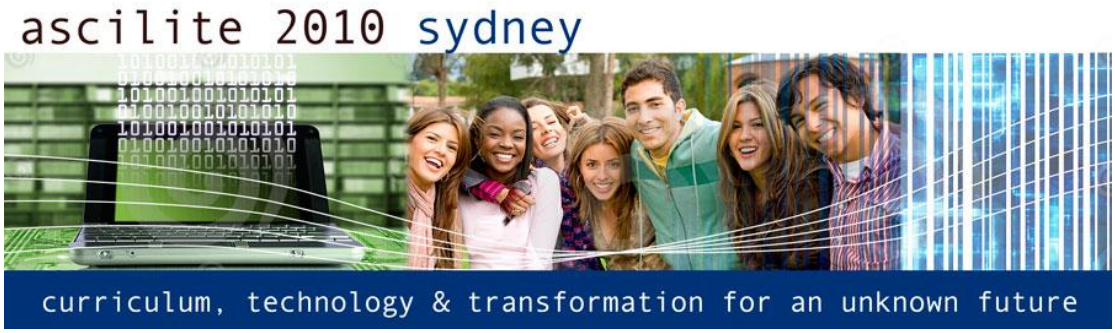

Developing teachers' understanding of molecular biology: Building a foundation for students

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Molecular biology often uses participation in active research laboratories as a form of educational training. However, this approach to learning severely restricts access. As a way of addressing this need, the University of Hawaii launched a project to expand this model to include newly developed online training materials in addition to a hands-on laboratory experience. This paper further explores the process of material development and assessment plans. A pilot case study of a group of advanced biology teachers who embark on learning molecular biology over a four-month period through online training materials and working side-by-side with medical researchers in a laboratory is described. Teachers were positive in reporting about the many areas they gained instruction in although some feedback suggested that the initial online materials over-emphasised abstract concepts and laboratory techniques and did not adequately connect to the active research problems or local context of most interest to teachers and students. The experiences of the teachers are shared in an effort to gain insight on how teachers perceive their participation in the study.

Keywords: molecular biology, blended learning, learning objects, higher education

Introduction

Constant advances to internet technologies have allowed the World Wide Web to become an alternate source for teachers who are looking to hone their skills in their particular content area (Boettcher and Conrad, 1999; Eynon, 2008). As online resources are being used in a variety of contexts to supplement instruction and training in medical schools, opportunities are consistently needed to provide educational initiatives that appropriately prepare students and science teachers with an introduction of skills, techniques, and applications for conducting medical research in a laboratory setting. The objective of this educational project was to develop an effective blended learning instructional program that assisted teachers as they help their students develop a familiarity for laboratory techniques prior to conducting molecular biology research in an authentic laboratory setting. The long-term objective of this project was to increase the number and quality of individuals available to conduct research in medically relevant areas of interest to the multi-ethnic population of the Hawaiian Islands.

The University of Hawaii's John A. Burns School of Medicine (JABSOM) is well positioned to encourage and support interested individuals, early in the career 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. The present project proposes to bridge this gap and develop the infrastructure to offer initial training in modern laboratory techniques in an efficient manner. Materials are available online allowing interested parties from multiple areas across the state to gain access to educational opportunities traditionally offered in locations on one island exclusively. This area of the study has been reported previously in Boulay, Anderson, Parisky and Campbell, 2009 and Parisky, Boulay and Anderson, 2010. This current paper reports on the initial results of this study. Further, these web-based instructional materials aim to be self-paced and offered freely to interested parties. This project provided the crucial infrastructure to disseminate basic molecular biology training to a wide audience, and enrich the pool of biomedical researchers in the State of Hawaii. This study addresses a critical factor limiting interested parties from effectively integrating into laboratories at JABSOM - their limited research experience and previous training. Teachers have had limited exposure to modern research techniques and need direct initiatives to efficiently supplement their previous training. The plan is to provide online access to professionally developed and packaged training materials that will increase knowledge critical to participating in a medical research laboratory.

With the surge of televised programming featuring crime scene investigations or other forensic sciences, interest among teachers and students in 'science' and 'science research' has increased in the United States. In the State of Hawaii, this resulted in a new challenge for its one medical school, the John A. Burns School of Medicine (JABSOM), the home of any research even tangentially related to forensic science training. Medical schools, including their high-end equipment and specialized scientists, are not typically available to school-aged children and their teachers. However, in a state isolated from any other state or country by thousands of miles of ocean, the medical community felt a certain amount of duty to provide a strong educational base for the youth in its community. This was particularly valued as 60% of the local medical practitioners receive their medical training within Hawaii. JABSOM decided to augment the early educational experiences of children as this was hoped to foster interest in medical research and strengthen the qualifications of the pool of future medical practitioners in Hawaii by addressing the knowledge base of those individuals teaching advanced biology. However, major practical questions emerged. What biomedical research techniques do experienced biology teachers commonly know? What do experienced science teachers perceive is useful to support their instruction from online training materials provided on molecular biology?

Literature review

Research shows that training opportunities in the laboratory provide learners with hands on experience and the current resources that allow them to hone their skills as they update their knowledge of the work that is occurring in research labs (National Science Foundation, 2003). Typically there are high school or undergraduate training programs that have been established to work with students. However, there are limited opportunities for teachers to receive the training that their students often go through once they have left the classroom and started working in research laboratories. Providing the same training and instruction that occurs in research labs will help teachers anticipate the needs of their students as they move onto the next stage in their education.

Building upon the well-accepted practice of laboratory internships, a new blended learning approach is proposed, combining 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.

Most applications of the blended learning approach are a combination of traditional instruction, distance learning strategies, and the use of multimedia to support the learner and their needs (Hoic-Bozic, Mornar, & Boticki, 2009). Blended learning, mixing online and face to face learning modes, is being utilized with the expectation that it will assist with transfer of knowledge (Lee, 2010). It is important to consider the use of specific learning objects when planning and designing various blended learning scenarios to ensure connection. 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.

Once learning objects are created and an infrastructure is in place to deliver these objects, there are really no additional costs to share and distribute these commodities. Typically the use of learning objects has been used to support traditional instructional approaches. Blending learning allows developers of distance learning programs to create instruction that is more student centered, as it allows the user to control their own learning experience by adopting the learning style that suits their needs (Ruiz, Mintzer, & Issenberg, 2006). It is important to consider learning objects as instances of learning design when the content is being developed in order to increase the effectiveness of each learning object as it is being reviewed by the user (Boyle, 2010). It is important to consider the structuring of how a concept will be taught with respect to the learning objectives in addition to considering how learning objects will be designed for basic learning activities.

Some of the teachers involved in the study are US National Board Certified science teachers. The National Board for Professional Teaching Standards (NBPTS) is a US-based, independent, non-profit organization with the goal of establishing standards for teaching effectiveness. National Board Certification process is highly extensive and it involves yearlong assessment of actual teaching practice based on rigorous standards established by NBPTS (NBPTS, 2008). National Board Certified (NBC) teachers of science have demonstrated extensive knowledge of the earth, life, and physical science that they teach. They typically show the ability to adapt and improvise instruction by designing lessons that are challenging and engaging (Bond, 2000).

Methodology

This study examines the new 'online instructional modules' developed to augment traditional laboratory internships. Firstly, the participants will be introduced. Secondly, the process for developing the online instructional materials will be discussed, and, thirdly, the research procedures used to pilot these materials, with local science teachers of children aged 14-18 years old, will be explained.

Participants

A group of 20 participants of advanced biology teachers (including 2 NBC teachers) piloted the molecular biology content and learning objects. For the group of participants, teaching experience in the area of biology was approximately thirteen 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.

Content of online training materials

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

Table 1: Molecular biology online training materials

Modules	Topics	Sub-Topics
Introduction to Molecular Biology	a. Laboratory Safety b. Molecular Biology Laboratory Equipment c. Measurements, Solutions, & Calculations d. Content Overview/Review	Objectives Content Animations Activities
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

There are a variety of videos demonstrating laboratory techniques in Molecular Biology located in several topics where the particular techniques are explained in the content area. In addition each module contains video introductions to each topic area. The Introduction module should take approximately 2-3 hours to complete. Each additional module should take approximately 6-9 hours to complete depending on the users' background knowledge in those respective areas.

The content of the instructional modules was assembled through three steps: 1) permission to use materials from a well-developed in-person training at the University of Calgary, 2) links to publicly available, well-known and highly regarded online resources, such as those of Cold Spring Harbor Laboratory or Howard Hughes Medical Institute, and 3) a web design overhaul based on recommendations from reviewers and the addition of video elements.

Step 1
In collaboration with Dr. Hutchins, Director of the Biotechnology Training Centre at the University of Calgary, a well-developed modular curriculum was modified to efficiently address the lack of access to rigorous training available in Hawaii. The Faculty of Medicine at the University of Calgary developed a series of curricular modules to efficiently increase the technical skills and scientific capabilities of its students. Their modules included the following topics: Nucleic acids, Proteins, Web-based Informatics, Cell Culture and Microscopy basics, Genomics/Proteomics, Integrated Cell Biology, and Genetics and Biochemistry. Dr. Hutchins allowed JABSOM to modify the developed curricular materials for Hawaii's target learner cohorts. These modules were repackaged for web-based delivery to better fit the issues of access to training of Hawaii's particular audiences. Figure 1 displays the original layout of the online training modules developed.

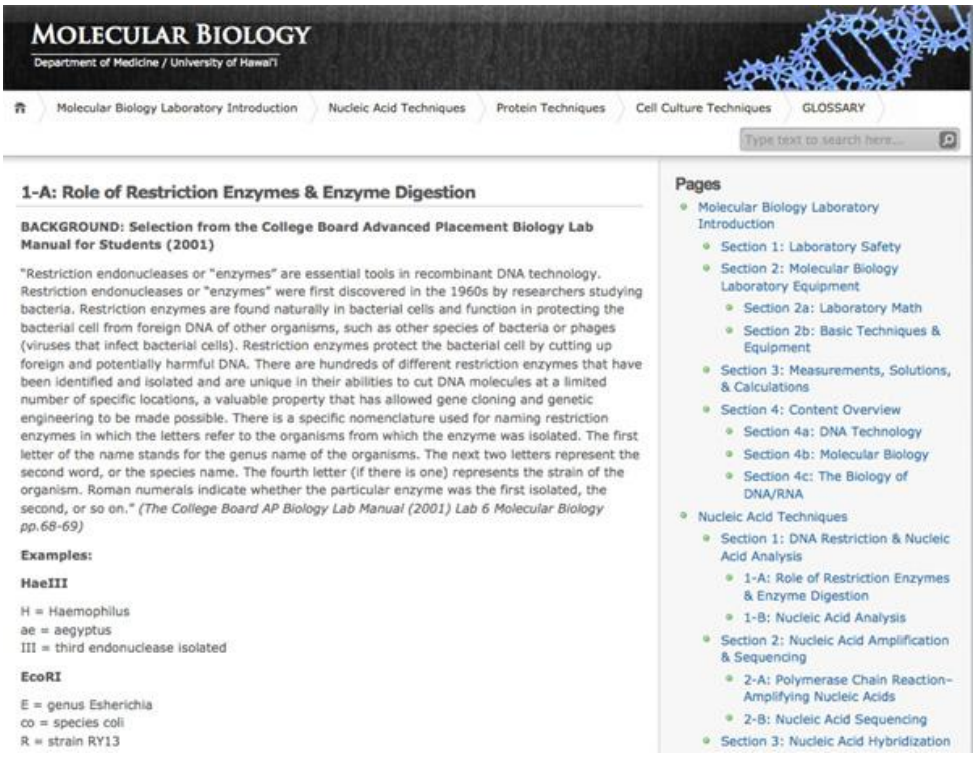

Figure 1: Original design of online training materials

Step 2

The development of the instructional modules incorporated an extensive review of web-based content materials available to the public from various distinguished sources. 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.

Step 3

The website design was completely overhauled by a multimedia specialist whose explicit role was to bring the site up to date with modern web design features (refer to Figure 2). The design change was implemented prior to introduction to the 20 advanced biology teachers. The web design changes were based on recommendations from the two National Board Certified teachers, the content experts, and the multimedia design specialist. The instructional modules were expanded to provide videos of laboratory techniques common to the current research investigations taking place in different JABSOM laboratories. The development and integration of new video segments unique to JABSOM have provided a virtual insight into the laboratory facility and allow for demonstrations of specific techniques utilizing authentic JABSOM research equipment. The video demonstrations have incorporated an important audio and visual component into the instructional modules to enhance the web-based learning environment.

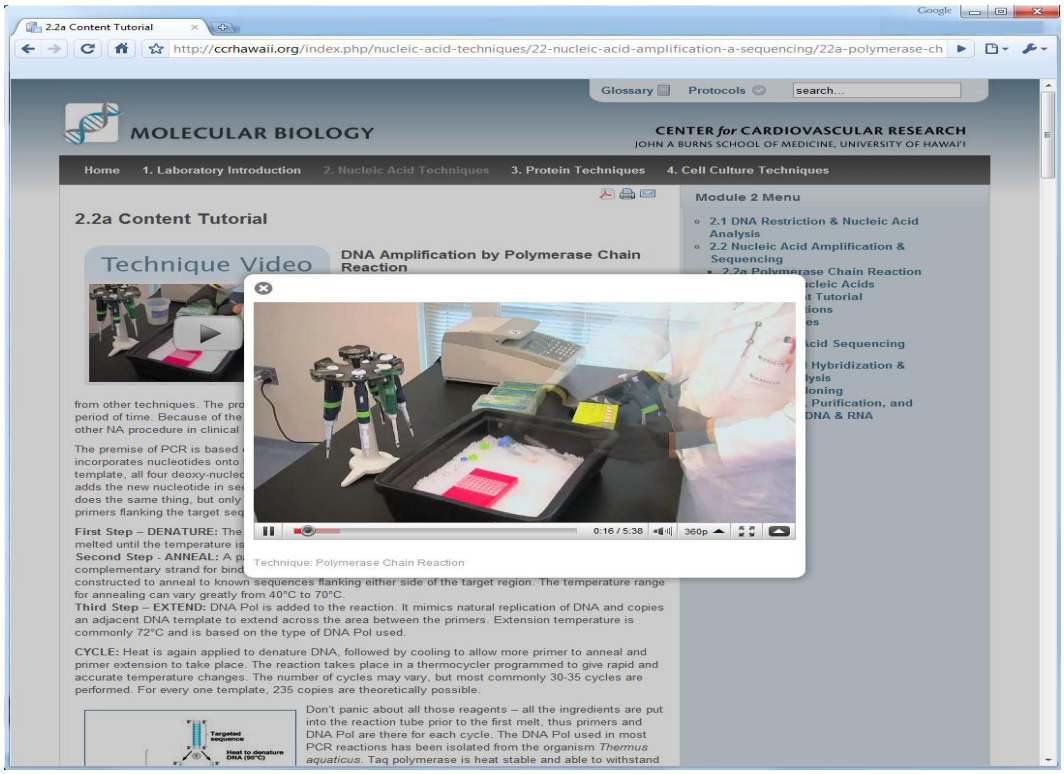

Figure 2: Current design of online training materials (inset is screenshot of a technique video)

This lead to the development of the research questions which were:

- What biomedical research techniques do experienced biology teachers commonly know?
- What do experienced science teachers perceive is useful to support their instruction from online training materials provided on molecular biology?

Procedure

All participants completed a survey prior to the commencement of a training program. The pre-program survey consisted of 18 questions and evaluated the teachers' background experience in Molecular Biology and what their expectations were for the online training materials. Two questions specifically addressed what molecular biology techniques the teachers had performed and taught in their classrooms. Participants were asked to mark those techniques from a list of 16 those techniques they had performed and subsequently in another question those they had taught to their students.
The training program was implemented with a combination of online training materials supplemented by seven in-class laboratory demonstration days, over a period of four months between February and May 2010. The participants were given access to the online training materials once they had completed their pre-program survey and prior to hands-on laboratory training. Therefore, the teachers were given access to the online instructional modules prior to working in an actual laboratory. They began by completing online-guided activities such as those explained above in the content development section. Then the participants performed work in a laboratory that covers the material they have been studying online.

Additionally, data in the form of weblogs (blogs) was collected from the 20 teachers as they created and maintained blogs during their four-month training program. These online archives provide rich insights into the impressions, learning, and feedback of the participants. The teachers were provided with prompts to stimulate their blogging every two weeks. The initial blog prompt asked teachers, "What can you use from the online training to support your instruction?" A variety of responses from this blog prompt have been considered in this paper.

Results

The Molecular Biology materials were first implemented online in the June 2009 and reported previously (see Boulay et al, 2009 and Parisky et al 2010). During its preliminary stages of development, the modules underwent a thorough review process from university faculty, molecular biology researchers, medical doctors, as well as local teachers and two NBC science teachers. The initial results previously gathered through the NBC teachers' personal cases of learning, emphasized the need to provide direct connections between the content and real-life research laboratories at various medical schools around the world. In other words, abstract information, such as that commonly found in textbooks, is now available online, but while this content was rich with engaging animations and interactive tasks in the form of learning objects, the information was still perceived as "abstract." The connection to everyday life or the active research underway was not clear enough. The materials were revised to facilitate these connections within the modules by including specific information on current research projects taking place in the different medical laboratories and providing actual scientists who are studying molecular biology at the medical school. This information was structured to fit the online format by creating instructional videos of technique demonstrations and interviews with researchers in the laboratories in addition to including electronic versions of scientific journal articles published by JABSOM researchers. The JABSOM-focused videos and journal articles are important instructional tools to provide implications for creating an authentic learning experience for Hawaii's secondary level teachers. Furthermore, it is believed 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. JABSOM looks forward to collaboration with fellow institutions in other countries which will enable it to share this resource with individuals who may benefit while providing us with a new partner in our work.

The results below have been reported under the headings of responses to the two research questions.

Research Question 1: What biomedical research techniques do experienced biology teachers commonly know?

The number of experienced biology teachers who stated that they had performed the following research techniques were: pipetting (20), centrifugation (20), DNA Electrophoresis (16), DNA/Plasmid purification (7), DNA ligation (6), Restriction Enzyme Digestion of DNA (10), Protein purification (4), western blotting (4), bacterial transformation (7), polymerase chain reaction (10), using a spectrophotometer (11), immunostaining (3), cell culture (6), tissue sectioning (4), and microscopy (14).

Subsequently, these same teachers were asked how many of the same techniques they have taught their students. Teachers indicated a lack of confidence in teaching certain techniques as one of the main reasons they hadn't attempted sharing those techniques in the classroom. Responses were the following: pipetting (15), centrifugation (8), DNA Electrophoresis (5), DNA/Plasmid purification (2), DNA ligation (0), Restriction Enzyme Digestion of DNA (5), Protein purification (3), western blotting (2), bacterial transformation (5), polymerase chain reaction (2), using a spectrophotometer (3), immunostaining (1), cell culture (1), tissue sectioning (1), and microscopy (8).

The results were varied when it comes to looking how extensive the teachers' experience with regard to previously performing Molecular Biology techniques. Out of the 20 teachers participating in the program, none had performed all of the 16 techniques that the online training materials covered. Only five teachers had performed at least 75% of the techniques before, and 10 teachers were not familiar with a majority of the techniques. The only techniques that were common amongst the participants were knowledge of the use of a pipette and a centrifuge.

Research Question 2: What do experienced science teachers perceive is useful to support their instruction from online training materials provided on molecular biology?

Teachers provided commentary about their use of the online training materials through their online blogs. Some of the responses to the prompt "What can you use from the online training to support your instruction?" include:

> "The virtual labs for DNA extraction, gel electrophoresis and PCR are really good and definitely visual enough even if the student doesn't read everything. These will be incorporated as

independent learning activities."(Participant 4)

"Wonderful labs and lectures!!! We can't wait to start incorporating what we learned." (Participant 5, Additionally three participants had similar statements)

"I think all secondary teachers should go through some type of laboratory experience, whether it be an easy lab course or a more in depth course. Lab courses allow teachers to keep up and fresh with their content. It is also helpful for the teachers to take these courses together with other teachers so they can discuss both what they are going over in the course as well as how they use it in the classroom. The lab courses also allow teachers to see what it is like being the student and give us a better idea about what the students are experiencing during a lab. This experience should make you a better a better teacher." (Participant 17)

"The meet a scientist talk has been interesting because we get to learn what specific research they are actually conducting in their labs."(Participant 9)

"I don't know where I am going with this, except to say that just the exposure to "real science" as it is performed in the lab is of value for the humble, sometimes isolated, high school teacher." (Participant 10)

"Improving secondary science teachers' lab techniques is obviously an important step towards helping students attain higher levels of technical competence. This may also lead to higher levels of learning by increasing the options available to students who attend public institutions." (Participant 13)

"Although so many things so far have been interesting, I think what most interested me was listening to Dr. Ralph Shohet discuss his research. I really enjoyed this because I felt I had enough background knowledge to understand what he was talking about (unlike the prior lecture), but it was a stretch to fully grasp his specifics. It made it exciting to learn something new. I realized that it must be the same feelings for my students. If I can take something complicated that they know pretty well, and build upon it, it makes for a very exciting and challenging learning experience. Interestingly enough, the next chapter I am covering in my A&P class is Cardiovascular. I hope to include some of Dr. Shohet's research information." (Participant 14)

"Now Dr. Shohet's talk about the hypoxia inducible factor (HIF) does have me intrigued and thinking about my physiology class. It really tied in concepts in biology (genetics) and physiology (cardiovascular system), among others." (Participant 1)

"This is a great way for teachers to stay connected to the "real world" and learn about new technologies that are really being used by scientists. It is helping me catch up with cutting edge techniques. It's really hard to know the "latest" in research when we're so caught up in the classroom. I really appreciate the opportunity to stay "current"." (Participant 18)

"I can't say enough about how important it is to have these kind of lab experiences." (Participant 20)

This demonstrates that these laboratory experiences were of benefit for the science teachers. They found them interesting, of value and they allowed for teachers to update the content knowledge they were then using in their high school teaching.

Discussion

When asked the question, "What Molecular Biology techniques should advanced biology teachers know?" this study found that despite a considerable number of years of experience amongst the science teachers, none of the participants were aware of all 16 techniques that JABSOM intended to cover in the online training. These results indicate that most of these highly experienced science teachers, many of whom are involved in a variety of aspects of leadership within the educational community, are not familiar with a majority of the techniques that are crucial to working in a molecular biology laboratory. Those teachers with National Board experience did not score much higher than the rest of the

participants. These results suggest that even the most experienced science teachers are in need of continuing their education with respect to the content they need to teach determined by workforce needs.

When reviewing the comments regarding how teachers view the online training materials, the researchers were pleased to note that all the teachers found this to be a great resource for their instructional needs. Most teachers demonstrated that they were aware how significant this training was with respect to their own teaching practices and how it relates to their students. Predominately commentary in the blogs was positive. It was also very helpful in assisting JABSOM to address the needs of the teachers and will be of benefit for future cohorts of teachers.

This study reinforces Berkes (2007) research that participation in laboratory internships showed an increase in interest amongst participants in continuing their life science/biology graduate school and careers while also increasing the student's biology laboratory self efficacy.

Conclusion

By providing Molecular Biology Laboratory training to teachers it is hoped to augment actual laboratory experiences that its students will be performing. These online training materials were designed to provide teachers with knowledge of the content and laboratory techniques that their students need to learn prior to working in a Molecular Biology laboratory. Advanced biology teachers do need to supplement their own learning experiences in order to provide opportunities for their students to perform foundational laboratory techniques. Drawing from the teachers' commentaries, it seems they are aware of the importance of understanding the field of Molecular Biology and how it relates to their students' needs.

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