Westfield State College have conducted classic experiments with onion and broad bean root tips in an effort to obtain a greater understanding of the cell cycle (Hoagland and Doe, 1997). Students use freshly prepared slides to count the numbers of cells in interphase and in each stage of mitosis, and to calculate a mitotic index. Most student generated data yield estimates for a mitotic index approximately 2-3 times greater than published estimates. Their lab reports inevitably attribute this difference to experimenter error. In other words, students conducting scientific experi-
ments which don’t yield the “correct” results view themselves as failures. Despite the fact that these students generate hypotheses, design and conduct experiments, analyze data, and then compare those data with published results, if their results differ from those published, they conclude that they failed because they are only students, not scientists. These attitudes change when they compare their data with other student generated data and find no significant differences. Students then begin to view themselves as scientists. Posting student-generated data on the WWW helps biology educators teach students to become scientists. Additional student-generated data sets are available on our Web pages (Hoagland, 1997f).

**Evaluation**

In an attempt to determine if students view the integration of the WWW and Internet into biology courses as valuable, I surveyed two primarily non-majors biology courses during the 1996 summer session and two majors biology courses during the fall 1996 (Hoagland, 1997g). Approximately 52% of the respondents were non biology majors enrolled in Environmental Biology (n = 14) and Human Biology (n = 8) during the summer 1996, and the remainder were biology majors in those summer courses (Environmental Biology, n = 1; Human Biology, n = 1) and in a second semester freshman course (Biological Concepts; n = 13) and Genetics I (n = 5) offered during the fall 1996. I made no attempt to separate non-majors responses from majors responses for this analysis. Despite the fact that 57% of students surveyed had no prior experience with the WWW and the Internet, they enthusiastically endorsed the use of this telecommunications technology in biology courses (Table 1). The few students who did not like using the WWW indicated that the problem was lack of access to adequate computer facilities. Those students who did not like using e-mail identified the lack of word-processing power in the SMTP mail editor as the major problem. The majority of students would also like cybersyllabi for all biology, chemistry, physics, astronomy, psychology, business, finance, and all other courses. Students reported that the lab results pages, hyperlinks, list of Websites, and search engines were most helpful.

**Why integrate Information Technology into courses?**

Since the 1950s science educators have been criticizing the methods of science education in the U.S. (National Society for the Study of Education, 1960). In the intervening years a consensus has developed around the necessity of incorporating scientific inquiry and the process of science into biology and other science courses (AAAS, 1990; Hobson, 1996; Moore, 1994; NAG, 1990; Nissani, 1989; Roy, 1996; Wilcox and Jensen, 1997; Woods, 1989). For example, my students have collected birth and death data from a Westfield, MA cemetery that are currently available on the Biology Department server (Hoagland, 1996c). When similar data become available from cemeteries in different regions of the U.S. (or the world), students will be able to conduct comparative, open-ended investigations. The WWW then becomes an additional teaching tool that can be used to assist students on their journeys to becoming scientists. Students will also be better prepared for life after college because information technology is becoming increasingly relevant to large sections of society (Resmer, 1997).

**Literature Cited**


Hoagland, B. (1997g). Student Responses to Class Use of the WWW and E-mail. http://biology.wsc.mass.edu/biology/experiments/suresp.htm


