Bringing field and laboratory work into the classroom by using online modules in the edX platform

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Abstract. We present two projects that aim at enhancing geoscience education in the classroom through the use of online modules in the edX platform.
"Deform the Earth" and "Virtual field trip" are two online modules that the department of Earth, Planetary, and Atmospheric sciences is developing in collaboration with MITx. These two modules will be first used residentially at MIT, and will be subsequently adapted to be freely accessible through the edX platform in order to expand access to geoscience education worldwide. Each module addresses different challenges in geoscience education. How to teach laboratory skills in the classroom, particularly in a field that is both dangerous and difficult to access? How to teach field skills in a dynamic and effective way? How to make sure the students make the most out of their field experience? We describe each module goals, learning outcomes, and instructional designs.

Keywords: Geoscience online modules, laboratory skills, field trip, edX, blended learning

1 Introduction

Teaching the practical skills of science has been an interesting challenge since the beginning of MOOCs (*Waldrop, 2013*). A variety of innovative uses of technology allowed the development of online labs (*de Jong, Sotiriou and Gillet, 2014*) for blended or online learning. The use of virtual, augmented and mixed reality and gamification of content has stretched even further the possibilities for teaching scientific skills. *(Psotka, 1995; Freina and Ott, 2015,*).
Geoscience education heavily relies on laboratory and field components. It is therefore particularly challenging to adapt to a classroom if easy access to laboratory facilities or field areas is not readily available. Geoscience education hence benefits from an effective use of multimedia materials that can bring the field and laboratory aspects of geoscience seamlessly into a classroom setting (*Libarkin and Brick, 2002*). MOOCs further present both a challenge and an excellent opportunity to expand geoscience education to underserved communities.
We present here the instructional design of two one-week long modules that will be used on campus (at MIT) in the fall of 2019: "Deform the Earth!" and "Virtual field

trip". Both modules are targeted innovations of the edX platform and are developed in collaboration with a faculty member at the department of Earth, Atmospheric, and Planetary Sciences at MIT and a digital learning fellow at MITx (MIT Open Learning). The objective of the modules is to teach field-geology and experimental rock mechanics skills using the edX platform, and reinforce these two skills that are particularly challenging to teach in a classroom. At this stage, we do not intend to replace the field excursion and the laboratory component of our classes, rather we intend to use the online modules to complement our classes and help our students consolidate their knowledge throughout the semester. However, our final objective is to create an introductory geology MOOC in which learners will acquire both observational and experimental scientific skills in a purely online setting.

2 Residential use of "Deform the earth"

2.1 Motivation for "Deform the earth"

Our understanding of plate tectonics relies on the knowledge of strength of geological materials. However, because the experimental protocols are difficult to explain in a classroom, and only few rock deformation laboratories exist world-wide, students overlook this component of Earth sciences and lack the knowledge to critically evaluate experimental results. "Deform the Earth!" is a one-week long module that will allow learners to visualize the components of a deformation apparatus, understand how extreme conditions of pressure and temperature are achieved, and how the data is acquired and analyzed, all without having to be in the laboratory.

At MIT, students can access the rock mechanics laboratory, however the experimental set-up is very involved and it takes on average three days to prepare one single experiment for an experienced user. Students struggle with the different steps of experiment preparation and often get lost in the details and forget the big picture. Moreover, we have noticed that similar, seemingly obvious mistakes, are repeated even though the students received a detailed one to one explanation. It is likely that the current training method leads to cognitive overload. We expect that the module will allow us to scaffold the student's learning. A blended learning model will be used in the class "Flow, deformation, and fracture in Earth and other terrestrial bodies" and the students will follow the module "Deform the Earth!" with a hands-on laboratory activity.

2.2 Learning outcomes

At the end of the module, the students should be able to design an experiment that can be performed in the experimental rock deformation laboratory, in order to test a hypothesis they developed. The students need to have a clear understanding of the scientific method (*Popper, 2005*), and the limitations of the experimental set-up they will use.

We expect the students to be able to describe each step of the experimental procedure they will perform. Finally, students should know what data they are going to collect and what data treatment they are going to perform in order to test their hypothesis.

2.3 Instructional design

The module is designed in four sections, incorporating research-based techniques for better learning:

1. Introduction to experimental rock deformation
2. Experimental procedure
3. Data treatment
4. Extrapolation to nature

The introduction to experimental rock deformation is done via interviews to members of the rock mechanics community and analysis of historically relevant papers. Deformation machine design and engineering solutions necessary to replicate the extreme conditions under which rocks deform in the Earth and other planets are introduced via case analysis of famous experiments. Assessments focus on dissecting the scientific method that was followed. The edX platform allows us to use how-to videos explaining each component of the deformation apparatus and the steps required to perform an experiment and integrate them into a learning sequence. The assessments are designed in order to address common misconceptions and experimental mistakes *(Adams and Wieman, 2011*). We use a variety of strategies for assessments in order to develop rigorous activities for our students (*Sandland and Rodenbough, 2018*). The data treatment is designed as worked examples (*Renkl, 2014*) using Matlab. Data analysis is an excellent place to use worked and faded examples as it reflects very accurately how users learn how to interpret the data, usually by working through previous analysis.
Finally, the extrapolation to nature section ties all the acquired skills together. The experimental results are used to understand how rocks deform in nature. In an open response assessment, students have to formulate a hypothesis and design an experiment to test it. Students are expected to grade each other's experimental plan before being graded by staff. The peer-grading stage will allow us to test how well they understand the scientific method.

3 Residential use of "Virtual Field trip"

3.1 Motivation for "Virtual Field Trip"

An essential part of the geology training is learning how to make reliable field observations. This skill is extremely difficult to teach in a traditional classroom setting and is usually taught through field trips. However, during the trip students receive a lot of information, ranging from how to make correct observations to geological processes and large scale geodynamics. Students have to make many new connections with freshly acquired information. We see that they struggle establishing connections to the big picture of plate tectonics, possibly because they are experiencing cognitive overload. It is impossible to go back to the sites to reflect upon the observations made at a later point, which would be an ideal situation to help their learning (*Clark et al., 2006*). The “Virtual field trip” module will allow students both to prepare for their field trip and to re-visit their field trip experience and strengthen the connections between observations and learned geological concepts. It will also allow students who could not participate in the field trip to access some of the teaching that is delivered in the field.

3.2 Learning outcomes

At the end of the module, students should be able to identify markers of the geological processes inherent to the Wilson cycle, a model of the cyclical opening and closing of ocean basins caused by movement of the Earth's plates (including rifting, spreading, subduction, and collision). They should be able to make observations and formulate hypothesis supported by those observations. Students should be able to communicate those hypothesis by drawing a geological cross-section of the studied area. A cross section is a graphical representations of vertical slices through the Earth’s crust, or in other words a two-dimensional slice of Earth's subsurface used to clarify or interpret geological relationships accompanying maps.

3.3 Instructional design

The module is divided in three sections that will be taken by students at different stages:

1- Introduction
2- Day 1
3- Day 2

The introduction revises concepts that were learned in class to ensure there are no misconceptions. It also gives a broad perspective on the history of supercontinents. Students will be required to complete this section before the field trip. The two following sections will be completed after the field trip and mirror the field trip structure. Each day is divided into “stops” corresponding to geographic locations chosen illustrating a particular process or supporting our current hypothesis for the local geological history. We are very deliberate in the use of video. VR technology would have been great for giving the students the experience of being in the field (*Jiayan Zhao et al., 2017*), but this module does not aim at replacing the field experience. The video is used in two ways. First, it enriches the students’ view of the area, giving access to perspectives that are not available in the field trip (with the use of drones or high magnified images). Second, it allows us to train the observational skills of the students: for each stop, they have to make observations on the video or on images, before hearing the explanation. The final assessment is an open response assessment of a geological cross-section. Students are expected to grade they peers before being graded by staff, this will lead them to test each other's hypothesis.

4 Conclusion: towards a MOOC

The two geosciences modules will be offered residentially this fall. The blended learning set-up will provide us with rapid feedback regarding the effectiveness of the instructional design. Some questions are obvious: does the experimental exposure shorten the hands-on training time? Does the virtual field trip make it easier for students to make big picture connections? Others questions are more subtle and difficult to answer. Could we design a hands-on activity that can be evaluated in a MOOC? How can virtual reality or mixed reality help us recreate a field trip? How can we make this MOOC accessible for all learners? We hope that our residential experience will allow us to build a stronger MOOC.

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