PERSPECTIVES

Challenges and Opportunities for Learning Biology in Distance-Based Settings

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Abstract: The history of learning biology through distance education is documented. A review of terminology and unique problems associated with biology instruction is presented. Using published research and their own teaching experience, the authors present recommendations and best practices for managing biology in distance-based formats. They offer ideas on resources for content, laboratory activities, safety and interaction among class participants. The need for research on the efficacy of virtual labs and simulations in adult biology education is noted.

Key words: online biology instruction, online science instruction, web based teaching, distance education

INTRODUCTION

Distance-education and internet-based learning are no longer novel concepts, as demonstrated by exponential growth of such courses (Dobbs et al., 2009). In science this trend is slower (Kennepohl & Shaw, 2010). We suspect that biology teachers fall into three camps with regard to distance education: (1) those to whom the process is so routine that they may give our paper only a passing glance (2) those who are new enough to the process that they are actively seeking information, and (3) those who have a deeply entrenched opposition to the whole idea. Our writing is aimed at all three. In this paper, we will provide a review/discussion of distance learning issues which are particularly relevant to biology.

Both authors, instructors in a small but nationally ranked community college in the rural southeast, have taught online for more than six years. In addition to utilizing various online strategies over the past 10-15 years, we both developed and teach a fully online non-majors biology course. One author also teaches online education courses. The other teaches a course for biology majors, combining face-to-face and online teaching. In addition to formal objectives for this paper, we will offer commentary on teaching biology in alternative formats as we draw examples from our experiences.

A Short History of Distance Learning

The exact origins of instruction delivered by the internet are foggy. Many writers place such instruction under the more inclusive moniker of *distance-learning* and claim roots as far back as the early 1800s in Europe. Correspondence courses, delivered by post, may represent the beginning of our modern practices (Casey, 2008; Dobbs et al., 2009; Schlosser & Simonsom, 2010). In biology the great Anna Botsford Comstock is of note. Her *Handbook of Nature Study* (1911) began as a series of lessons for an at-home study package for teachers. In early years, some colleges combined on-campus intensive summer study with correspondence courses (Schlosser & Simonsom, 2010).

As technology advanced beyond the press and post so did distance education. Audio conferencing, then visual media, became utilized (Anderson, 2008). In homes, television brought students to the screen for enrichment courses or certificate programs (Dobbs et al., 2009). Respected universities began to offer fully distance-based degree programs at least as early as the 1960s (Schlosser & Simonsom, 2010). Today, the process of offering courses online is fostered by commercially available *learning platforms* such as eCollege, Blackboard and webCT which allow for organization of course materials and communication among participants (Landry, et al., (2008). A trend among universities requires students to complete some minimum number of hours in online courses before they are awarded a degree (Dobbs, Waid & del Carmen, 2009). Online classes are generally more flexible in time and space than their traditional counterparts (Anderson, 2008). Students with extensive family or work commitments remain the target group (Schlosser & Simonsom, 2010). They have fueled the market for alternative options in education. There is little doubt that distance instruction will continue to develop with emerging technology.

Problematic Terminology

So far we have used the terms *distance* and *internet* almost interchangeably. We argue that internet-based learning is one form of distance-education. An idea developed further in our paper is that *internet-based learning* may not take place exclusively by computer. So, we refer to our work as *distance-based teaching*. The United States Department of Educational Research notes that distance education is characterized by the separation of the learner from the source of instruction. Technology allows learners to get information and to interact (Anderson, 2008; Casey, 2008). Interpreted loosely, that technology may be mail delivery. The internet is the predominant technology today. So terms such as *electronic learning (e-learning)*, *internet-based learning* and *web-based instruction* have found their way into our lexicon (Rivera & Rice, 2002; Anderson, 2008). The phrases *face-to-face instruction* or *seat-based classes*, often refer to instruction taking place in a traditional classroom or lab. *Web enhanced* or *hybrid* refers to a mixture of formats in which students meet in a classroom for some required number of hours per term and participate in online instruction for the balance of time (Rivera & Rice, 2002; Shea et al., 2006). Our school uses the term *web enhanced* a bit differently; the enhancement is seen as purely supplemental. Table 1 summarizes many of these commonly used terms.

Anderson (2008) offered a set of terms to distinguish the timing of instruction. If a student may access the course material at any time the delivery is *asynchronous*, even when deadlines or timeframes for assignments are specified. If a student is required to complete two lessons per week for sixteen weeks, the format is asynchronous if he were free to access content on Wednesday as easily as Friday or at 3:00 am as easily as 2:00 pm. *Synchronous* delivery involves access in real time. For example, all distance students may be required to access the course each Friday at 5:00 pm and participate for three hours in a discussion. Alternatively students may interact by remote television or webcam at a specified time. In short, activity occurs live; absences are treated the same as for a seat-based class. Dobbs et al., (2009) reported that students favored asynchronous delivery while Bernard, et al. (2009) noted that synchrony produced higher student achievement. Classes may combine both formats.

An additional set of terms (*interaction treatments*) describes how course participants access content and communicate. The essentials (as listed in Bernard et al., 2009) follow. *Student/teacher interaction* involves communication by telephone, e-mail or discussion forums. *Student/student interaction* may utilize discussion boards, group web pages, chat rooms, or student-created slide presentations (such as PowerPoint™). Anderson (2008) stressed its importance in building in a sense of community to a course. The presence of a community of learners (as opposed to a group of people, each learning in isolation) appears to be essential to student success in online courses (Shea et al., 2006; Anderson, 2008), though student/student interaction may place unwelcome constraints on some students even if required in an asynchronous format (Anderson, 2008). *Student/content interaction* may take several forms, including reading textbooks, visiting web sites, listening to lectures on sound files or watching laboratory videos. Table 2 provides examples of course components with a checklist of which interaction treatments they may satisfy.

Why the Reluctance?

As noted, science is not taught as often in a distance-based setting (Kennepohl & Shaw, 2010) perhaps due to concerns specific to science teaching and general distress about online instruction. Casey (2008) reported that distance education is viewed

Table 1. Terminology related to distance learning with examples of class activities.

Generally Synonymous Terms	Definition	Examples
Traditional class Face to face class Seat based class	Students and teacher meet exclusively to almost exclusively in an archetypal classroom or classic laboratory setting	A typical freshman level biology class with lecture and lab. An environmental biology class with two field trips.
Hybrid class Web enhanced class	Students and teacher have required face to face meetings in addition to interacting by way of the internet to complete the mandatory number of class hours.	Physiology students go to campus once per week to complete a lab. Assignments and discussions are done by way of the internet. Graduate students work independently on botany field projects. They communicate in chat rooms but come to campus monthly for poster presentations and guest speakers.
Web based class Internet class Online class Networked class Electronic class (E-class)	Students complete all (or nearly all) course requirements at a distance, mostly using the internet for delivery and interaction.	Freshmen complete discussions and hand in assignments using a course delivery platform. They do lab at home using a kit they purchased. They visit campus (or an approved proctor) to take the required final exam. Genetics students view digitized lectures twice weekly. They use the class web site to post questions. The class takes three exams by way of a testing feature built into the course delivery platform.

Table 2. Possible elements for distance based biology classes and checklist of interaction treatments.

Possible Elements for Distance Based Biology Classes	Interaction Treatments Checklist: Student-Teacher	Student-Content	Student-Student
Course Cartridges or Access Codes from Publishers	√	√	
Discussion Boards and Chat: Live and Asynchronous	√	√	√
Electronic Mail	√	√	√
Interactive Television or Video Conferencing	√	√	√
Lab Demonstration Videos	√	√	
Lab Procedures Instructional Videos	√	√	
Lectures on Sound Files	√	√	
Library Resources: Supplemental Books, Journal Articles, etc.		√	
Listservs	√	√	√
Slide Presentations from Publisher, Teacher or Students	√	√	√
Student Group Pages	√	√	√
Telephone: Individual and Conference Calls	√		√
Tests & Quizzes: Online or Written, Proctored or Unproctored	√	√	
Textbooks: Paper or Electronic		√	
Web Sites Related to Course Content		√	

with more suspicion than other modes of instruction. Many faculty view online education as inferior and predict decreased learning (Kirtman, 2009). Ward (2008), in a survey of over 100 college science instructors from various disciplines, noted that a strong majority viewed distance science courses negatively and were resistant to accept them. Why? Some teachers may lack the technical knowledge or support to teach online (Kennepohl & Shaw, 2010). The practice requires a different mindset and teaching style, and prior training is recommended (Miller, 2008). One way to get a feel for online education is to enroll in online courses or seminars.

Science is a complicated discipline to learn and teach, and specialized equipment or complex models are often required (Downing & Holtz, 2011). It is not surprising that the greatest challenge for many distance instructors is implementing laboratory and field work effectively (Cancilla & Albon, 2008; Ward, 2008; Reuter, 2009; Downing & Holtz, 2011).

Research Findings, Best Practices & Advice

Important factors to consider in distance-based science learning environments include transmission of course material and inclusion of content-based student assignments and activities. We will now present some of our own practices and experiences with these factors, and review the current literature.

Transmission of Web-Based Learning Content

Distance instructors may ask, "How do I convey the content knowledge that would normally be presented during lecture?" Pursued alone or in combination, options such as pre-existing web sites, printed books, e-books, recorded lectures, and other resources provide flexibility. Most learning platforms allow teachers to include *Uniform Resource Locators* (URLs; i.e. web addresses) for use by students. Teachers simply need to select a few to meet their needs.

Traditional classes use textbooks as a primary content source, and distance classes are often similar. Fully accessible, free of charge, quality texts are available online. One example (Kimball's Biology Pages: home.comcast.net/~john.kimball1/BiologyPages/) is based on a classic text by John Kimball (1994). Publishers often include online content for their books, free or fee-based. Others offer content as CD ROMs or *cartridges* where an entire course is loaded into a learning platform. Cartridges may be electronic versions of textbooks or may include interactive quizzes and animations. Some contain grading packages and other features (Landry, Payne & Koger, 2008). As a rule, we are not enthusiastic about course cartridges due to challenges in finding balance between content and quality.

The challenge of transmitting content can actually become an opportunity for increased learning. One of the easiest transmission tools is slide-based lectures which can include text, graphics, animations, instructor narration, and even written scripts for the hearing-impaired. Students may move through material at their own pace, so challenges regarding absences and concentration lapses are eliminated. The convenience of online lectures may contribute to the overall satisfaction students attribute to distance learning (Walker & Kelly, 2007).

Web-based lectures do have disadvantages, including lack of visual cues and feedback which help teachers evaluate understanding (Miller, 2008); inability of students to ask real-time questions, and lack of in-depth conversations about content during lecture. A variety of options can meet these challenges. Telephone, instant messaging and electronic mail may be used to communicate with any student, distance or traditional. Most learning platforms include discussion boards allowing asynchronous exchanges among students. *Live chat*

Table 3. Sample teaching, learning and assessment sequence from a web-based freshman genetics unit.

Activity		Description
Step 1:	Student Preparation	Students read material from textbook, external links and instructor-made slide presentations.
Step 2:	Guided Practice	Students view animations, video clips, and they participate in interactive games and quizzes.
Step 3:	Formative Assessment	Each student completes a low-stakes quiz online. Depending on the result, he or she may move ahead or complete additional practice.
Step 4:	Short Writing Assignment	Students write an essay on genetics. The instructor evaluates these. Students may then revise the essay as needed and then expand the essay into a project.
Step 5:	Project	Each student completes a slide presentation and posts it to the class web site.
Step 6:	Peer & Instructor Evaluation	All slide presentations are evaluated by the instructor and by peers.
Step 7:	Final Product, Class Debate	On the discussion board, everyone participates in an online debate regarding genetic engineering and its implications.

options are available too. Further solutions include creating review activities and assignments that build on lectures or apply the material to real-world problems.

From Transmission to Application: Moving Beyond Memorization

Many distance activities reinforce content and allow students to apply knowledge. These include web-based review centers provided by text publishers, online content quizzes, narrated (and often interactive) animations, links to web content, and discussion board activities. These create opportunities that would be difficult to incorporate into traditional classes, but they must be carefully employed to ensure effectiveness. For instance, Muchovej (2009) found that optional online quizzes did not significantly improve scores when quiz questions were recycled on exams. A low number of students completed the optional quizzes, suggesting that how the learning strategies are employed is important.

Web-based technologies allow instructors to utilize sequentially built knowledge and skills. An example from one of our freshman biology courses is summarized in Table 3. Notice that the activities, in this case centered on learning genetics content, build upon one another to progress from knowledge to application.

Laboratory Activities

Published research concerning labs in distance-based science courses is spotty (Kennepohl & Shaw, 2010). Reuter (2009) reported no significant differences between online and traditional lab grades in various science courses. In a small study, Lunsford & Bolton (2006) reported similar success rates on biology content exams for nonmajors taught traditionally and online. By its nature, science involves frequent laboratory work, a fact reflected in most biology courses. Providing laboratory experiences is challenging in a web-based course (Kennepohl & Shaw, 2010). Specifically concerns about lab content, materials, and safety arise. The quality of a class may suffer if planning is not done carefully (Miller, 2008). We recognize these concerns while challenging our colleagues to honestly question the quality of seat-based lab practices, especially those offered to undergraduates and non-majors. As uncomfortable as it may be to admit, Cancilla & Albon (2008) reminded us that seat-based lab practices are often rushed, prescribed and lacking in authenticity. Lab activities in any format always require careful planning. Some of the choices for distance courses will be discussed below.

Hybrid, Power-Lab and Mentoring Options

An easy solution is to offer a traditional laboratory meeting via a hybrid class (Kennephol & Shaw, 2010). A variation is the *power lab.* These are required, extended lab meetings (Cancilla & Albon, 2008) which may be offered several times per semester, in the evenings, or on weekends. Students satisfy the laboratory component in a traditional way despite the unconventional scheduling. If only one or a few lab objectives require a traditional solution, a laboratory mentor working with individual students may be an option. For example, if a teacher places high value on microscope use, students may locate a site for completion of such work (e.g. high-school teachers or hospital lab technicians are eager to assist our students). Colleges and universities have been sending students to clinics, classrooms, labs, field stations and other locales to enhance their on-campus studies for decades. You may wish to invest time to formulate a preapproved list of off-campus mentors or lab sites. Safety and liability issues should be considered when having students work off-campus.

Instructor responsibilities for safety are the same whether lab is conducted in a traditional or a distance setting. Specific challenges related to liability and insurance are too complex for this article, but educators and institutions should examine their practices to ensure that students are not exposed to unreasonable risk. A good overview is provided by the National Science Teachers Association (NSTA) (nsta.org/about/positions/liability.aspx). Table 4 also provides some tips.

Virtual Labs, Simulations & Demonstrations

By definition, a virtual or simulated experience is approximated by a computer. Virtual labs are becoming commonplace in distance-learning (Anderson, 2008). In online and traditional classes, we recommend limited use of simulations. We prefer to utilize simulations as a supplement, as we have

Table 4. Tips for safety and liability concerns involving off campus lab or field work.

General Safety Tips	Working From Home	Potential Legal Issues	Safety at Home
Remember that all lab activities (even paper and pencil materials) could have some potential safety or legal risks. Strive to keep use of chemicals, sharp objects, heat, etc. to a minimum. If your labs require a lot of potentially dangerous items consider an on campus, a hybrid or a power lab option.	Enclose required safety materials such as goggles or gloves in lab kits. Supply detailed instructions for disposal of chemicals or specimens. Put Material Safety Data Sheets (MSDS) in lab kits or post them on the class web site. Supply demonstration videos to emphasize safety for specific lab procedures.	Require students to view a safety video or attend a safety training session, even at off campus facilities. Require students to sign a safety contract specifying liability and attesting that they understand safety procedures. Requires students to purchase and maintain accident insurance if appropriate. Ask off campus sites to treat students as they would treat employees concerning safety and liability.	Post contact information for the Poison Control Center on the class web site. Post a flow chart concerning first aid procedures and when it is necessary to call 911 for a safety emergency. Provide specific precautions in lab procedures such as "Do not mix with other chemicals" or "Avoid contact with eyes" or "See MSDS".

found virtual activities ranging from useful to terrible. One can access quality film images of dissections online at no cost (e.g., exploratorium.edu/learning_studio/cow_eye/step01.html). Also, teachers have the option of filming their own demonstrations (Kennepohl & Shaw, 2010). In other cases publishers offer flashy, expensive computer simulations that, in general, are heavy on production but ineffective at building scientific process skills. We are not aware of a recent, quality study of the efficacy of virtual labs and simulations in adult biology education. Clearly there is a need for research. Asbell-Clarke & Rowe (2007) noted a study comparing traditional and virtual labs for introductory chemistry classes. Students, by and large, learned no lab skills or techniques but did pick up additional content knowledge about chemistry. Reuter (2009) reported that virtual labs are coming to be viewed as secondary in value to authentic lab and field experiences. One advantage is that students are able to access simulations asynchronously and therefore at their own convenience (Cancilla & Albon 2008).

Working at Home: Kitchen Labs, Remote Instrumentation and Other Options

Though some courses do not lend themselves to web-based lab assignments due to need for equipment or concerns for safety (e.g., microbiology), many freshman-level labs can be easily and safely completed by students in their own homes. So called *kitchen science labs* tend to require little to no specialized equipment. They are particularly common in non-majors courses (Reuter, 2009). Asbell-Clarke & Rowe (2007) found that well planned kitchen activities can promote mastery of inquiry skills. From their homes our students have completed labs concerning scientific measurement, observation of metamorphosis, experiments involving diffusion, mark and recapture modeling, and use of homemade pH indicators. Be sure to supply students with a list of required materials in advance.

Another option involves offering materials (slides, reagents, dissection specimens, etc.) to students as *lab kits* (Kennepohl & Shaw, 2010). Teachers may mail kits to students, distribute them during face-to-face meetings or collaborate with college bookstores for dispensing. There is a growing industry involving the commercial packaging of laboratory kits. One source with a variety of options is Hands on Labs/LABPAQ (holscience.com). While all of these alternatives require a significant commitment from instructors, the outcomes allow students flexibility in scheduling. Also, labs can be sequenced into the flow of lectures, and lab results can be discussed online.

Instructors should provide safety instructions. Directives on organization of work areas, chemicals, clothing, equipment, and clean-up may be needed. Teachers may also consider a *safety contract* which must be completed by students to show they have understanding of safety considerations. Another approach is the use of a pre-lab *safety quiz* which could be easily integrated into many distance-learning platforms. An excellent example of safety considerations specifically focused on distance-learning labs is given by Hands-On Labs, mentioned above. Table 4 provides more suggestions.

Remote instrumentation is commonplace in biology and involves manipulation of scientific apparatus from distant locations. Control and data transmission are usually accomplished via the internet. Examples include sensors, cameras, chromatographs and machinery for collecting samples. (Educase Learning Initiative, 2006; Kennepohl & Shaw, 2010). Remote instrumentation fits well with distance-based learning. Equipment is usually accessible at any time and data are often easily shared. In fact they may be shared and contributed to not only within classes but among them, even among multiple colleges (Cancilla & Albon, 2008). This can save time and travel, and provide authenticity as students work with actual data (Educase Learning Initiative, 2006). Practical lessons on sample size may be cleverly built into large data sets. On the downside, remote instrumentation may be costly. Some researchers or sponsors may object to sharing raw data (Educase Learning Initiative, 2006).

Library and Internet-Based Review Projects

Teachers have long sent students to libraries to complete what could pass as lab work. Perhaps students study classification by writing a review of organisms from various taxa or they may read research articles for class discussion. These tasks are easily accomplished online. Respected journals are available online and most libraries maintain access to databases for retrieving articles. In addition, many internet search engines provide full articles for free. Examples ideal for academic research include Google Scholar (scholar.google.com) BioOne Journals (bioone.org) and Scirus: For Scientific Information Only (scirus.com). Scientists routinely use online sources for their research so it follows that students should as well (Cancilla & Albon, 2008).

Inquiry-Based Learning

Inquiry activities, those which mimic scientific practice (NRC, 2000) are possible in distance-based formats. One option we have found effective is long-term independent research projects providing experience with scientific inquiry. Our students complete a research project in which they formulate a question, hypothesis and design. They present findings via slide presentations or research papers posted on the class website. Lunsford (2008) reported a guided inquiry in which distance students monitored yeast respiration using a bottle and balloon apparatus. Other examples include a project in which a student investigated correlations between firefly lighting and temperature and humidity. Projects of this type require several conditions for success. Goals and guidelines must be clear. Detailed instructions, with examples of previous student work, help meet this requirement. Students can sequentially build the skills necessary to complete the project. Leading up to inquiry assignments, our labs are designed to give students practice with observation, measurement, sampling and statistics. Lectures and labs also cover design, variables, replication, randomization, etc.

DISCUSSION

Internet-based learning is no longer a novel concept, though science has been slower than other disciplines to embrace the genre. Reluctance comes from concerns about effectiveness of distance-learning and issues specific to science education. In this paper, we have addressed concerns involved with the transmission of biology material in distance-learning. Specifically, we have discussed the effectiveness and challenges of transmission strategies such as traditional and electronic texts and slide-based lectures. We have outlined student activities and assignments (like essays, presentations and discussions) which build knowledge sequentially. Challenges related to labs have been reviewed and solutions offered. We have called for teachers and researchers to explore virtual laboratory activities and simulations and what role, if any, they should have in our distance teaching practices. We have considered other learning approaches like research and review projects and inquiry-based learning. We believe that there are many obstacles related to effective biology teaching in distanced-based settings. Most of these challenges can be overcome with careful planning and proper application of technologies and educational theories. Distance-based biology teaching can offer many advantages over traditional settings for those willing to explore the possibilities.

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