Expanding Access to Science Field-Based Research Techniques for Online Students through OER

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ABSTRACT

Adoption of Open Educational Resources (OERs) by the science, technology, engineering and mathematics (STEM) community has yet to become an integral part of higher education classrooms. Many STEM faculty have been reluctant to develop and use OERs because the process of developing these resources is time-consuming and finding appropriate resources for higher education remains overwhelming. The team, Matias, Woo and Whitley-Grassi at State University of New York (SUNY) developed a process to help generate OERs for topics that are generally associated with laboratory equipment or field research techniques in ecology and earth sciences, as well as general science. This project draws on the need to develop resources and expand access to scientific field-based research techniques through OERs for students learning at a distance. Engaging in undergraduate scientific virtual field experiences is an educational opportunity for students with a desire for an enriched learning experience in the sciences, particularly in ecology and earth sciences, but that cannot participate in a traditional field-based curriculum. This article discusses the current status of the use of OERs for STEM education and our approach to developing three OERs in the areas of microscopy, geologic history interpretation and biodiversity. The team concludes by sharing some of the challenges and lessons learned in the process.

Keywords: open educational resources, science, technology, engineering and mathematics (STEM), microscopy field-based curriculum, virtual field experience

Introduction

Research shows that incorporating hands-on, field experiences with lectures has the potential to create a problem-based learning environment that engages learners in authentic scientific inquiry (Orion, 1993; Simmons, Knight, and Lopez, 2008). However, due to the distributed environment and online-enriched educational model that many institutions are now facing, opportunities for students to engage in scientific field experiences are often minimal in the curriculum. Engaging in undergraduate scientific virtual field experiences is an educational opportunity for students with a desire for an enriched learning experience in the sciences, particularly in ecology and earth sciences, but who cannot participate in a traditional field-based curriculum.

The team firmly believe that motivated students in science, technology, engineering, and mathematics (STEM) concentrations with demanding schedules or other barriers to access should have the opportunity to learn about scientific field research while they acquire professional development. Thus, they developed three OERs and a process to help generate skills and knowledge for topics generally associated with laboratory equipment or field techniques. Phase 1 of the project included OERs that aim to teach students about: the basic functionality of microscopes (Introduction to Microscopy); the geologic history interpretation of rocks exposed at the surface (Geologic Outcrop Analysis and Relative Dating of Rocks); and the identification of invertebrates (Biodiversity Sampling of Invertebrates). The project draws on the need to develop resources and expand access to scientific field-based research techniques for students learning at a distance or with other barriers to access.

The value of this project lies in increasing access and portability to scientific techniques while supporting an instructional model that allows for further refinement, development, growth, and use across and beyond the institution. In this article, the team discusses the current status of the use of OERs for STEM education and our approach to developing OERs as well as the challenges and lessons learned in the process.

Status of OERs in STEM

The concept of OERs is nothing new to the science, technology, engineering and mathematics (STEM) community. If you have searched for educational resources online, you have probably noticed that there is no shortage of STEM resources for teaching. Major government-funded institutions in the US such as the National Aeronautics and Space Agency (NASA), for instance, provide powerful free to use teaching tools. Additionally, as recent research has demonstrated, the OER movement continues to gain traction across campuses globally (Johnson, Adams Becker, Estrada, and Freeman, 2015). Why, then, do educators at colleges and universities not embrace the plethora of open digital educational libraries and repositories in STEM?

Unfortunately, the vast majority of openly available resources are targeted towards primary and secondary education rather than higher education. In recent years, more and more professional associations and institutions have embraced the OER movement by encouraging faculty and researchers to share educational materials (e.g. lesson plans) openly on their sites. Table 1 shows some examples of sites that adhere to the openly available principle of OER access for STEM subject areas as well as sites that serve as search engines to a wide range of resources.

Perhaps, one of the most important issues affecting the creation and adoption of STEM OERs is the culture of STEM education itself. Departmental and institutional cultures often do not adequately value, support and reward effective pedagogy. Teaching excellence is rarely a deciding factor for tenure in many STEM departments, particularly at research-oriented institutions. Consequently, many STEM faculty are left with the decision to prioritize scholarship over teaching effectiveness. Furthermore, even when educators know about the existence of OERs, most of the repertoires remain disconnected from each other and one must invest a lot of time and energy searching for materials adequate for the different subjects and academic levels. STEM educators are not the only ones suffering from this difficulty. In 2014, an in-depth exploration of OERs in higher education by the Babson Research Group revealed that half of the over 2,000 member strong faculty surveyed were deterred from using OERs due to the lack of a comprehensive catalog of materials (Allen and Seaman, 2014). According to their report, faculty perception of the time and effort required to find and evaluate OERs remains a significant barrier to their adoption.

Table 1. Examples of repertoires specifically for STEM OERs (higher education included) and websites that search across platforms.

	STEM Area	**URL**
American Association for	Physics and astronomy	www.compadre.org

Physics Teachers (AAPT) comPADRE Network		
Digital Library for Earth System Education (DLESE)	Earth science, geology and environmental science	www.dlese.org
Chemical Education Digital Library (ChemEd DL)	Chemistry	www.chemeddl.org
Applied Math and Science Education Repository (AMSER)	Wide range of STEM fields, built specifically for use by those in community and technical colleges	amser.org
Science Education Research Center (SERC) of Carleton College	Geosciences	serc.carleton.edu
The National Science Digital Library (NSDL)	All STEM fields, both formal and informal educational resources	nsdl.oercommons.org
OER Commons	Wide range of areas including science and mathematics	www.oercommons.org
Multimedia Educational Resource for Learning and Online Teaching (MERLOT)	Wide range of areas including STEM	www.merlot.org
TEMOA	Wide range of resources, including for STEM fields compiled by the Tecnológio de Monterrey, Mexico.	www.temoa.info
European Union Open Science Research Project	Wide range of STEM areas.	www.opensciencerresources.eu

Another important issue is the lack of standards and quality control between repertories. A standard categorization or curating method might help faculty, especially faculty in STEM fields, in their adoption of OERs. Porcello and Hsi (2013) discuss the use of crowdsourcing as an option to improve the quality of STEM OERs. They present four components essential to the success of OERs, emphasizing application to STEM: 1) convergence toward common metadata; 2) balancing expert and community definitions of quality; 3) community input; and 4) interoperability. Efforts by programs like the Multimedia Educational Resource for Learning and Online Teaching (MERLOT) of the California State University System (US), where communities engage in building OERs based on evaluation standards, leverage the STEM OER community to develop quality content that is easy to use and have the potential to be effective teaching tools.

The Approach

The development of OERs is growing in popularity as more faculty and administrators realize the collective power they can attain by sharing resources in higher education (Cannell, Macintyre, and Hewitt, 2015; Clements, Pawloeski, and Manouselis, 2015; Johnson et al., 2015; Porcelle and Hsi, 2013). But the process of developing these resources can be time-consuming and often requires the use of additional assets. Thus, many faculty continue to be reluctant to develop OERs. This is particularly noticeable in STEM areas where fieldwork is essential for learners' training, such as ecology and geology, where most of the available OERs are for pre-college education or do not have the rigor expected by many higher education instructors. For instance, the field setting provides the ability to see the interconnections among different components of the Earth system. In nature, students have the opportunity to learn from nature and about science. This important learning experience is difficult to replicate in the online environment, hence the learning environment could be enhanced with field-based OERs. Based on the necessity to infuse their online and blended courses with hands-on field experience, a process was developed to help generate stand-alone OERs for topics that are generally associated with laboratory equipment or field techniques in the areas of ecology and earth sciences, as well as general science. Drawing on that process, a series of OERs were designed.

The Project

The OER project builds on a blended summer course with a three-day face-to-face meeting at the State University of New York (SUNY) Oneonta's Biological Field Station and Upland Interpretive Center in Cooperstown, New York. This unique project leverages resources utilized during the summer course to create a series of OERs. For example, both facilities visited during the face-to-face component are adjacent to Ostego Lake, which provided us with the opportunity to showcase general ecology, earth science, and scientific inquiry activities. Dynamic OERs were developed based on field experiences at these facilities incorporating scientific equipment as well as mobile devices, which could be adapted for a broad audience and/or science subject.

The goal of the project is to provide students with the research skills they need to increase their competency in scientific research after graduation by engaging them in common field-based research techniques and methods for data collection and analysis through a series of interactive online activities. Field-based learning helps students strengthen their ability to reason spatially, to integrate information and to critique the quality of data. Educators can help students make these connections by fostering pathways from observation to interpretation. Through the application of current technological tools, SUNY engaged in an innovative approach to STEM learning and the application of the scientific method by developing OERs on: Introduction to Microscopy (basic principles of using a microscope), Geologic Outcrop Analysis and Relative Dating of Rocks (geologic history interpretation of rocks exposed at the surface) and Biodiversity Sampling of Invertebrates (identification of invertebrates). With the creation of these OER, SUNY would like to engage students virtually in activities that typically involve a field trip.

The Process

The process of developing the OER fell to two people, the "Content Developer" and the "Instructional Designer" (Figure 1). Each of these individuals worked both collaboratively and independently. Figure 1 shows both roles and their respective tasks during the development process. The two primary responsibilities of the content developer were to envision the incorporation of the field- or laboratory-based experience within the OER and to provide the subject matter content. The instructional designer's main responsibilities included creating the digital objects and keeping the project moving. As such, the team worked actively together at the beginning and end of the process (tasks shown as dark grey in Figure 1), and independently during the rest of the development period (tasks shown as light grey in Figure 1).

Zoom in Original (jpeg, 142k)
Figure 1. Visual of roles in the OER design process. The content developer and instructional designer worked collaboratively during tasks shown in dark grey, and independently (but simultaneously) during tasks shown in light grey.

The collaboration with the instructional designer at the beginning enabled the content developer to better frame the OER in what could and should be done technically and pedagogically. Selecting the appropriate approach to convey the subject matter and to provide experiential learning that normally occurs outdoors proved to be an overwhelming task in both scope and complexity. Thus, progress was often halted by the amount of time required from the content developer and the unrealistic expectations of the available resources. During the initial stages, the instructional designer also completed a content inventory on the particular subject of the OER. The content inventory included a list of all materials needed in order to create the OER as envisioned by the developer, such as multimedia elements, images, video clips, and written content.

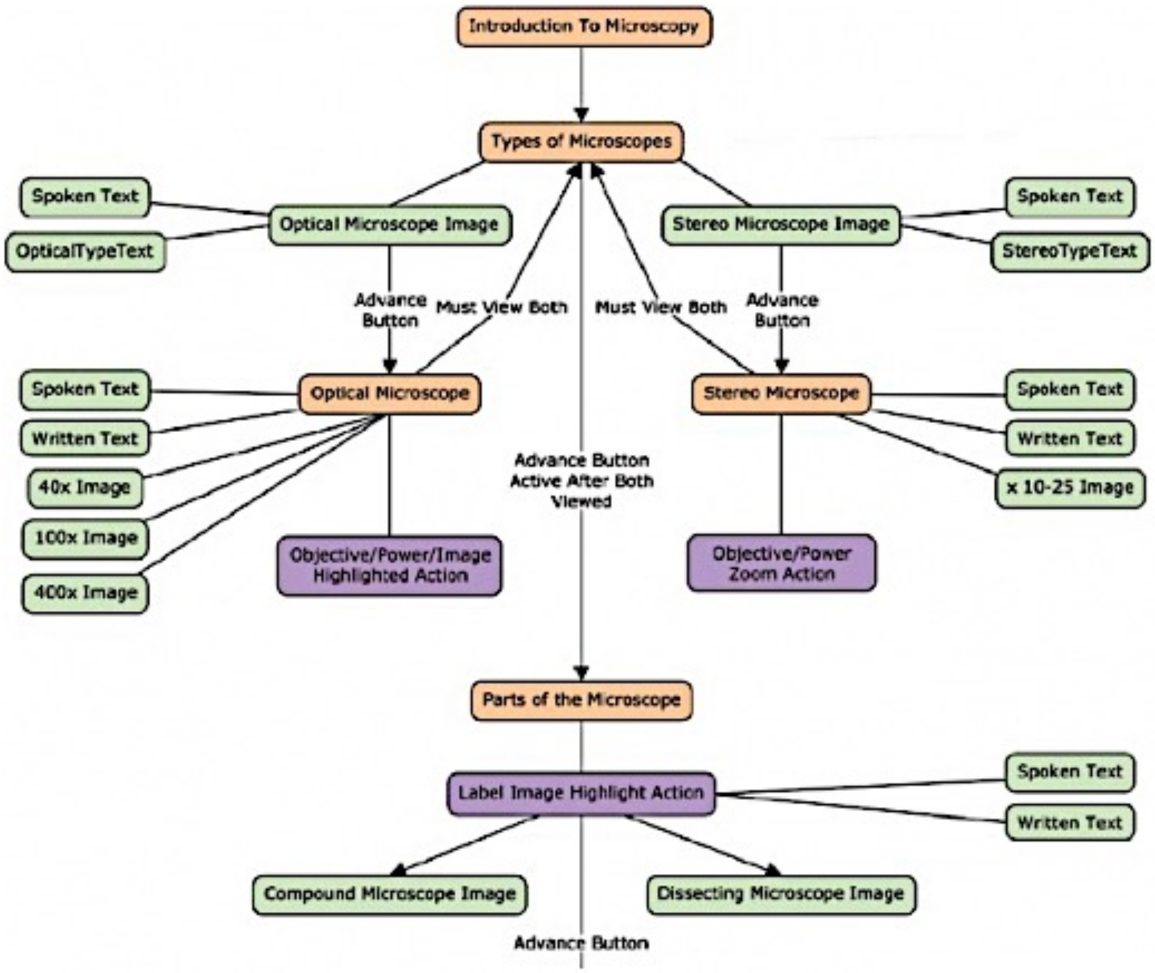
The process thus came to evolve into a parallel but extensive consultative process from the curriculum developer with an instructional designer used to frame the goals and outcomes of the specific OER. This was done through the use of a lesson plan template that was developed (see Figure 2). The template allows the content developer to conceptualize the learning objectives, identify the necessary resources, background information and the learning that should happen for the learner to meet the objectives. At the same time, the instructional designer collected the necessary resources to achieve the objectives and decided on different interactive approaches to present the content. For example, the microscopy OER uses a simple approach using pop-ups to show the basic functionality of the microscope. On the other hand, the Geologic Outcrop OER utilizes videos and animations to convey how geologists interpret rock formations in the field.

Time Frame:	Description of Activity:
Levels 100/200/300/400:	
Learning Objectives (3-5 objectives):	
Required Background Information:	
Materials Needed (including equipment to be purchased):	
Procedure / Flow of Lesson:	
Assessment Plans and Documents: (Attach: e.g. tests, checklists, observation protocols, and rubrics)	
Context for Content:	
Resources to be Developed:	
Representative Courses:	

Zoom in Original (jpeg, 283k)

Figure 2. Template form used by content developers to provide the pedagogical goals of the OER to the instructional designer.

An important aspect of utilizing the OER pre-development form (Figure 2) is that it focuses on the pedagogical aspects rather than the technology. It was imperative to have clear learning objectives and outcomes before developing any content and/or pieces of the OER. After the lesson plan was completed and resources (e.g. photographs and/or videos in the field) collected, the developer focused on the production of content materials and the instructional designer began to map the content for the OER. The usefulness of concept maps was quickly learned when mapping the different content aspects of the OER. Figure 3 shows an example of the organizational concept map for the Microscopy OER. In this example, two main types of microscopes and their components are presented in the OER through the use of images, text, and audio.



Zoom in Original (jpeg, 431k)

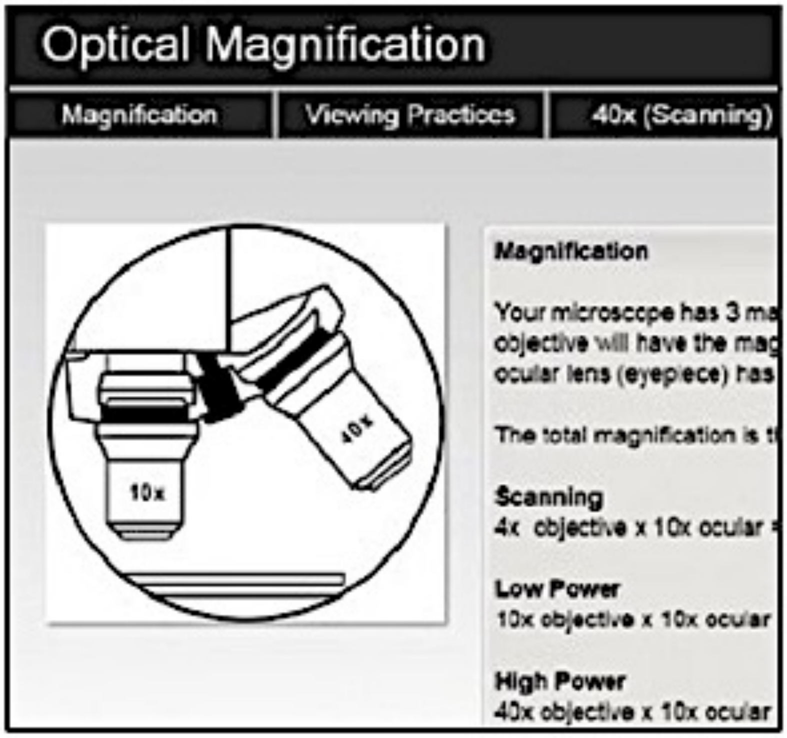
Figure 3. Example of a concept map drawn by the instructional designer based on the consultation with the content developer previous to the development of the storyboard.

The next step in the process involved the use of a storyboard approach by the instructional designer to create a mock-up of the components of OER. The storyboard document specified the visual elements, text elements, audio elements, interactions and branching of every screen in the OER. After both team members agree on the design presented in the storyboard, the content developer role is to provide with the content material for the demonstration and/or activity that meet the objectives originally proposed. Probably the most time consuming and arguably difficult part of the process was the content development. It was essential to share tasks in order to create content in a timely manner. Photographs and videos were taken in the field in parallel to the content development.

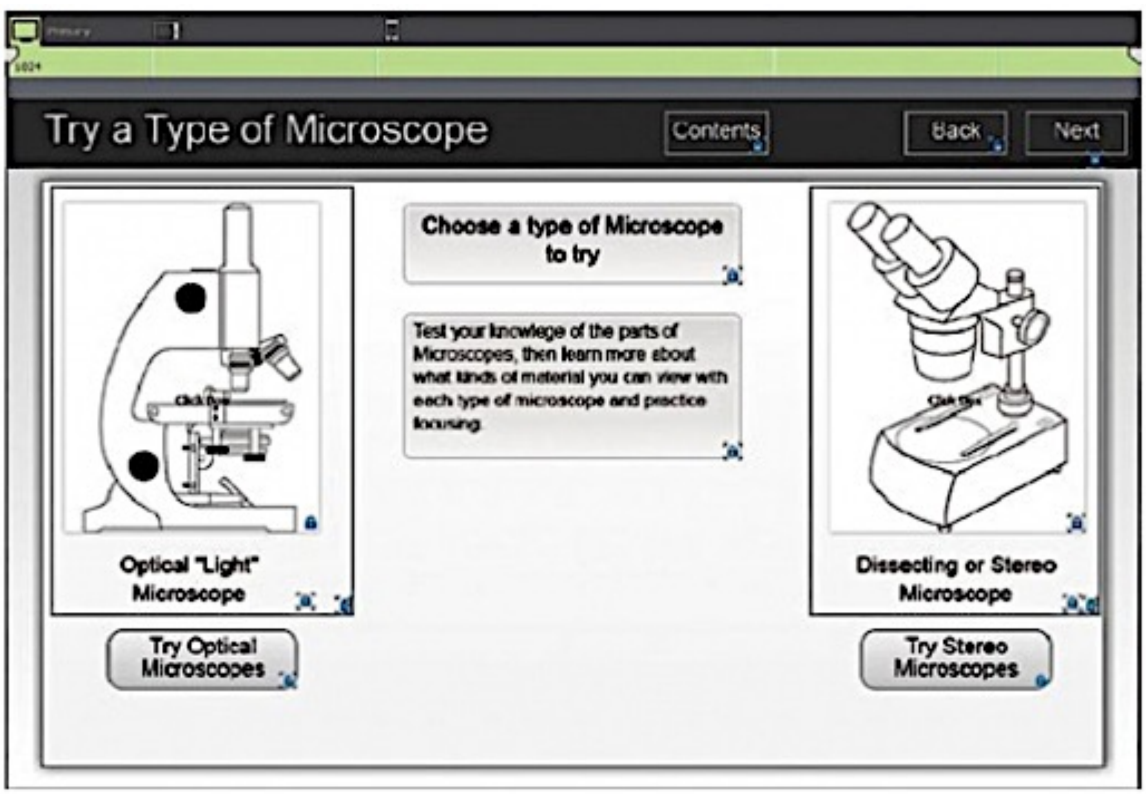
As the pieces of content came together, the instructional designer developed a mock-up or sample of all of the parts of the OER (see Figure 4). The storyboard and eLearning content for the OERs was created in HTML 5 using the authoring tool Adobe Captivate ®. This tool creates interactivity that is accessible through multiple devices (e.g. computer and mobile). An important advantage to using this particular tool over others currently available (e.g. Articulate Storyline) is the ability to move seamlessly from the storyboarding step into a mock-up and final learning object. After the team reviewed each mock-up, revisions and corrections to the design and layout were made. For instance, the mock-up for the Geologic Outcrop Analysis and Relative Dating of Rocks OER revealed the need for more contextual information for the activity where students are asked to identify rocks for a specific section from a photograph. Completing the lesson plan document (Figure 2) at the beginning of the development process was of great help when trying to figure out what was missing from the activity. Hence, the team was able to isolate the skills needed to simulate the field experience virtually into the OER Inevitable, sometimes drastic changes were needed based on input from one or both the instructional designer and curriculum developer.

The process did not end with the final production of the interactive learning object. Each final object was checked for Americans with Disabilities Act (ADA) compliance and attributions using the Creative Commons added. In the United States of America, and as a public institution of the New York State, SUNY is required to adhere to the Federal Section 508 Accessibility Program (http://section508/ gov). In order to ensure that OERs were in compliance during development, the team followed the guidelines provided by the US Board Standard for Electronic and Information Technology (EIT). The team particularly focused on providing the following: textual alternatives to non-text context such as photographs; appropriate document structure, such as headings, to allow for clear meaning and facilitate navigation; and, captions and/or transcripts for videos and narrations (see Figure 5). Additionally, OERs were created using HTML 5 output as opposed to Flash to allow for access through multiple platforms, including mobile devices.

In the end, SUNY aims to create OERs that are both technologically functional and pedagogically sound to meet the needs of their learners. In the near future, SUNY would like to expand the process to also include the revision and redesign of the OERs based on feedback from students. The OERs developed during the first phase of this project will be shared with the community through the Multimedia Educational Resource for Learning and Online Teaching (MERLOT) and any appropriate OER repository.



Zoom in Original (jpeg, 69k)
Figure 4. Screenshot of a storyboard slide used in the Introduction to Microscopy OER



Zoom in Original (jpeg, 104k)

Figure 5. Screenshot of part of the Introduction to Microscopy OER showing the ADA compliant, high contrast responsive design approach used in this project. The storyboard and eLearning content for the OERs were created in HTML 5 using the authoring tool Adobe Captivate ®

Challenges and Lessons Learned

In the long-term, OERs will likely experience the same kinds of challenges that many virtual learning environments may encounter, such as the sustainability of the project (e.g., typically through funding availability or maintenance of material and interface), evaluation and feedback, computing infrastructure, and inequity of access to the materials depending on country or socioeconomic status (Atkins et al., 2007). It seems clear that sustainability is likely the most salient issue, as it encompasses the interaction of all large-scale challenges that enable the success, failure, or longevity of Open Educational Resources, such as the virtual (e.g., software, computer-based platforms, advancement in disciplines) to the realistic (e.g., funding, staffing, maintenance, evolution of technology) (Downes, 2007). The authors realize that the sustainability of the OERs, and those they wish to create in the near future, may inherently confront the same challenges, therefore steps need to be taken to meet the individual obstacles as they surface. Some longitudinal challenges may be difficult to proximally identify. However, in the short-term, there were some clear challenges that were considered necessary to address before producing the OERs.

In building their OERs, one of the major decisions that they needed to make was to choose a specific software program in which to design their virtual content. The decision was particularly difficult as they needed to identify a platform on which it was easy to design, edit, and modify their content. Moreover, each finished project needed to be universal to all popular operating systems, and had to include the ability to function on all popular web browsers with appropriate plug-ins.

The failure of many virtual laboratories, OERs, or online supplementary materials is the inability to work on cross-platforms, and therefore selectively biases the students who may have access to the formatted software, operating system, or browser and plug-ins. The incorporation of these software and programming layers increases the complexity of the design and therefore decreases the ability for their OERs to operate on more universal or cross-platform systems. Indeed, if the OERs were inaccessible to the target population of traditional students, and as in the case with their students at SUNY Empire State College who were non-traditional, then it clearly created an additional bias for populations that were already challenged by the norms of accessible technology.

Another major challenge that was faced was to create OERs that were truly accessible for all kinds of disabilities. The OERs were designed on visual platforms with images, videos, text, and voiceovers to accommodate individuals with disabilities that made hearing and seeing difficult. However, the challenges also extended beyond sight and sound and may include the inability to manually move through each exercise because of the inability to use hands or fingers. These challenges meant that there was a need to create a version of each OER that accommodated all possible likely disabilities or create multiple versions of their virtual learning environments in which students could select the best mode of delivery.

Furthermore, consideration of the implementation of various types of assistive technology that may enable students to access material more efficiently was taken into account. For their field component, the use of more sophisticated technology, such as tablets and handheld GPS units, which were visual, but were specifically operated by touch were employed. It is likely that other kinds of assistive technology, such as text-to-speech, speech recognition software, augmentative communications software, mobility or positioning equipment, instructional formats created in different modes, or various input/output devices will also need to be considered. Clearly, the available options for assistive technology are extensive, and these options should be considered for individual student needs upon course enrollment.

Finally, in terms of resources and the field-based aspect of the OERs, finding time to engage in the necessary field activities and weather conditions certainly prove to be a limiting factor. Without a clear commitment to the collaboration from the institutions, faculty acting as content developers and instructional designers may find it hard to dedicate the required amount of time.

Future Work and Final Remarks

The rationale and process for designing OERs create an innovative tool for more readily open access to an otherwise underutilized aspect of sciences. Laboratory studies are often assumed as exclusively physical and hands-on, yet this bias clearly limits access to various students, particularly those who exemplify underserved or underrepresented populations. Thus, their OERs will allow all students to experience virtually common field techniques in ecology and earth systems without undermining the integrity of the disciplines.

In the near future, SUNY would like to extend their current work to include other common field techniques, such as mapping using Global Positioning System (GPS). As methods may adopt the use of more technology, it also seems practical to include the use of emerging technologies in their virtual content. Consequently, there is the need to continue to update and improve upon current versions of OERs to include the latest advances in methodology, technique, and technology. In addition to the three virtual field experiences created during the first phase of their project, the intent is to create OERs in areas such as: species identification (e.g. invertebrates and flora), mapping of species using a GPS (e.g. invasive species), and animal behavior.

Clearly, there are other kinds of experimental field techniques that could also be incorporated into virtual exercises. However, the intent is to continue to create easily replicable methods that can be adapted to a variety of science and non-science areas. For instance, the use of GPS technology for mapping enables real-time data collection applicable to geosciences, agriculture, conservation biology, social sciences, business, and emergency management.

The creation of OERs also extends beyond mere implementation. SUNY hopes that the models serve as an initial blueprint in which others can base their OERs in terms of the platform, software, content, and organization. Ideally, the OERs can be utilized to suit the likely needs of individual educators and their targets population of students regardless of their subject matter area. The flexibility in the design is a critical feature of OERs, such that it can serve multiple applications and that it may enable others to use the programming framework and only need to modify the content.

Furthermore, the model can be expanded beyond the focus of ecology and earth systems. There is no limitation on content, and hence, those wishing to modify the content adaptors may wish to utilize the OERs in other STEM areas (e.g. Introduction to Microscopy could also be used in genetics or cell biology courses) or to replicate the approach in other disciplines within the within the physical sciences of chemistry and physics. Moreover, examining STEM across the curriculum to identify courses that may benefit from the addition of OERs, either to supplement current physical or virtual components or to increase the level of accessibility for students with disabilities. Additionally, other non-STEM areas, such as the humanities and the arts, may also be able to emulate the general platform design and approach using field-based activities to create learning virtual environments with content from respective disciplines. The hope is that the process of integrating hands-on, fieldwork into the OERs to recreate the experience needed to develop important research skills is transferred and replicated in non-STEM areas that have a clear applied learning component, such as performance (e.g., theatre, dance, music) and visual arts (e.g., photography, drawing, painting, ceramics). There is already an inherent interdisciplinary interaction across disciplines, as the visual designs of the virtual interface may employ artistic aptitude, and the craft of the text may be influenced by writing and literature.

The ultimate purpose of the OERs was to be able to disseminate instructional content to audiences who seek alternative means for education or require access to learning content because of accessibility issues. At the present, there is a repository for OERs and other STEM resources within the State University of New York (http://navigator.suny.edu), however, the intention is to make them available beyond the institution's educational system. There is the potential for global dissemination by placing them in the Multimedia Educational Resource for Learning and Online Teaching (MERLOT) and any appropriate OER repository. Advocacy by many international government and non-profit groups to promote STEM education further suggests that this approach could potentially provide students around the globe with another opportunity for engagement in the sciences.

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