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Designing Online Resources in Preparation for Authentic Laboratory Experiences

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Abstract

Professional development for science teachers can be benefited through active learning in science laboratories. However, how online training materials can be used to complement traditional laboratory training is less understood. This paper explores the design of online training modules to teach molecular biology and user perception of those modules that were part of an intensive molecular biology “boot camp” targeting high school biology teachers in the State of Hawaii. The John A. Burns School of Medicine at the University of Hawaii had an opportunity to design and develop professional development that prepares science teachers with an introduction of skills, techniques, and applications for their students to conduct medical research in a laboratory setting. A group of 29 experienced teachers shared their opinions of the online materials and reported on how they used the online materials in their learning process or teaching.

Keywords

Molecular Biology; Blended Learning; Instructional Design; Online Education

INTRODUCTION

Science teachers need time to visit science laboratories to update their skills and knowledge of modern scientific techniques. Professional development in science education is benefited by participation in active research laboratories. This paper explores the design and user perception of online training modules that were part of an intensive molecular biology “boot camp” targeting high school biology teachers in the State of Hawaii. The John A. Burns School of Medicine at the University of Hawaii had an opportunity to design and develop professional development that appropriately prepares science teachers with an introduction of skills, techniques, and applications for their students to conduct medical research in a laboratory setting. The objective of this educational project was to develop an effective professional development program that will assist teachers as they help their students develop a familiarity for laboratory techniques prior to conducting molecular biology research in an authentic laboratory setting. One of the main components of the program is the online learning materials that review molecular biology content and the techniques that are being utilized in research laboratories. This paper will discuss the design process for the online materials and provide a glimpse into the perspectives of the teachers that have used it as part of the program.

Literature

Building upon the well-accepted practice of authentic laboratory internships, a new blended learning approach has emerged, which combines learning objects (digital and web-based), including virtual laboratories, to augment laboratory training. This approach could vastly improve access to high quality instruction and address the needs of more than a few select students a year. Moreover, as teachers help students engage in authentic scientific practice within the classroom they build students' integrity, diligence, fairness, curiosity, openness to new ideas, skepticism, and imagination, which reflect the scientific "habits of mind" (AAAS, 1990, p. 185) as essential to scientifically literate individuals. Diverse methods are used to teach science in the classroom. While there is no single way science should always be taught, there is an increasing emphasis on inquiry (NRC, 2000). How inquiry is defined has been virtually left up to teacher interpretation, and many believe that having tools in hand represents inquiry and that will occur through authentic laboratory experiences. This change will be accomplished with an effective contribution by scientists in collaboration with the preparation of high school science teachers (Munn et al. 1999).

Learning objects in online education provide educators with resources that are re-useable, cost effective, and available to a virtually unlimited amount of learners via the Internet. The use of learning objects in conjunction with traditional instructional strategies in a blended learning approach supports distance learning by allowing the user to take control of their online experience and utilizing the learning style that suits their needs (Ruiz et al., 2006.) Blended learning has been a successful strategy for online education as learning objects tend to be dynamic and are geared toward a student-centered approach that allow learners to interact with the resources at their own pace and according to their schedule. Blended learning is based on a combination of traditional instructional strategies, online education, and learning that is supported by other technologies, the result is a learning environment that is tailored to the learner's needs (Hoic-Bozic et al., 2009). The online materials focus on learning through authentic application of knowledge and skills. Through our program teachers learned to understand not only basic molecular biology techniques, but also the concept used to link the techniques, enabling teachers to better apply what they have learned in real-world situations. Teachers also learn to help students evaluate and decide which tools and techniques to use, and teachers are encouraged to provide students the opportunity for social interaction, within the context of science, both inside the classroom and beyond (Edelson, 1998).

Previous studies that compared the application of computer simulations with traditional instruction seem to indicate that using computer simulations can successfully enhance traditional instruction. Within traditional education they can be a useful add-on or in this case as a pre-laboratory review. In Martinez-Jimenez's (2003) study, students in both the control and experimental groups performed an experiment on the extraction of caffeine from tea. A pre-laboratory simulation program introduced the experiment for the experimental group. Student performance was evaluated and the researchers found that using the preparatory simulation leads to better comprehension of the techniques and basic concepts used in their laboratory work.

Context of Study

The University of Hawaii's John A. Burns School of Medicine (JABSOM) is the only one medical school in the State of Hawaii and is in an excellent position to encourage and support interested individuals, especially students who have been introduced early into the STEM pipeline, to participate in modern, advanced medical research. However, the potential pool of high school students and their teachers, often lack the basic research skills that

would allow them to efficiently integrate into laboratory experiences at JABSOM. This project bridges this gap and develops the infrastructure to offer teacher development training in modern laboratory techniques in an efficient manner. These online training materials provide online access to professionally developed and packaged training materials that will increase knowledge critical to participating in a medical research laboratory.

Methodology

This study discusses the online instructional modules developed to augment traditional laboratory internships. First, the process for developing the online instructional materials will be reviewed. Second, the use of these materials in two separate training groups of secondary science teachers, who teach students ranging from 14–18 years old, will be explained.

The online training materials are divided into four main modules with each module consisting of several topics. Each of the 16 topics is divided into subtopics that contain the learning objectives, content material, animations, and activities (refer to Table 1).

Each topic focuses on a specific application and begins with an overview video and a set of objectives. Each topic contains the following:

- Content Tutorials: important background information, detailed text and illustrations that describe and depict the molecular biology significance, practical uses, and procedures.
- Animations: video and audio enhanced simulations.
- Activities: virtual labs, case studies and problem-sets from professional institutions and organizations.

Within a topic, there is a right-sidebar menu to navigate to the parts. Figure 1 shows an example of a module content and general layout.

The content of the instructional modules was assembled through two main sources: 1) permission to use materials from a well-developed in-person training at the University of Calgary, and 2) links to publically-available, well-known and highly regarded online resources, such as those of Cold Spring Harbor Laboratory or Howard Hughes Medical Institute. The training materials may be accessed at <http://www.ccrhawaii.org> and an overview of the development of the materials is provided in this paper; however, for details on the two-year development process of the online materials please refer to Boulay, Parisky, and Campbell (2010); Boulay, Parisky, and Fulford (2010); Parisky, Boulay, and Anderson (2010); or Boulay, Anderson, Parisky, and Campbell (2009).

The modules integrated various animations, simulations, tutorials, virtual labs, videos, and additional web-based content from the sources described below. The reviewed sources included materials developed by the Howard Hughes Medical Institute, the Cold Spring Harbor Laboratory and Dolan DNA Learning Center, the Massachusetts Institute of Technology, The National Human Genome Institute, the National Center for Biotechnology Information, the University of Calgary Biotechnology Training Centre, the Arizona Biology Project, and the University of Maryland Baltimore County's Applied Molecular Biology Program. These sources provided an array of content materials presented in various formats that include two-dimensional and three-dimensional guided animations, video segments, interactive tutorials and problem-sets, laboratory protocols, and virtual laboratory investigations. These up-to-date, technology-enhanced virtual learning resources enriched the curriculum materials provided through the collaboration with Dr. Hutchins at the

University of Calgary. The developed module subsets contained specific learning objectives, content, and learning activities.

Each module contains video introductions to each topic area. In addition, videos demonstrate laboratory techniques in Molecular Biology where the techniques are explained in the content area. The development and integration of video segments unique to JABSOM provided a virtual insight into the laboratory facility and allow for demonstrations of specific techniques utilizing authentic JABSOM research equipment. The technique videos cover the following: Centrifugation, DNA Electrophoresis, DNA/Plasmid Purification, DNA Ligation, Restriction Enzyme Digest, Western Blotting, Polymerase Chain Reaction, Spectrophotometer Use, Tissue Sectioning, Microscopy, and Pipetting.

Evaluation & Revision of Instructional Modules

An overall plan for the assessment of the online materials was submitted January 2009. The Committee for Human Subjects granted a certificate of exemption (CHS# 16844). A multi-step approach to revision of the online instructional modules was proposed, using content reviewers and group pilots.

Content Reviewers

An initial team of well-funded medical researchers are providing overall insight, feedback, and accuracy check of the content disseminated in the modules. Dr. Daniel Bernstein, Stanford University, and Dr. Ralph Shohet, Director of the Center for Cardiovascular Research at JAB-SOM, are the most active volunteers to review the content of the online materials. They provided feedback on the module, assessment tools, participated in semi-structured interviews to collect suggestions and ideas to improve the instructional modules.

Participating Teachers

A group of 29 participants consisting of advanced biology teachers (including 3 National Board Certified teachers) piloted the molecular biology content and learning objects. For the group of participants, teaching experience in the area of biology was approximately ten years as a group average. The participants taught advanced biology classes such as Honours Biology, Advanced Placement Biology, Anatomy/Physiology, College Prep Biology, Biotechnology, and Forensic Science (in addition to General Biology). The teachers also served at their school sites that included leadership roles such as department chair, Hawaii Science Teachers Association Biology section chair, science fair advisor, school science fair coordinator, state science content panel member, advisors for Health Occupations Students of America (HOSA), a coordinator for the Pacific Symposium for Science and Sustainability, and representatives on leadership team/professional development committees at the school site, district, and state levels.

The participants were selected from a pool of biology teachers at the secondary level from the State of Hawaii, including the islands of Maui, Kauai, Oahu, and the Big Island. The Center for Cardiovascular Research chose those individuals that had significant experience teaching advanced courses in biology as they would be exposed to those students who were most likely to follow a path leading into biomedical research careers. Additional screening for participants who had demonstrated leadership experience at their respective school sites was important in this study as input from the leadership of the science teacher community in the State of Hawaii was sought.

Data Collection & Analysis

For the participating teachers, each participant completed a background demographic survey and a survey on their confidence and knowledge to perform and teach various biomedical research techniques. Further, each participant completed a post-training survey and wrote a reflective statement about their learning experience. Two doctoral students from an Educational Technology department at the University of Hawaii examined and coded the data teachers reported in their open-ended survey questions or their reflective statements. Only comments relating to the online materials have been examined for this paper. Using constant comparative method, themes emerged from the teachers' comments referencing the online materials.

Results

Experienced teachers will not make use of online materials in exactly the same way. How teachers used the materials emerged as an important theme from among their comments related to the online training materials.

Online Materials used as Preview

Several teachers commented that they used the materials to preview techniques or labs that they would be shown in their laboratory training days.

"I felt like the labs were going to be above my understanding when I first looked at what we were doing but the (online) materials helped me understand and catch up on content so I felt prepared for the labs."

"It helped give me a preview of the technique and it's importance."

"It was vital to the day's techniques. Especially for the ones I was not very familiar with."

The less experienced a teacher was with the research techniques prior to training, the more frequently they commented on using the online materials as refresher or a scaffolding tool before they attended laboratory demonstrations.

Online Materials Useful for Students

The intention of the online materials developed was not aimed at students directly using these materials. However, several teachers indicated they planned to use various parts directly in their teaching.

"Before the program started I was sent a link to a resource website that was full of back ground information, lab technique videos, interactive links and animations to help me prepare for the program. I bookmarked many of the resources for future use with my students, I had come across some of them before but there were so many new, useful ones too."

"I found the (online) material extremely helpful in giving me some basics for each day. Some of the tutorials were a little lengthy, but the animations were great and fairly easy to understand. I will be using some of the stuff as part of my curriculum in the future."

The animations in which students can see complex phenomena visually were among the most noted resources teachers felt useful and beneficial to their students.

"Molecular animations were great & some of the technique videos will help prep my students for labs."

The ease of having so many resources organized together and the high-quality animations seemed to encourage teachers to use the materials with their students or directly into their teaching, although this was an unintended use of the site.

Professional Organization

Teachers while unsolicited made several mentions about the professionally designed materials and their organization contributing to the use of the materials.

“Lastly, I just want to say that this experience has been one of the most practical and fun programs that I have participated in. It has real application in my classroom and in my own learning. The website was very organized and complete; it was very helpful in teaching the concepts. I will recommend this program to all science teachers. I hope that there is a part 2 so that I can participate again.”

“The clear organization of the online materials made it possible to go back and find information later.”

“I thought the design was nice and it was easy to navigate.”

These comments above demonstrate the completeness of the website, the website’s organization contributing to finding information at a later point, and the ease of navigation, according to the teacher participants. While designers may well know the benefits of a well-organized and professional site, it is interesting to note that teacher participants highlighted these elements frequently as they discussed how and in which they used the online materials.

Next Design Step

The initial results gathered through the initial reviewers’ personal case of learning, emphasize the need to provide direct connections between the content and real-life research laboratories at various medical schools around the world. While we decided to develop instructional videos of technique demonstrations from actual laboratories, more is needed to bridge the abstract biomedical research techniques with the actual scientists and their current research project. The next design step will involve recording interviews with researchers in the laboratories, using VoiceThread, in addition to including electronic versions of scientific journal articles published by JABSOM researchers. The JABSOM-focused videos and journal articles will be important instructional tools to provide implications for creating an authentic learning experience for Hawaii’s students and secondary level teachers. Furthermore, we believe that these specific connections will establish a stronger awareness among Hawaii’s science students and teachers of the biomedical research areas that are currently being studied and are of need of future investigation in Hawaii. Furthermore collaboration with other institutions in a variety of countries will enable us to share this resource with individuals it may benefit.

Conclusion

This paper described the design and user perception of online training materials that were part of an intensive Molecular Biology professional development opportunity targeting high school biology teachers in the State of Hawaii. While many individuals are hesitant to consider teaching science online, a blended learning approach to science may be highly valuable. Teacher participants identified the usefulness of videos that demonstrate techniques or procedures as a precursory activity to their seeing hands-on demonstrations. Further, teachers find online materials, especially with high-quality multimedia animations, particularly useful with students and directly into presenting content to students. Finally, the organization, design, and navigation of online materials contribute to the usability and integration into classroom teaching. Design projects are generally in evolution, as is the case

presented in this paper; however, designing materials that bring science teachers and scientists together is very rewarding. Links that bridge science teachers to understand on-going science projects will hopefully lead to improved student learning and student experiences with science.

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Biographies

Dr. Rachel Boulay: Dr. Boulay has been developing new educational programs aimed at increasing interest in medical research and improving the preparedness of individuals to contribute to medically relevant research. She has focused on developing outreach partnerships with stakeholders connected to science and medical education from the community and educational institutions in the state.

Alex Parisky: I am currently a doctoral student in Educational Technology. I am an Instructional Designer for the Center for Cardiovascular Research at the John A. Burns, University of Hawaii. I am doing my dissertation research on how medical schools use distance learning systems to supplement traditional medical education.

Dr. Peter Leong: Dr. Leong has over 5 years experience in the development and delivery of online courses and distance education. Dr. Leong's research areas include the role of social presence and cognitive absorption in student satisfaction with online learning environments and faculty development. Dr. Leong has been instrumental in the development and implementation of Second Life as an educational platform at the College of Education.

MOLECULAR BIOLOGY

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[Home](#)
[1. Laboratory Introduction](#)
[2. Nucleic Acid Techniques](#)
[3. Protein Techniques](#)
[4. Cell Culture Techniques](#)

4.2b Content Tutorials

Technique Video

I. TISSUE CULTURE METHODS

Cells should be monitored daily for morphology and growth characteristics, fed every 2 to 3 days, and subcultured when necessary. A minimum of two, 25 cm² flasks should be carried for each cell line; these cells should be expanded as necessary for the transfection experiments. Each time the cells are subcultured, a viable cell count should be done, the subculture dilutions should be noted, and, after several passages, a doubling time determined. As soon as you have enough cells, several vials should be frozen away and stored in liquid N₂. One vial from each freeze down should be thawed 1-2 weeks after freezing to check for viability. These frozen stocks will prove to be vital if any of your cultures become contaminated. Procedures:

A. Media preparation

When working in a tissue culture facility, you will be responsible for maintaining your own stock of cell culture media; the particular type of media, the sera type and concentration, and other supplements will depend on the cell line. Do not share media with anyone else because if a culture or a bottle of media gets contaminated, you have no back-up. Most of the media components will be purchased prepared and sterile. In general, all you need to do is aseptically combine several sterile solutions. To test for sterility after adding all components, pipette several milliliters from each media bottle into a small sterile petri dish or culture tube and incubate at 37°C for several days. Use only media that has been sterility tested. For this reason, you must anticipate your culture needs in advance so you can prepare the reagents necessary. But, please try not to waste media. Anticipate your needs but don't make more than you need. Tissue culture reagents are very expensive; for example, bovine fetal calf serum cost ~ \$200/500 ml. Some cell culture additives will be provided in a powdered form. These should be reconstituted to the appropriate concentration with double-distilled water (or medium, as appropriate) and filtered (in a sterile hood) through a 0-22 µm filter.

All media preparation and other cell culture work must be performed in a laminar flow hood. Before

Module 4 Menu

- 4.1 Intro to Cell Culture & Aseptic Technique
- 4.2 Maintaining Cells
 - 4.2a Maintenance
 - 4.2b Tissue Culture Methods
 - 4.2b Content Tutorials
 - 4.2b Animation
- 4.3 Transfection Methods
- 4.4 Expression Analysis

Figure 1.
An Example of the Online Training Module

Table 1

Molecular Biology Online Training Materials

Modules	Topics	Sub-Topics
Introduction to Molecular Biology	a. Laboratory Safety b. Molecular Biology Laboratory c. Measurements, Solutions, & Calculations d. Content Overview/Review Activities	Objectives Content Equipment Animations
Nucleic Acid Techniques	a. DNA Restriction & Nucleic Acid Analysis b. Nucleic Acid Amplification & Sequencing c. Nucleic Acid Hybridization & Expression Analysis d. Molecular Cloning e. Preparation, Purification, Quantitation of DNA & RNA	Objectives Content Animations Activities
Protein Techniques	a. Protein Expressions & Proteomics b. Protein Detection & Analysis c. Protein Purification	Objectives Content Animations Activities
Cell Culture Techniques	a. Intro to Cell Culture & Aseptic Technique b. Maintaining Cells c. Transfection Methods d. Expression Analysis	Objectives Content Animations Activities