REFLECTIONS FROM THE MOVING THE LABORATORY ONLINE WORKSHOPS: EMERGING THEMES

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ABSTRACT

How to move science-based labs online has been one of the main obstacles associated with the development of online science programs. In the spring of 2006 and again in 2007, we organized online workshops broadly based around the central theme of Moving the Lab Online. The objective of these workshops was to provide a forum for the exchange of ideas, thoughts, and experience associated with the challenges of moving science labs into the online environment. Produced by Sloan-C, the first workshop, entitled "Practical Techniques for Utilizing Remote Instrumentation to Enhance Science Education," focused primarily on the technical aspects of using remote instrumentation. The second, entitled "Changing the Laboratory Learning Experience Using the Online Environment," looked at issues associated with teaching online labs using remote instrumentation. A number of similar themes emerged from these workshops. These ranged from a need to better articulate the role of the laboratory experience to questions of whether labs even need to be part of the online science learning experience, to the need for the development of best practices. This paper presents the authors' reflections on the prominent themes and discussions that emerged from the Moving the Lab Online workshop series.

KEYWORDS

Online Laboratories, Remote Instrumentation, Online Learning

I. INTRODUCTION

The Internet and the online environment have already become indispensable tools for practicing scientists, supporting a variety of research and collaborative activities ranging from remote surgeries [1, 2], to planetary and space exploration [3, 4], to real time earth observatories and ocean-floor laboratories [5, 6], to data mining and data sharing [8, 9] and teaching [10, 11, 12, 13, 14, 15, 16]. Science is now routinely conducted in a decentralized environment with collaborating scientists located around the world building virtual communities and sharing resources. A diverse range of online tools such as desktop sharing, video and web conferencing, and course management systems support these activities. Shouldn't the teaching labs of today also embrace these online technologies and practices as the reality of how science is conducted? Shouldn't we incorporate them into the teaching laboratories as essential for the development of science literacy and for educating new scientists? We believe this is true. We also believe in the need to identify and develop these tools for use in both online and face to face teaching and learning environments in a way that ensures that we are not simply replicating the traditional laboratory experience online. Rather, the online environment should be used to create new, more authentic learning

opportunities by exploiting the strengths of the available online tools to create new and more effective learning opportunities in the laboratory-based sciences.

These questions formed the basis of two "Moving the Lab Online" workshops organized by the authors and produced by the Sloan-C in the spring of 2006 and 2007. The objectives of the workshops were to provide a forum for the exchange of ideas, thoughts and experience associated with the challenges of moving science labs into the online environment. Moodle was used as the primary workshop delivery platform administered by Sloan-C with individuals from a number of institutions providing recorded Macromedia Breeze presentations related to their experiences developing and conducting online labs. Additional information, from literature references, to links to web-based resources, to the ability of participants to connect directly to remote instruments, provided additional content to support each of the workshops. Discussion forums and a final live session using Elluminate Live! allowed presenters and participants to more fully develop and extend ideas developed during the workshop. This paper provides the authors reflections on some of the central themes that emerged from the Moving the Lab Online Workshops.

A. Redefining the Teaching Laboratory

Instructional laboratories have historically been accepted as essential for the training and education of scientists and for the promotion of science literacy in general. At most institutions, individual laboratories are typically conducted in three or four hour time blocks one or two days a week. During these laboratory periods, students usually follow scripted procedures to achieve some predetermined experimental outcomes with little or no opportunity to repeat, expand, or modify experiments based on observations or interpretation of experimental data. In fact, laboratory activities are often so tightly controlled that they do not resemble working laboratories at all and often fail to convey the excitement of research and discovery. This is true across the scientific disciplines from Anatomy to Zoology, raising many important questions as to the purpose of teaching laboratories and whether they are, in fact, effectively training and educating students to be scientifically literate let alone practicing scientists. As educational institutions regularly commit significant financial, personnel, space, and other resources to support teaching laboratories, these types of questions are becoming increasingly important, causing some institutions to either reduce or eliminate teaching labs altogether or to explore opportunities, such as the use of online and virtual labs, as alternatives to traditional laboratories. However, as we migrate toward the use and development of these online resources, we need to ask whether the traditional laboratory is the model we want to move online, or should we be looking at the online environment as a new and/or complementary way to improve education and training in the sciences.

What are teaching labs and why have they evolved into the form they generally have today? Look at a typical course catalogue from any university and it quickly becomes apparent that there is no common description or definition of a teaching laboratory that can be adopted universally. There are computer labs, field labs, chemistry labs, engineering labs, marine labs, anatomy labs, and even art and language labs to name just a few, each with their own set of activities and student responsibilities. Laboratory objectives that specifically articulate the knowledge, skills and values to be developed during the laboratory are rare. Common features among labs, however, tend to be the use of a specialized space (usually a bricks and mortar laboratory or room), block timetabling, and the manual manipulations of physical samples. Whether painting a portrait, mixing chemicals, looking through a microscope, dissecting specimens or building a circuit, these manipulations are commonly referred to as "hands-on" activities, the objectives of which, at least superficially, are knowledge application (from associated lectures) and the development of discipline related technical skills. We asked our workshop participants how they would define a lab and why labs so often take this form and found that a universal definition of a teaching lab as well as the rationale for typical laboratory format was elusive. This finding mirrored the

findings of a recent National Research Council's commissioned report, "*America's Lab Report: Investigations in High School Science"* [17]. In the absence of a common definition for a laboratory, the report promotes the concept of the "laboratory experience" as stated below:

> Laboratory experiences provide opportunities for students to interact directly with the material world (or with data drawn from the material world), using the tools, data collection techniques, models and theories of science.

Shifting our thinking away from defining an online laboratory to that of developing an online laboratory experience will allow us to more effectively exploit the online environment for the delivery of laboratory-based sciences. This idea is supported by the report's association of laboratory experiences to include "teaching and learning that may take place in the laboratory room or *in other settings*" that include "interaction with simulations" and "remote access to scientific instruments and observations" [17]. This view represents a significant departure from the traditional belief that science has to be taught as a series of "hands-on" activities conducted in a specialized space within a defined timeframe. In other words, the laboratory experience can and should occur, using the central mantra of the online community, anytime/anyplace. What does this say about moving laboratories online? Perhaps the most important concept that we should focus on is using the online environment to provide a significant *laboratory experience* rather than trying to replicate the traditional face-to-face laboratory. This, in fact, was one of the central themes to emerge from the Moving the Labs online workshops and one that we are currently striving to develop as part of the Integrated Laboratory Network (ILN) Project. Discussion forums related to this topic can be found at the ILN project Moodle site available online [18].

B. The Need for an Online Consortium and the Associated Development of Best Practices

Although a variety of institutions and groups across multiple disciplines have approached the development of online science labs, most of these activities have occurred in isolation [11, 12, 13, 14, 15, 16]. Currently there is no consortium, such as Sloan-C, to serve as a centralized organization to nurture the idea and to gather and provide easy access to information, resources and networking opportunities associated with the development of online labs. Interestingly, during the workshops frequently asked questions typically began with "How do I…?" or "Where can I…?" These questions sought examples of conducting online labs within specific disciplines. The lack of a central repository of information represents a significant hurdle to actually moving labs online and leads directly into the next theme to develop from the workshop; that is, what are the best practices associated with moving and delivering laboratories online?

The lack of defined best practices and clear examples associated with the design, development, and delivery of online labs makes moving labs online extremely challenging. Those currently involved in the field are charting new territory and, by default, are establishing the best practices. This is both good and bad. For one, it is intellectually very interesting to work on the challenges of moving labs online: the research generated from this work will make an important contribution to the emerging scholarship of teaching and learning science online. On the other hand, early adopters are at a critical development stage in the evolution of moving labs online. That is, efforts to move labs online that produce poor outcomes (student dissatisfaction, poor quality of program delivery, poor quality materials, and poor overall student experience) have a significant potential to negatively impact the acceptance of online labs. Our failures could surely hurt us more than our achievements will help us as we strive to gain acceptance of online labs as a legitimate avenue for the delivery of science education. To this end, it is essential for those involved in the development of online labs and programs to actively work within their professional

societies to promote the acceptance of online labs. This includes, among other things, disseminating the research findings at meetings, organizing symposia, collecting assessment data, and publishing. Ultimately however, a consortium needs to develop that will serve to bring individuals and institutions from a variety of disciplines together in a learning community to develop and share best practices. This may ultimately be done under the umbrella of an established group such as Sloan-C. Alternatively, it may have to come about independently as a critical mass of practitioners active in the development of online labs develops through projects like the ILN [11], iLabs [12] or CASPIE [13] programs. In any case, a consortium that develops and promotes best practices will be an important resource for institutions and individuals interested in moving labs online.

C. Addressing the "Hands-On Issue

One of the arguments heard most often against moving labs online has been the need for "hands-on" activities as part of the student's laboratory learning experience. Indeed, we believe that the argument for the need of a hands-on experience is directly related to two sets of skills commonly associated with the scientific process. These are the ability to observe and the ability to manipulate. Observations of sights, sounds, smells, and touch provide important clues about natural systems, while the ability to manipulate things that are observed allows scientists to test hypotheses and draw conclusions. Can these skills be taught online? Certainly, online technology will continue to improve and may facilitate these processes in the future. Emerging technologies providing online tactile feedback, audio/video and robotic technologies, and even digital scent technologies may provide students with new opportunities for developing these hands-on skills. However, although clearly on the horizon, the real impact of these technologies remains some years away.

In the meantime, how do we address the hands-on argument with the online technologies of today? First, we must understand a disconnection between the *intent* and the *reality* of providing students "hands-on" experience in the traditional teaching lab. The *intent* is that students have an authentic laboratory experience that leads to a deeper understanding of natural systems by allowing them to observe and manipulate objects in the material world. The *reality* is that time limitations associated with most labs generally mean that hands-on activities tend to be limited and are used primarily to train students in the technical skills used by practicing scientists. As mentioned earlier, at most institutions today, the commitment to the hands-on laboratory experience is embodied in prescribed procedures, predetermined experimental outcomes and strict timelines. This format does not resemble an authentic laboratory experience and undoubtedly evolved, in part, if not primarily, to time management concerns and class size. Given the fact that a limited number of lab hours are available, science programs have doled out the time in a way that at least provides all students with a higher education version of an authentic laboratory experience. Students may work in large groups that prevent many of them from using, or even putting much thought into the use of laboratory equipment and procedures. They may not have to think about their observations or even the reason for their lab experiments or to wonder what they would do next based on their observations. This form of hands-on laboratory experiences has been deemed more valuable than having no hands-on experience, even if this experience is far removed from the experience in actual laboratories. Is this approach a good use of time and resources?

This being said, perhaps we need to rethink the role of the teaching lab. If we look at the mechanics of delivering laboratories to large numbers of students, it is clear that the time that students spend in the labs should be used wisely. Unfortunately, existing bottlenecks slow the movement of students through a typical lab and therefore limit the opportunities to use the available laboratory time more effectively. For example, access to specific resources, such as instrumentation, is one such bottleneck. Instruments can often only analyze one sample at a time and some of these analyses can take minutes to hours to conduct. Further, access to these instruments is generally only available during the specific class time. Because the

use of instrumentation is often one of the essential hands-on activities in a lab, movement in the labs tend to be slowed until every student, or more realistically, group of students, has had a chance to use the instrument to analyze a sample.

This is one example of a bottleneck that the online environment can remove, thereby radically changing the way we conduct labs. When instruments, virtual simulations, and associated training and lecture materials can be remotely accessed twenty-four hours a day for the analysis of samples, the instrument access bottleneck is removed from the lab. Of course this means redefining the hands-on experience as one that includes the use of remote instrumentation and virtual simulations. This also means that more time is available to develop realistic experiences within the face-to-face lab, such as conducting real research, field studies, or engaging in higher-level experimental design. Well designed remote labs have the potential to significantly enhance learning outcomes across multiple disciplines and could do so 24/7, opening the door for a wide variety of new learning opportunities and collaborations.

D. Rethinking the Laboratory Experience: Blended and Alternative Laboratory Delivery Mechanisms

1. The Blended Lab

Perhaps the greatest impact the online environment will have relative to moving labs online will be for the development of blended laboratory activities. For example, a major difficulty to teaching labs, and in fact a major criticism of labs in general, has been a disconnection between lecture and laboratory activities. Often, due to large class size and limited lab resources, lectures and laboratories are out of sync, requiring students to cycle through different laboratory activities in groups with no effective background preparation. As a result, labs become an exercise in following instructions rather than a mechanism for providing new experiences or building upon previous practice. The online environment could be an ideal method for bridging the gap between lecture and laboratory. Resources related to the labs, including laboratory simulations and training materials, can easily be compiled and presented within the online format. Forums can be established that allow groups to share data as well as laboratory experiences. For example, posting problems that may arise while conducting labs for others to avoid or allowing groups of students to compare and comment on results would support student learning needs and build community in the classroom. In theory, the online environment will allow interactions between different sections of the same course as well between different courses. Many times, the same instruments and similar procedures are used in multiple courses. By providing online access to training materials as well as to the instruments themselves, instrument use can be reinforced both vertically and horizontally throughout the curriculum.

2. The Power Lab

An alternative to the traditional lecture/laboratory course would be the Power Lab. In this scenario, the lecture materials for a course, such as general chemistry, could be presented entirely online, with a face to face laboratory offered asynchronously for short, intense periods. For example, labs could be offered for a week during spring break, intersession, or summer session rather than in three hour blocks. Full-day labs for a one week session would easily cover the typical 30 laboratory contact hours available in a 10-week face to face general chemistry course. If the online course included extensive materials covering laboratory techniques as well as orientation and training sessions with remote instrumentation, students would come to labs better prepared to conduct specific laboratory activities. This could be accommodated with the use of case studies designed to help students to understand and operate the required laboratory instrumentation. Successful completion of the case studies would prepare students to use instruments during the Power Lab. An additional advantage to Power Labs would be the possibility of combining

laboratory activities to focus on a specific question rather than as a series of discreet and unrelated exercises typical of a once a week three hour lab. At many universities, teaching labs are not as heavily used during the summer months. In addition, many universities provide dormitory rooms and meal plans for short stays during the summer in support of camps and other activities. The availability of lab space and inexpensive housing would make many universities ideal locations for the delivery of Power Labs.

3. Online Science and Instrumentation Centers

One way to facilitate moving labs online will be through the development of regional centers that provide an online laboratory experience. These centers would most likely be located at an established college or university and would provide online and face to face laboratory experiences. The centers would specialize in the creation of online labs, virtual simulations and development of supporting curricular materials. They would also provide remote access to instrumentation and would be capable of delivering Power Labs. Online labs developed by the centers could be used by institutions providing online degree programs in the sciences. In this way, distance education programs could focus on the online course content which would then be supplemented with online or Power Labs developed by the centers. Each distance education program could then decide the laboratory experience, either online or through Power Labs, that would be required for their students. These centers could be supported, in part, through the use of lab fees charged as part of the course.

II. DISCUSSION

The online environment is just now starting to make an impact on the traditional laboratory-based sciences. Discussions from the Moving the Laboratory Online workshops have shown a significant interest in online labs across many disciplines. They have also shown that a community of interest and practice is beginning to form and gain experience in developing and delivering online laboratories. Experience has shown that moving labs online is indeed possible and effective; however, doing so comes with the cost of rethinking the role of labs within the curriculum. The online environment cannot and should not be used to try and replicate the traditional face to face laboratory. Instead, the development of online labs should focus on defining and developing the laboratory experience to provide the knowledge, skills and values necessary for students to become scientifically literate and technically competent individuals.

Online labs will continue to gain acceptance as legitimate alternatives to the face to face laboratory experience. As online resources continue to be developed, the quality, quantity, and diversity of online lab offerings will also expand. In addition, blended labs will continue to evolve and will incorporate many of the tools available within the online teaching community.

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