TechTrends (2020) 64:439–450
https://doi.org/10.1007/s11528-020-00481-9

ORIGINAL PAPER

Instructional Development of Media-Based Science OER

Juhong Christie Liu[1] · Elizabeth Johnson[2]

Published online: 15 February 2020

Abstract
Video and interactive media provide visual exposition and review for students to formulate cognitive representations where learning and reflection take place, especially in science laboratories. More inclusively, open educational resources (OER) with interactive content can facilitate access to media-enhanced learning. This paper reports part of a multi-year ongoing design-based research (DBR), focusing on the instructional development of media-based OER content in two geoscience laboratory education projects. The researchers have taken a case study approach to analyzing and exploring the design and development of accessible and interactive OER media, including photography and videography space, lighting conditions, camera settings, interactive media production, and OER publishing platforms. Findings have revealed the instructional development procedures, workflow and protocol of generating closed captioning for scientific video, data management techniques, and operability of media content in publishing platforms. The results are of practical and innovative values to the instructional development of science OER.

Keywords Video and interactive media · Instructional development · Open educational resources (OER) · Geology · Geoscience laboratory · STEM and science learning

Introduction

Visual learning in science with hands-on and field-based experiences are critical for students to be successful and continue research and career paths in science, technology, engineering, and mathematics (STEM). These visualizations facilitate learning sophisticated concepts and procedures with means beyond word expressions (Kartiko et al. 2010; Mayer et al. 1996). As technologies become more affordable and accessible, video and interactive media are found to enhance learning through procedural and conceptual representations, and support reflective thinking across disciplines of social science, natural science, medical and health sciences (Hung 2011; Rapp et al. 2016; Schmidt-McCormack et al. 2017). These media-based learning effects can only be fulfilled when subject matter expertise, instructional design principles, and media production best practices are fully integrated with the design and development of learning materials (Chiu and Churchill 2015; Krygier et al. 1997; Schmidt-McCormack et al. 2017).

This study was intended to document the exploration, analysis, and initial evaluation of the instructional development of video and interactive media as open educational resources (OER) (McKenney & Reeves 2019). Aspects included the procedures of interactive media OER development, technology selection and use, project management, and operability of open access publishing systems (van Rooij 2011). Also, the study sought explanations of workflow and data management in these collaborative multi-year OER development projects.

For undergraduate science majors, laboratory sessions have been rotated with lectures as standard instructional methods (Galloway and Bretz 2016; Hofstein and Lunetta 1982). With a history of "cookbook" approaches of instruction, laboratory sessions lack learning-centered instructional resources and are limited by time and access to equipment (Carabajal et al. 2017; Moss and Cervato 2016; Hofstein and Lunetta 1982). In interdisciplinary fields such as geosciences, instructional materials for laboratory and analytical methods often depend on combining multiple commercial publications which are

✉ Juhong Christie Liu
liujc@jmu.edu

Elizabeth Johnson
johns2ea@jmu.edu

[1] James Madison University, Libraries, MSC 4602, 1251 Carrier Drive, Rose Library 5319, Harrisonburg, VA 22807, USA

[2] Department of Geology and Environmental Science, James Madison University, MSC 6903, 801 Carrier Drive, Room 3232, Harrisonburg, VA 22807, USA

costly and are presented in printed static text and images. These generate an intimidating cost concern to students and lack engaging activities, such as inquiry-based learning (Grissom et al. 2015; Moss and Cervato 2016). The limitation of access to instructional materials and equipment also restricts review options for students.

Open educational resources (OER) enable opportunities for learners to access instructional content with minimal cost and for instructors to reuse and remix the materials to suit their student learning needs (Caswell et al. 2008; Wiley et al. 2012). For instance, OER video and interactive media have been adopted in medical education, which supportively facilitate procedural and conceptual learning (Choque-Velasquez et al. 2017; Rapp et al. 2016; Schmidt-McCormack et al. 2017). However, science OER repositories represented by the National Science Digital Library (NSDL) OER commons does not currently provide media-based OER for all disciplines (NSDL OER commons, 2019). Also, results from national studies (Allen and Seaman 2014) indicate limited awareness of using and developing OER by STEM faculty.

This case study documented two OER development projects. The iterative development of solutions to the design and development of video and interactive media with interdisciplinary expertise and technology affordances fits the scope of design-based research (DBR) (Bower 2008; McKenney & Reeves, 2019). As a case study in real (vs. non-experimental) settings, this research studied the instructional development of the OER media content for geoscience laboratory methods classes, with the intent to explore answers to the following research question:

- How can video and interactive media be developed for open educational resources (OER) through a multi-year team-based project in geoscience?

The answer to this research question will be of practical value to researchers and practitioners in instructional design, media development, and educational research. The design and development of media-based OER, especially through a multi-year team-based collaboration, will also provide insights for teamwork flow, communication strategies, and data management protocols.

Literature Review as Exploration and Analysis of DBR

In a DBR, the literature review provides information for analysis and exploration as well as set the understanding of the context for the instructional or non-instructional problems to be solved (Amiel and Reeves 2008; Mckenney & Reeves, 2019). For these reasons, the following review synthesizes existing literature on media-enhanced learning in science, learning in science laboratory classes, and instructional design and development of multimedia for online learning environments.

Media-Enhanced Learning in Science

Schmidt-McCormack et al. (2017) designed, developed, and implemented pre-lab, experiments, and data analysis video clips for undergraduate upper-level chemistry majors. A five-member team consisted of two chemistry faculty members, a post-doctoral fellow, a graduate student who had been a teaching assistant in this laboratory class, and an undergraduate who had previously taken two laboratory courses. The pre-lab video clips were created with lecture capture technologies, Panopto and Powerpoint slide presentations with instructors' annotations and audio explanations. The experiment videos were real-time clips of five to twenty minutes in length. These videos recorded graduate assistant operations in the lab and demonstrated steps of using instruments, with accompanying scripts on the same screen in a different column. For the data analysis video, simultaneous screencast of the operational procedures in Excel with handwritten formulas on the SMARTboard was captured. These dual channels of processing information were aligned with the multimedia design principles by Mayer (2002, 2014), according to Schmidt-McCormack et al. (2017). These videos were implemented in a Physical Measurement class in Fall 2014 and an Analytical Measurement Laboratory class in Spring 2015 (Schmidt-McCormack et al. 2017). With verbal consent from students, the researchers collected data through class observations, video interviews with 21 students, and administration of an online Meaningful Learning in the Laboratory Instrument (MLLI) by Galloway and Bretz (2015a, 2015b) with 12 responses. Admitting the limitations of a small sample size from one higher education institution, the researchers concluded that students were able to establish connections between the lab sections and the lecture part of the course. Students gained attributes of self-regulated learning such as self-motivation of checking videos to help laboratory performance. Students also preferred to access video content through relevant learning units in a learning management system.

Learning in Science Laboratory Courses

With hands-on experiences for scientific exploration, laboratory activities have the potential to enhance affective aspects of the course in addition to cognitive growth, such as constructive social relationships and positive attitudes (Hofstein and Lunetta 1982). However, limited facility and teaching resources are frequent concerns in science laboratory-based education (Hofstein and Lunetta 1982; Galloway and Bretz 2016).

Galloway and Bretz (2016) studied undergraduate student cognitive and affective aspects in chemistry laboratory courses. Students wore action cameras and lapel microphones in their laboratory classes as well as being videotaped with a tripod camera. Post-class interviews were accompanied by students watching the video episodes. The researchers concluded that the cognitive and affective aspects of meaningful learning were disconnected from psychomotor learning.

In the geosciences, Grissom et al. (2015) redesigned a physical geology laboratory class to go beyond traditional lab manuals through integrating inquiry-based learning activities. Following the rubric by Buck et al. (2008), these activities utilized structured, guided, and open inquiry activities by motivating students to conduct lab procedures with provided questions, explore provided resources, and design their experiments.

Enhancing student laboratory learning was also researched by using web-based visualized resources to prepare for real experiments. Zimmerer et al. (2003) conducted a study using Internet-based graphics, videos, 3D representations, and simulations to assist real lab-based learning in Instrumental Analytical Chemistry laboratory classes in Germany. A data bank co-created by 13 universities and commercial partners facilitated these electronic media. This visual data bank enabled students to manipulate the media with scientific information, for example, finding controls of a virtual infrared spectrometer that could be used in the real laboratory exercise. Students were pre-assessed on their performance and understanding of virtual experiments and operation safety through homework with an oral test before they started to conduct the real experiments. The virtual access to media-based preparatory materials was perceived by students as increasing learning efficiency through clarification with visual and interactive explanations and saving time and cost during the real laboratory-based experiments.

Design and Development of Multimedia for Science

The development of effective multimedia has been proposed and tested based on learning theories and cognitive principles (Mayer 2002; Mayer and Mayer 2014). Based on cognitive science and experiments with human learning scenarios, Mayer and Mayer (2014) have proposed twelve general principles for multimedia-based learning. These include presenting words together with images, using relevant individuals' typical conversational styles, and including speakers' images. Segmenting content in digestible units, providing an overview of the lesson, and presenting spoken words together with images support student understanding of essential procedures and concepts. Removing redundant information, highlighting important spots or keywords, deleting extraneous presentation components, positioning critical phases with images, and grouping related images and words together can eliminate extraneous processing and help students focus on intended content (Mayer 2002; Mayer and Mayer 2014; Schmidt-McCormack et al. 2017).

Facing the complexity of multimedia development, Liu et al. (1998) interviewed sixteen individuals with expertise in multimedia development. In addition to the roles, characteristics, and responsibilities of project management, instructional design, programming, photography and videography, the researchers identified the process of multimedia development, including funding for technology and resources, planning, designing, production, testing, and marketing. The study presented tips and techniques of multimedia development and confirmed that planning with careful analysis of context and resources, time allocation, and personnel preparation consisted of the key to success.

Specific to laboratory instructions, Michel et al. (1999) reported a study on creating and using digital video clips to enhance teaching by illustrating atomic spectrometry. Students developed short movie clips of 15–60 seconds in length for laboratory reports in Analytical Chemistry classes. The instructor also used short video clips in-class presentations. The length of short clips helped the efficiency of loading the media content on computers or projectors. In addition to very detailed reports of the hardware, software, and procedure of creating these video clips, the researchers recommended two golden rules of video making for scientific movie clips. The first was that the camera should be moved as close to the subject as possible as long as ensuring safety. Secondly, manual focusing should be used rather than automatic focusing. Automatic focusing of video cameras often led to 'hunting' by the camera for the correct focus point, especially if there was a confusing background (Michel et al. 1999). In their study in Germany, Zimmerer et al. (2003) recommended that the use of mental models reduce initial distraction and allow students to focus on the most relevant features of a laboratory session. Introductory geoscience books used to provide mental models with sketches. Zimmerer et al. (2003) also suggested images or video clips in science laboratory sessions scaffold higher-level learning with the live learning experience.

Design-Based Research as a Case Study

DBR in science links empirical and regulative cycles together to advance scientific understanding through iterative testing and refinement during the development of practical applications (McKenney & Reeves, 2019). This type of research takes place in a real-life context and can draw upon day-to-day experiences through observations, reflections, documents, and reports. In this research, a case study methodology fits the scope of DBR (Creswell 2013; McKenney & Reeves, 2019).

The bounded system in this case study paralleled the context analysis of a DBR. The context consisted of two projects of developing OER sponsored by the National Science Foundation (NSF) starting from 2016 and by Virtual Virginia Library Consortium (VIVA) starting from 2019 at a 4-year university focusing on teaching and undergraduate research. Both projects involved the design and production of video and interactive OER content for laboratory methods and instrumentation for two upper-level geoscience undergraduate classes as well as undergraduate student research. The OER for using the Scanning Electron Microscope (SEM) was used in three sections of Introduction to Petrology, GEOL 300 offered in Fall 2017, Spring 2018, and Spring 2019. The Introduction to Petrology was a four-credit required core course for the bachelor of science (BS) degree in Geology that included lecture and lab components. Students in this class were expected to be able to identify and classify rocks and interpret the textures and chemistry of minerals based on the analysis and observations of hand samples and with an SEM.

The OER content were also extensively used in a half-semester unit of a lab-intensive upper-level undergraduate elective course GEOL 390, Laboratory Techniques in Geology offered in Spring 2017, 2018, and 2019. Students in this course created thin sections of rocks for microscope and analytical work. They were also anticipated to analyze samples using Raman and Fourier-Transform Infrared (FTIR) Spectroscopies, and Scanning Electron Microscope (SEM).

The project team consisted of a geoscientist, an instructional designer who was the primary researcher, and student media specialists. Visual content was captured as raw images and video footage in geoscience labs. The student media specialists edited clarity, converted illustration, and added animation to these visual content with consultations to and mentoring from both the geoscientist and instructional designer.

Within this bounded settings for the case study (Creswell 2013), data were collected as initial analysis in the context of the laboratory, through analyzing space and lighting conditions for photography and videography backdrops, capturing raw images and video footage, filing team meeting notes, logs and journals in the design and development process, and tracking reflection notes. The initial iterations of this DBR and associated data collection procedures were illustrated in Fig. 1.

The *analysis* phase of this DBR included four major components which did not necessarily take place exclusively, 1) the literature review was conducted iteratively based on ongoing evaluative needs and informed the other components of the analysis stage; 2) the context and facility analysis included obtaining existing conceptualization about scientific media development and defining hardware and software; 3) the understanding of institutional geoscience laboratory teaching was obtained through meetings with the primary stakeholder, the geoscientist of these projects, and observation of classes; 4) the access to the course syllabus, schedule, major assignments, and grading criteria provided essential understanding of instructional materials and methods to the instructional designer for the OER development.

The data for the *exploration* phase of this DBR were mainly from three major research activities which not happened exclusively either, including 1) the site visits to collect the blueprints of the laboratory, to evaluate the light and sound conditions, and to locate available equipment in different departments and on the same campus; 2) the exploration of OER in geoscience and how the content would be possibly presented and integrated in teaching and learning, which included a study tour of the Science Education Resource Center at Carlton College (SERC) at https://serc.carleton.edu/NAGTWorkshops/mineralogy/optical_mineralogy_petrography.html. SERC was the very few open access resource sites for geoscience education; 3) to test the technologies as funded by the NSF and VIVA grants, such as the video camcorder and the OER publish platforms, http://courses.lumenlearning.com and http://viva.pressbooks.pub.

The *design* phase included searching for and mapping solutions to light adjustment and optimization of audio effects to personalize the media with the instructor's voice according to the multimedia learning principles (Mayer and Mayer 2014), adjusting focus, level, angle, and height settings of camera, and procedures of developing closed caption for videos and adding alt text for images.

The *development/production* phase included creating prototypes by publishing videos on the YouTube channel, assigning Creative Commons attributions, linking the playlist to the geoscience course site in the Canvas learning management system, collecting usability and informal evaluative feedback, and revising these prototypes. The prototype here was identified as parts of a planned solution that "range from partial to complete components of the desired solution. They often contain samples of what the finished product might look like; and they exhibit functional futures" (McKenney & Reeves, 2019, p.147). The findings below were drawn from both finished media products and prototypes.

Practical Findings from the DBR

Planning along with Analysis

The planning stage of this project included analyses of the real sites of geoscience laboratories, reusing existing OER, establishing team communication guidelines, mentoring undergraduate media major students in a scientific settings, and formulating engaging questions that could enhance the interactivity of the developed media content. The fieldwork, site visits, and meetings with the subject matter expert (SME) provided the foundation to understand the real context of this

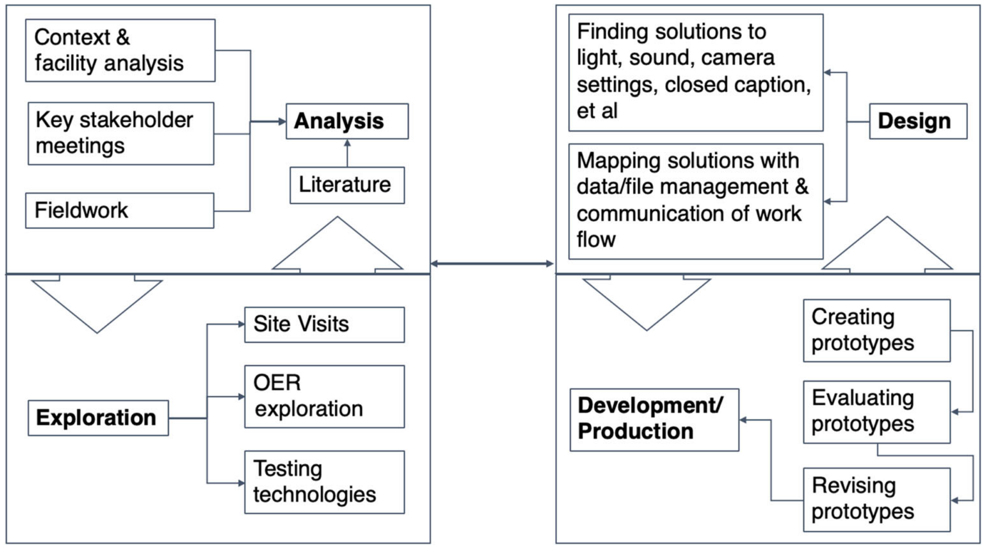

Fig. 1 DBR research design (adapted from McKenney & Reeves, 2019)

project. Directed by the SME, the team conducted an exploration of existing OER for geoscience laboratory instruments. The team also performed on-site meetings to perceive the noise of a rock saw laboratory and observe the laborious work in preparing thin section samples. Lab sessions were observed in the small spaces that used to house FTIR and Raman spectrometers and the SEM. These observations identified limited space for video setup and noise from lab equipment like vacuum pumps, so that media capture was prepared to optimize the raw footage. These also introduced the needs of capturing real images and footage for lab safety requirements. The work of this stage compared the light and space limitations for media development in a science lab, which was very different from the procedures and conditions in a professional media studio.

Reusing Existing OER

The team kept a shared journal on reflections of the geoscience laboratory instrumentation reviews on MyScope (https://ammrf.org.au/myscope/), an OER site co-created by eight universities in Australia (Fuery et al. 2017). The majority of the content was perceived very useful, but MyScope did not include embedded questions with the media. These materials, especially the section of Scanning Electronic Microscope (SEM), were selectively used in GEOL 300 and GEOL 390 between 2017 and 2019. After a review, the project team members found some content was overwhelming and suggested chunk the information when integrating MyScope content in a class session.

Establishing Team Communication Protocols

Timeline and communication strategies are critical to teamwork-based instructional design and DBR (Larson and Lockee 2014; McKenney & Reeves, 2019). With a project timeline and objectives shared at the very beginning, the team has established expectations of day-to-day communications, including:

- Be responsive to team member emails;
- Exchange cell phone numbers and only use instant messages in cases of emergent questions;
- Find a virtual collaborative space where faculty members and students on the project team can seamlessly hold discussion and share files that carry timestamps and automatically track version updates so that no accidental overwriting would cause problems and project management could be semi-independent of human monitoring.

Mentoring Media Major Undergraduates in Geoscience Settings

Undergraduate students majoring in media arts and design were team members responsible for creating and editing media content. This was intentionally planned in the project to provide these students with real project-based learning. However, to develop discipline-specific media that could meet learning needs, the media arts undergraduate students had to adapt to developing media with scientific, cognitive, and precise views. These required the SME and instructional designer becoming mentors to help these students understand the scientific and learning aspects of media creation. Literature indicated that scientific video and interactive media produced with scientific knowledge and expertise would be more engaging to learners when explaining complex concepts and inspiring solutions (He et al. 2012; Michel et al. 1999; Schmidt-McCormack et al. 2017). To help the media art and design major undergraduate students on the team gain the scientific perspectives and the teaching and learning methods in geoscience classes, the team continuously experimented with mentoring approaches.

Inviting the media art student on the team to enroll in an independent geoscience research class provided both academic and practical incentives and conditions for her/him to be involved in the science learning environments. The weekly regular meetings with the faculty member in a geoscience lab, accompanied by scientific discussions and immersion in the observations and perception of using equipment familiarized the student media specialist with the language and information to make initial decisions at capturing an image and video footage.

Sharing a journal for media capture, editing, and creation was used as a reflective learning experience for these media arts undergraduate team members. Through discussing the problems, scenarios, and possible solutions documented in the journal with the instructional designer, the students informally learned the perspectives of viewing media development for teaching and learning purposes, and started to share resonance on using phrases like “cognitive load”.

Reserving a working space for the student media specialist in a science environment was another way of providing mentorship with scientific perspectives for none-science major media developers. This facilitated the proximity between the student media specialist and the SME, which set a natural ambiance for using scientific language and accessing equipment easily for clarifications. The SME provided media specialists with sketches or raw photographs for diagrams with subject-specific annotations. In the working space, the SME also verbally described the interactivity to the media specialists with actual equipment demonstration when needed (See an example of a draft set of diagrams in chemical bond diagrams Fig. 2).

Formulating the Habit of Asking Learning-Centered Questions at the Planning Stage

To efficiently accomplish the various pieces in an OER development project, the team usually started each planning session with the key question of *Which skills or learning objectives will this task fulfill or support?* Following this question, the team asked, *What instrumentation will need to be used in the shot(s)? Is the instrumentation ready to be used or does it need to warm up and/or have calibration? Is the lab available during the time for recording? Is all the necessary equipment ready? Is it necessary to reserve loan equipment for that day?*

Using these questions, a script of key points or tasks for media capture of the day would be generated. This helped guide the student media specialist to generate the shots efficiently and also helped the project management in tracking the shots and applying remakes such as audio recording or additional editing.

“An outline script gives a more authentic feel to the recordings. A goal of this project is to show that problems will arise in the laboratory- we ‘let things happen’ or allow fluidity to the content so we can show students what it is like to problem-solve in the lab. Some problem-solving can also be planned. For example, we prepared well-polished and poorly-polished thin section blanks before shooting to show some real examples of work that novice students might produce.” (Adams, C. media arts student production notes.)

Equipment and Software for Media Production

Creating media for science OER needed three basic categories of technologies. These evolved from the pre-award of grants to the actual project implementation. Initially, proper hardware was planned for capturing images and video footage and storing content as independent backup copies. Software for editing media, creating interactive content, and publishing OER were also included. The most important, however, was the mechanism for team connection, project management, and data management for multi-year projects, which would not have been given enough attention at the project plan stage.

The hardware used in this project included an HD Camcorder and a DSLR camera. Mobile phones with a megapixel camera were also useful when there were limited space and time and a tripod could not be set up or where only a phone could have the reach. A light kit with adjustable umbrellas like the brand of LimoStudio enabled professional shots in laboratories where there were poor light conditions. When space was limited, the umbrella lights were replaced with flexible lamps. A robust tripod with a level adjustment was found very helpful to take steady shots. The student media specialist always carried a spared media transition disk-like 32GB or 64GB SanDisk to keep filming for a complete lab class, which could easily last 2 h. A wireless lavalier microphone system was essential to capture quality audio articulation of the SME in a science lab which usually had background noise of ventilation systems or machine operation sounds. The movement of the narrator during lab tasks could also generate interruptive sound. Therefore, a desktop microphone like a Blue Yeti microphone was important to create clear explanatory voice-overs for videos by replacing the noise background from geoscience lab sessions with clear articulation and accurate captioning.

The software used in the project included programs for media editing, teamwork communication, and project and data management. Image and video editing software included Final Cut Pro or Adobe Creative Cloud which were sponsored by the home university of the SME and instructional designer. Audacity, a free program for both Windows and

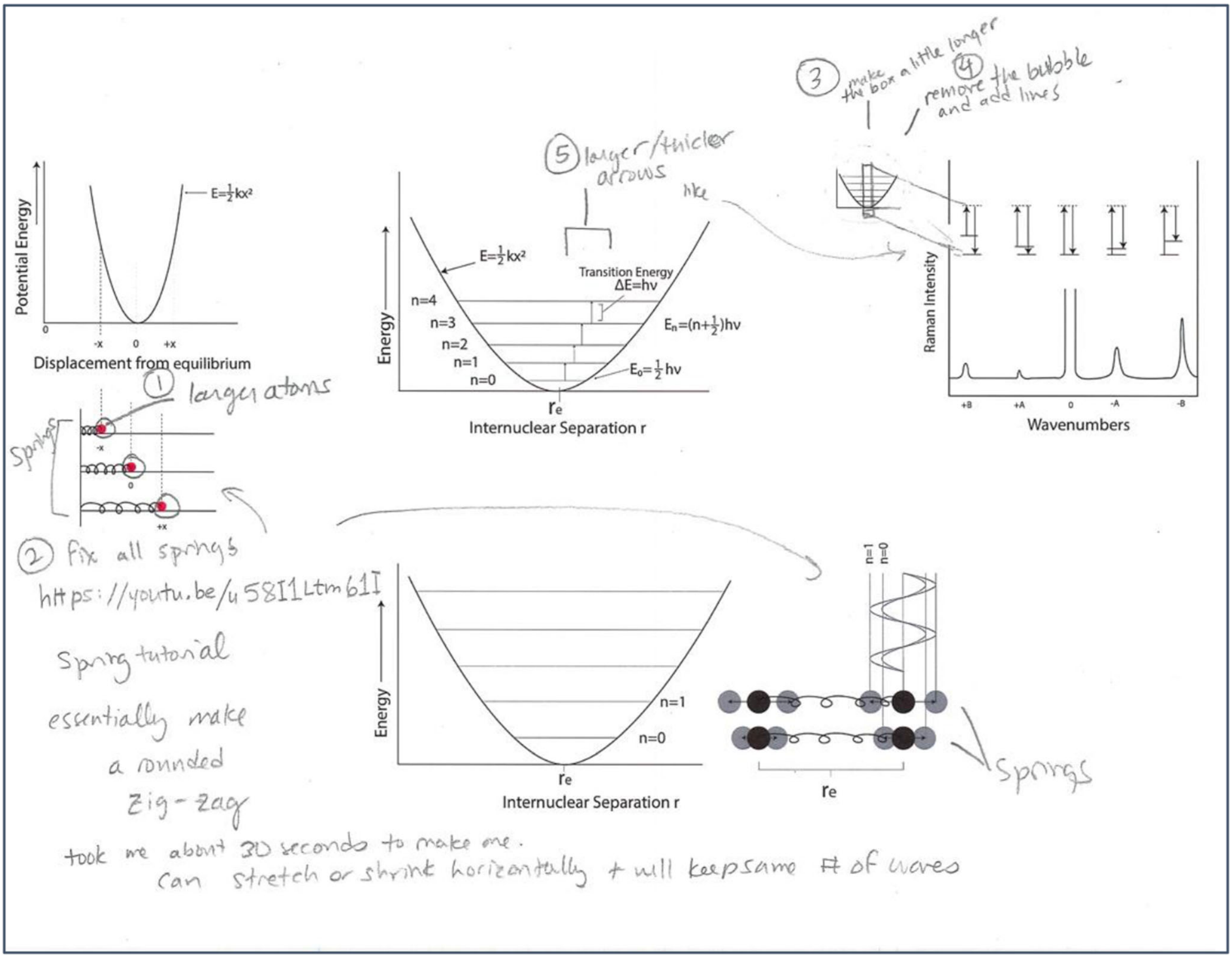

Fig. 2 Chemical bond diagrams

Mac operating systems, was used for audio recording and editing. TechSmith Camtasia Studio, funded by the NSF grant, was used for screen recording. Adobe Animate funded by NSF and H5P, an open-access program, were used for creating animated and interactive objects. The teamwork communication was supported with emails, team member phone messages when urgent communication was needed, Google Docs, Google Sheets, FreedCamp, and Open Science Framework (OSF). The Google Apps were used for ongoing communication about images and video footage of raw and various editing status. FreedCamp was used as a team-configured project management system among members within and between collaborative institutions. The platform offered shared discussion options with file attachment or links and tracked tasks with a team-based calendar. It also offered separate folder options depending on personnel or nature of tasks, before the institutionally supported adoption of OSF in 2017. OSF helped team communication with email notifications of shared content updates.

Design and Development of Prototypes

At the prototype development stage, nearly six hundred raw images and more than two hundred video clips were captured. The media specialists kept a journal with procedural records and reflections of production first with Dropbox pages and later with Google Sheets. The SME and instructional designer conducted iterative evaluations of these images and video clips. These led to practical discoveries of producing quality media in the live settings of geoscience laboratories, including light condition adjustments, camera settings for optimal achievement of white balance, and needs of making decisions about creating close-ups or wide-angle shots.

Lighting Condition Adjustment for Quality Raw Images and Video Footages

Lighting is of critical importance to accurately represent a concept or procedure and arouse meaningful thinking of the audience (Gloman and LeTourneau 2012). It is important to

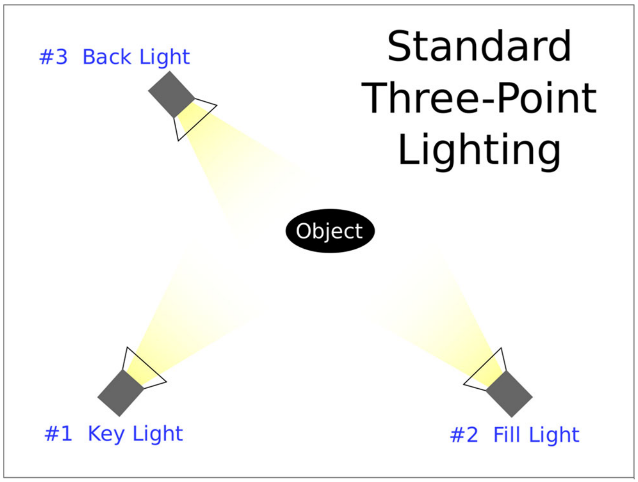

Fig. 3 Three-point Lighting (Wikipedia)

think about the shot angle in terms of camera placement and lighting before an actual image or footage capture. To reach the optimal lighting condition while capturing images or videos, a three-point lighting set is usually desired (Fig. 3). A trial set up before the actual shots can save the work of hours of subsequent reproduction and editing.

The pre-shot planning was very important in labs where there could be limited space for equipment and lighting. In this current DBR project, space sometimes was not ideal for setting up three points of light. Therefore, two points were mostly used and two umbrellas of a LimoStudio light kit were used with height adjustment to reach the optimal light reflection for filming effect. With blueprints of the lab spaces obtained ahead of time, pre-shooting mapping with the floor map of labs helped expedite the workflow (Fig. 4).

Adjusting and Placing Cameras for Quality and Flexibility

Proper light, focus, and angle are the three major practical aspects when placing and adjusting cameras for high-quality optimal images and footage. The adjustment of white balance is also very necessary to reproduce the proper ratio of white and most of the modern cameras have the auto white balance (Gloman and LeTourneau 2012).

In labs with incandescent lights, there were always layers of yellowish tint that was unnoticed by bare eyes but very likely to be captured in images or video footage. The media specialist set the initial white recognition with a sheet of blank print paper to manually calibrate the camera white balance. This solved the issue and saved time later for the correct auto white balance adjustment. Proper adjustment of levels on the camera as well as the tripod also resulted in focused and clear images and footage.

When taking bird view shots, a lateral tripod mount with a tilting handle was necessary. This might affect the sufficiency of natural light on the lab site; therefore, extra light of a lamp

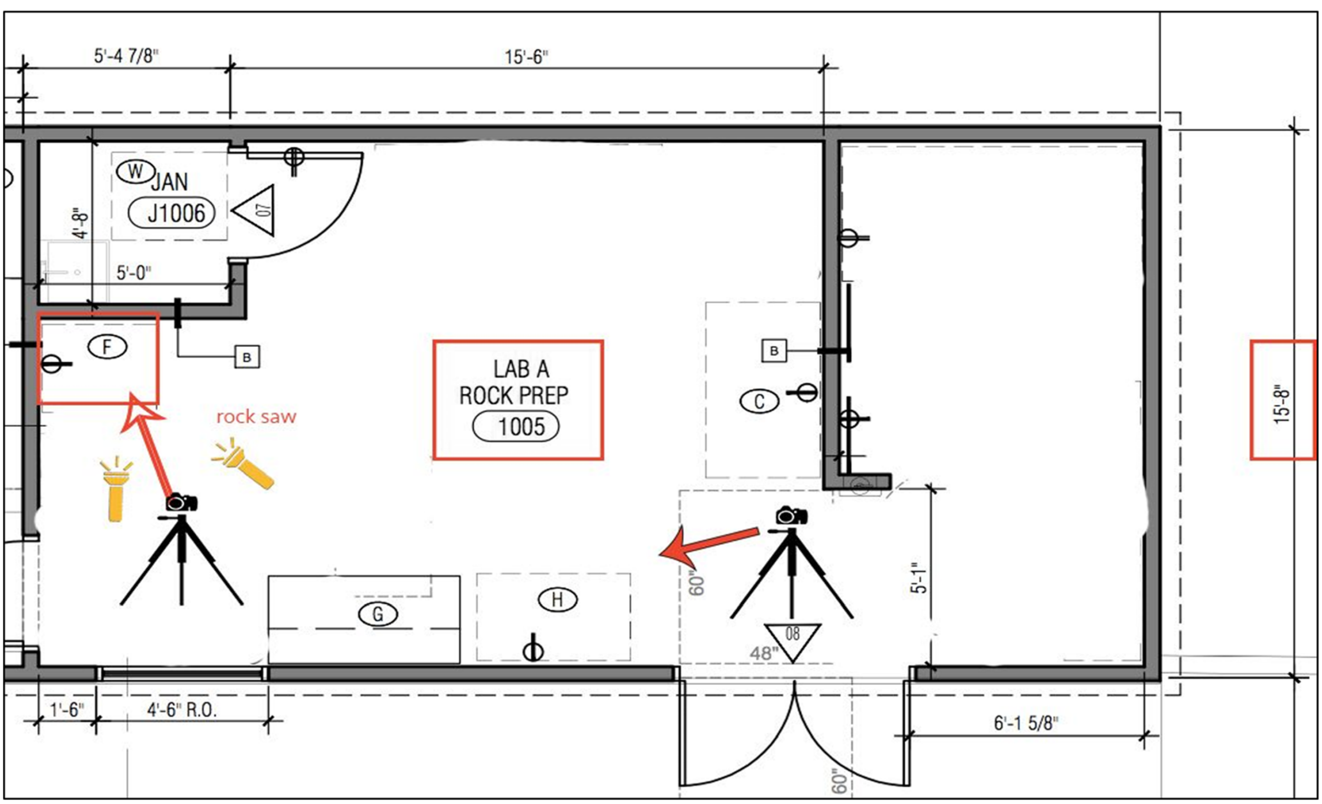

Fig. 4 Lighting kit arrangement and camera placement in a geoscience lab

was set up for the best quality. Sometimes space did not allow the setup of a tripod. The media specialist needed to climb to space and hold the camera as stable as possible to capture the raw media.

These technical details enabled the flexibility of making wide-angle and close-up shots. For instance, Fig. 5 used a wide-angle view so that students could identify the looks of different models of research-grade microscopes for lab methods and petrology classes. The placement of the camera needed pre-shot trials to ensure accuracy and quality. Additional attention to the backdrops in terms of color contrast and lighting sources helped generate optimal media products with the least editing.

Figure 6 illustrated the realistic close-up of the illuminator located in the base of the petrographic microscope. Figure 7 demonstrated the inside bird eye view of a Fourier-transform infrared spectrometer (FTIR). This view was not easily accessible during the day-to-day use of the instrument. Figure 7 was also a great foundation for the abstract illustration of Fig. 8, which simplified details of the reality but allowed the labels with a clear expository explanation. These were also good examples of applying the multimedia learning principle of *coherence* of deleting extraneous elements and *signaling* by highlighting important elements or parts.

Data and File Management

The team explored various systems for file and data management. These included Google Drive and Dropbox for file storage and sharing, Freedcamp for project management of online discussions and time management without extra filling of institutional email inboxes, and a LaCie Rugged 2GB portable drive. Because of the variety of file formats, file folder sizes of videos and interactive media and the intention to maintain the original data identity, the team also explores other data management systems such as Dataverse. In the summer of 2017, the home institution of the SME and instructional designer started the institutional subscription of Open Science Framework (OSF) which provided the flexibility of keeping the project and its sub-level objects or discrete pieces of data public or private. OSF allowed the data tracking with a timestamp, version management with repeated files written over the previous ones as long as the file name staying the same, and user management. Within OSF, a Digital Object Identifier (DOI) was assigned to any discrete artifact uploaded

Fig. 5 Taking a wide-angle shot

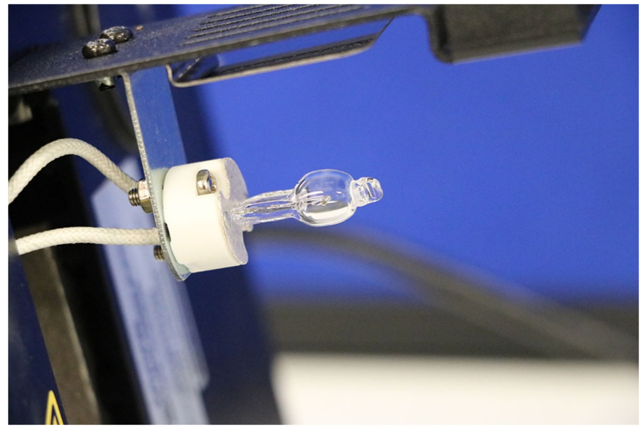

Fig. 6 Close-up view of an illuminator on a petrographic microscope

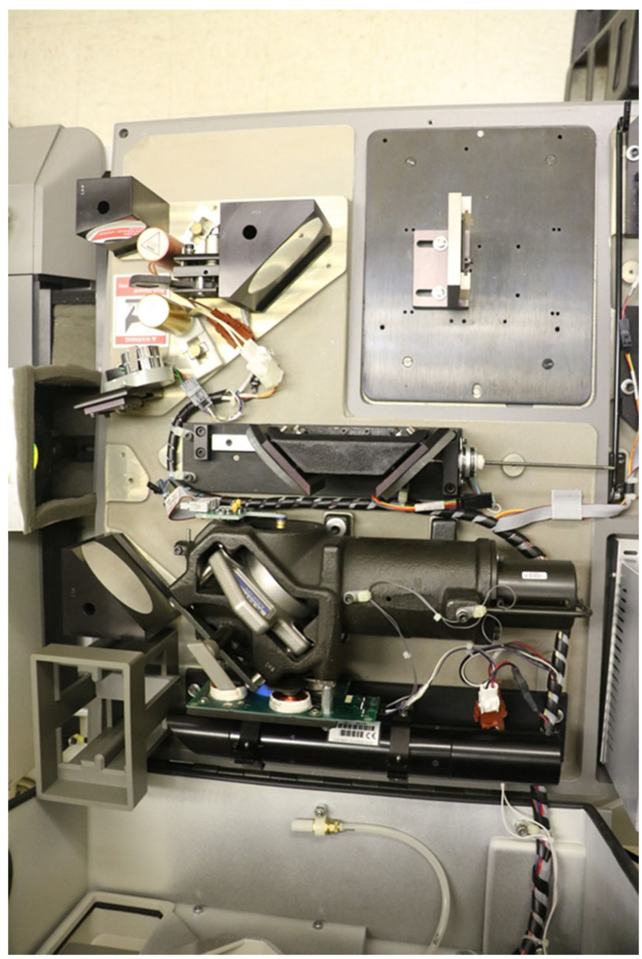

Fig. 7 Close-up bird eye view of the inside of an FTIR spectrometer. (This is the same view as the illustration below)

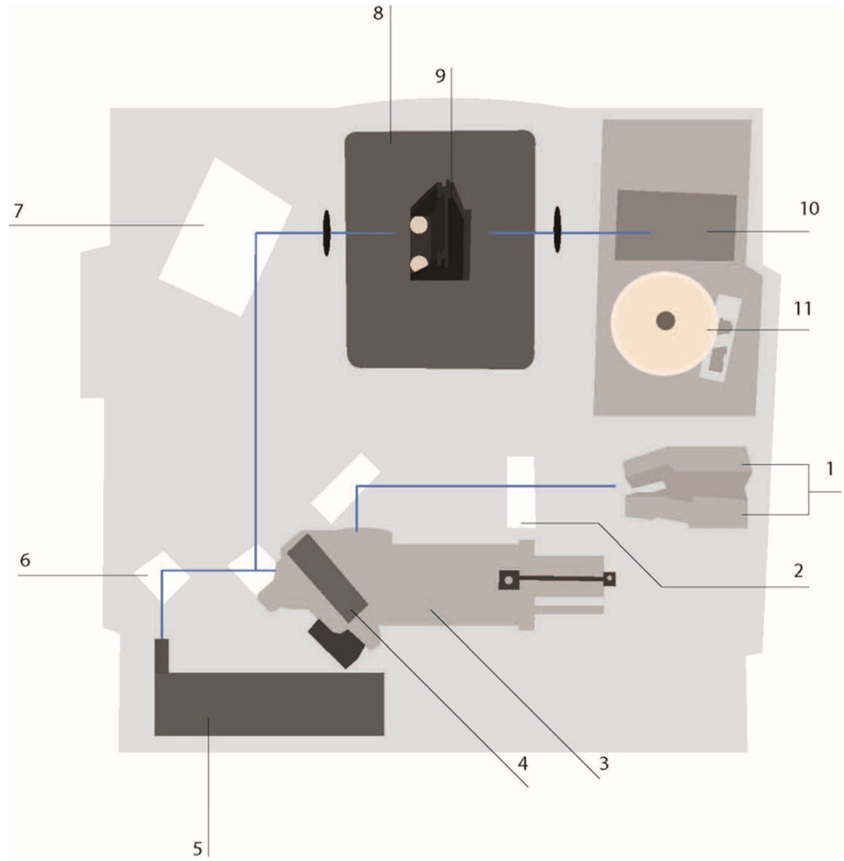

Fig. 8 Simplified labeled illustration of the bird's eye (or top-down) view of the interior of the FTIR Spectrometer

to the system. DOI allowed the unique identification of the information or digital object created in these projects. In the past two years, the team also explored the naming descriptors for various levels and sub-levels of the files within the OSF projects. The internal tagging system and a wiki in the OSF also allowed for the searching functions with descriptive notes for the stored data.

OSF played an important role between file editing, storage, and sharing before the developed media content was published through http://courses.lumenlearning.com and http://viva.pressbooks.pub. It also became a communication hub between the SEM, media specialist, and instructional designer because an upload from a team member could trigger an email notification to the rest of the team.

Accessibility, Interactivity, and Operability of Media Development

The accessibility of the developed media in this case study was achieved through three aspects. First, any video clip published to the YouTube AmiGEO channel (Analytic Methods in Geosciences) was assigned a Creative Commons - Attribution license so that it became open for others to reuse, retain, revise, remix, and redistribute (Wiley 2017). Secondly, images inserted in the OER sites of http://courses.lumenlearning.com and http://viva.pressbooks.pub were accompanied with meaningful "alt text" as annotated by the SME. Thirdly, the closed captioning of the YouTube videos needed closer attention to accessibility design and development. With its built-in voice recognition technologies, YouTube applied automatic closed-captioning/CC subtitles to an uploaded and published video clip. However, YouTube auto-captioning could misinterpret technical vocabulary within scientific videos. After the first cycle of prototype production, the researchers developed a procedure to produce accurate closed captioning:

- Allow YouTube to create auto-captioning as a clip is uploaded;
- Publish the edited video to YouTube as unlisted;
- Edit the scripts of the automatic transcription within YouTube Video Manager to retain its timestamps;
- Download the edited .srt file and edit the scientific terminology and grammar in a plain text editor, TextEdit for Mac and Notepad for Windows;
- Upload the revised .srt file which retains the timestamp associating script with the video clip;
- Unpublish and delete the English(automatic) version to avoid confusion to the audience;

- Publish the edited English version and make the video public;
- Adjust the Creative Commons – attributes license and other settings.

The interactivity and operability were gradually achieved in the exploration and transition between Adobe Animate and H5P for the OER publishing platforms, variations of Pressbooks. A dozen interactive media were created with Adobe Animate and played as flash files at the early stage of these multi-year OER development projects. Because of the operability of flash files was terminated in major web browsers, the research team took technical transition and conducted applied research for integrating the designed interactivity in OER development.

The applied research resulted in the use of H5P, an open-source platform for easily creating HTML5-based interactive content such as pop-up questions on presentations, a hotspot on images, video quizzes, slideshows, jeopardy, and games. H5P could be installed at the system admin level in WordPress, Moodle, and Drupal. The H5P plugins allowed the possibility of two major discoveries related to interactivity and operability of media for this OER development research:1) inclusion of Creative Commons – Attribution license to H5P objects through editing *metadata*; 2) reuse of H5P objects created in one OER book in another OER book. The first discovery ensured open content and access to these H5P objects from other geoscience teachers, students, and researchers. The second discovery ensured the easy reuse of these objects in different geoscience OER.

Conclusion and Discussion

The OER textbooks present instruction in more interactive and flexible formats than traditional science textbooks which used to be in the printed text and static images. OER Interactive media can enhance student learning through affordable, visualized, and procedural presentations, and scaffold review and reflections on complex concepts and procedures even without laboratory equipment at hand. However, OER repositories like the NSDL OER Commons (https://nsdl.oercommons.org/) need instructional development of more discipline-specific media content, such as geosciences.

This case study has adopted an iterative DBR approach to analyzing and developing OER with the integration of instructional design, multimedia learning principles, and project management and data management in instructional development. The results have unveiled that the OER design and development team need to willingly make the adjustment to evolving technologies, customize visualization techniques, and consider open access to learners with all abilities. The discoveries provide practical recommendations on technology selection, media production procedure, project management, and accessibility applications in video and interactive media development of OER.

Not without limitations, the ongoing OER development projects in this DBR only has taken place in one university. This is why the research team is collaborating with geoscience reviewers in the United States and possibly around the world to review and reuse the developed content and turn prototypes to functional OER in geoscience classes. The procedures of instructional development for OER, technology selection and use, project and data management, and related protocols such as closed captioning for YouTube videos documented through this case study can serve as references over time to science educators and instructional designers.

Acknowledgements This paper is based on the research in OER design and development projects funded by National Science Foundation (NSF #1611798) and Virginia's Academic Library Consortium (VIVA 002VCRS19). The media production has been from the media art and design talent of Ceanna Adams, Mark Peale, and Katherine Whitbred. The projects have also received technology and instrumentation support from the Libraries and College of Science and Mathematics at James Madison University.

Compliance with Ethical Standards

Ethical Approval All procedures performed in studies involving human participants were per the ethical standards as reviewed and approved by the Institutional Review Board and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

References

Allen, I. E., & Seaman, J. (2014). Opening the curriculum: Open Educational Resources in US higher education, 2014. *Retrieved from* https://files.eric.ed.gov/fulltext/ED572730.pdf

Amiel, T., & Reeves, T. C. (2008). Design-based research and educational technology: Rethinking technology and the research agenda. *Journal of Educational Technology & Society, 11*(4), 29–40.

Bower, M. (2008). Affordance analysis–matching learning tasks with learning technologies. *Educational Media International, 45*(1), 3–15.

Buck, L. B., Bretz, S. L., & Towns, M. H. (2008). Characterizing the level of inquiry in the undergraduate laboratory. *Journal of College Science Teaching, 38*(1), 52–58.

Carabajal, I. G., Marshall, A. M., & Atchison, C. L. (2017). A synthesis of instructional strategies in geoscience education literature that address barriers to inclusion for students with disabilities. *Journal of Geoscience Education, 65*(4), 531–541.

Caswell, T., Henson, S., Jensen, M., & Wiley, D. (2008). Open content and open educational resources: Enabling universal education. *The International Review of Research in Open and Distributed Learning*, 9(1).

Chiu, T. K., & Churchill, D. (2015). Exploring the characteristics of optimal design of digital materials for concept learning in mathematics: Multimedia learning and variation theory. *Computers & Education, 82*, 280–291.

Choque-Velasquez, J., Kozyrev, D. A., Colasanti, R., Thiarawat, P., Intarakhao, P., Jahromi, B. R., & Hernesniemi, J. (2017). The open access video collection project “Hernesniemi's 1001 and more microsurgical videos of neurosurgery”: A legacy for educational purposes. *Surgical Neurology International, 8*, 188.

Creswell, J. W. (2013). *Qualitative inquiry: Choosing among five approaches*. Los Angeles: Sage.

Fuery, C., Whiting, J., Cribb, B., Williams, J., & Cairney, J. (2017). Online microscope simulators for training and outreach. *Microscopy and Microanalysis, 23*(S1), 2300–2301.

Galloway, K. R., & Bretz, S. L. (2015a). Development of an assessment tool to measure students’ meaningful learning in the undergraduate chemistry laboratory. *Journal of Chemical Education, 92*(7), 1149–1158.

Galloway, K. R., & Bretz, S. L. (2015b). Measuring meaningful learning in the undergraduate chemistry laboratory: A national, cross-sectional study. *Journal of Chemical Education, 92*(12), 2006–2018.

Galloway, K. R., & Bretz, S. L. (2016). Video episodes and action cameras in the undergraduate chemistry laboratory: Eliciting student perceptions of meaningful learning. *Chemistry Education Research and Practice, 17*(1), 139–155.

Gloman, C., & LeTourneau, T. (2012). *Placing shadows: Lighting techniques for video production*. Routledge.

Grissom, A. N., Czajka, C. D., & McConnell, D. A. (2015). Revisions of physical geology laboratory courses to increase the level of inquiry: Implications for teaching and learning. *Journal of Geoscience Education, 63*(4), 285–296.

He, Y., Swenson, S., & Lents, N. (2012). Online video tutorials increase learning of difficult concepts in an undergraduate analytical chemistry course. *Journal of Chemical Education, 89*(9), 1128–1132.

Hofstein, A., & Lunetta, V. N. (1982). The role of the laboratory in science teaching: Neglected aspects of research. *Review of Educational Research, 52*(2), 201–217.

Hung, H. T. (2011). Design-based research: Designing a multimedia environment to support language learning. *Innovations in Education and Teaching International, 48*(2), 159–169.

Kartiko, I., Kavakli, M., & Cheng, K. (2010). Learning science in a virtual reality application: The impacts of animated-virtual actors’ visual complexity. *Computers & Education, 55*(2), 881–891.

Krygier, J. B., Reeves, C., DiBiase, D., & Cupp, J. (1997). Design, implementation, and evaluation of multimedia resources for geography and earth science education. *Journal of Geography in Higher Education, 21*(1), 17–39.

Larson, M. B., & Lockee, B. B. (2014). Streamlined ID: A practical guide to instructional design. Routledge.

Liu, M., Jones, C., & Hemstreet, S. (1998). Interactive multimedia design and production processes. *Journal of Research on Computing in Education, 30*(3), 254–280.

Mayer, R. E. (2002). Multimedia learning. In *Psychology of Learning and Motivation* (Vol. 41, pp. 85-139). Cambridge, MA: Academic press.

Mayer, R., & Mayer, R. E. (Eds.). (2014). *The Cambridge handbook of multimedia learning*. Cambridge: Cambridge University Press.

Mayer, R. E., Bove, W., Bryman, A., Mars, R., & Tapangco, L. (1996). When less is more: Meaningful learning from visual and verbal summaries of science textbook lessons. *Journal of Educational Psychology, 88*(1), 64–73.

Michel, R. G., Cavallari, J. M., Znamenskaia, E., Yang, K. X., Sun, T., & Bent, G. (1999). Digital video clips for improved pedagogy and illustration of scientific research—With illustrative video clips on atomic spectrometry. *Spectrochimica Acta Part B: Atomic Spectroscopy, 54*(13), 1903–1918.

McKenney, S., & Reeves, T. C. (2019). Conducting educational design research. New York, NY: Routledge. https://doi.org/10.4324/9781315105642

Moss, E., & Cervato, C. (2016). Quantifying the level of inquiry in a reformed introductory geology lab course. *Journal of Geoscience Education, 64*(2), 125–137.

National Science Digital Library (NSDL) OER Commons (2019). Retrieved from https://nsdl.oercommons.org/

Rapp, A. K., Healy, M. G., Charlton, M. E., Keith, J. N., Rosenbaum, M. E., & Kapadia, M. R. (2016). YouTube is the most frequently used educational video source for surgical preparation. *Journal of Surgical Education, 73*(6), 1072–1076.

Schmidt-McCormack, J. A., Muniz, M. N., Keuter, E. C., Shaw, S. K., & Cole, R. S. (2017). Design and implementation of instructional videos for upper-division undergraduate laboratory courses. *Chemistry Education Research and Practice, 18*(4), 749–762.

van Rooij, S. W. (2011). Instructional design and project management: Complementary or divergent? *Educational Technology Research and Development, 59*(1), 139–158.

Wiley, D. (2017). OER-enabled pedagogy [Blog post]. Iterating toward openness. Retrieved from https://opencontent.org/blog/archives/5009

Wiley, D., Green, C., & Soares, L. (2012). Dramatically bringing down the cost of education with OER: How open education resources unlock the door to free learning. Center for American Progress.

Zimmerer, C., Thiele, S., Salzer, R., Krauseneck, A., & Körndle, H. (2003). Internet teaching: Laboratory course in analytical chemistry. *Microchimica Acta, 142*(3), 153–159.