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Remote operations could be the future for Earth Sciences teaching: A speculative discussion

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Abstract: The current pandemic situation has created havoc in the regular workings of many institutions such as those dedicated to teaching and, therefore, the urge for alternatives to traditional face to face teaching has raised. However, for certain subjects, such as the Earth Sciences, distance teaching approaches could be seen as counterintuitive to the essential foundations of the subject (where empirical information, especially from fieldwork, was paramount for its foundation and growth). We consider in this work remote operations, which could complement, improve and perhaps even replace the traditional approach for Earth Sciences teaching, potentially producing better learning outcomes, even in relation to laboratory and fieldwork, including work concerning studies in locations out of planet Earth. Additionally, we consider the possible advantages for other professional settings related to this area, such as those concerning terrain characterization for Engineering works, mineral resources and environmental studies, as well as possible support for space missions and stations in other astronomical bodies (where mineral exploration and extraction could be developed and, hence, especially benefit from remote operations).

Keywords: COVID-19, fieldwork, laboratory work, space exploration and exploitation.

1. Introduction

The currently ongoing pandemic has caused major disruptions in teaching activities around the world. However, given that this is a problem happening worldwide, this also means that there will be a wider interested audience (which also means a wider market).

One can admit that other situations of generalized isolation will happen in the future. They could be due to the occurrence of pandemics (promoted by an increasingly "de facto" borderless world) and to climatic catastrophes (in a sense akin to the mathematical catastrophe theory) promoted by climate change and related events (floods, landslides).

Other situations of isolation such as sickness and disabilities (of staff and students) can promote generalized or individual problems of access, in a temporal or permanent matter. The solutions to overcome these situations will have, hence, wider social importance (see, for example, [1]).

Besides the immediate questions about teaching, the issues discussed here concerning the use of remote operations could be relevant for developing skills that will be useful in diverse professional settings and it might help to prepare students for 21st-century workplaces where collaborators can participate from anywhere. Just like the internet, which began as a government (military) project, the investment in these teaching alternatives could contribute to diverse business opportunities in several geological areas such as mineral exploration and environmental studies, especially for hardly accessible areas or those with conditioned access resulting, e.g., from radioactive conditions.

Teaching based on remote interactions could also have several advantages in terms of reducing stress, atmospheric pollution, and overcrowding (as a side effect, the reduction of crowding could reduce the number of people exposed to street crime or low-tech terrorist attacks). Being potentially more flexible in terms of schedule, it will be advantageous for working students or people with caring activities for infants or elderly and sick people.

2. Materials and methods

The materials considered include both objects and concepts relevant to Earth Sciences classes (we will attempt to formulate a global discussion that applies to minerals, fossils, rocks, structures, etc.). We are focused on the geological points and we will not discuss specific equipments for the execution of the remote operations.

We will consider two overly broad methodological options: interaction with humans and with remotely controlled electronic systems. However, obviously, in the analyzed context, the interaction with humans will necessarily involve the use of some kind of electronic system. These will be discussed in relation to the traditional geological methods (fieldwork, hand sample observation, polarizing microscope, etc.).

We must call the reader attention to an important shortcoming of the discussion presented here: we will not consider safety issues related to the considered procedures (which, in some situations could render then unviable). We will also, in general, avoid limitations related to economic factors.

3. Discussion

Interaction with human agents will be the easiest option to implement in the short term but the least interesting in the long term, especially considering the possible use of these procedures in future professional settings (namely those in extreme environments, for example in extraterrestrial places).

An extremely simple and currently feasible technique for deploying this method of remote operations by communication with other humans will be to implement live interactions between teachers and students. Expectedly, this could be presently done without great effort or cost and there are some examples related to survey of distance places (personal communications to the first author from Prof. C. Leal Gomes and from Ana Patrícia Matos).

The interactive process can include requests from the teacher for the students to perform specific activities (it can also be performed the other way around, with the students requesting actions from the teacher).

During the current pandemic, there has been a more complex situation that nonetheless might be very pertinent for the future: when some students (but not all) are unable to attend laboratory activities. In this situation, it is necessary to preserve the privacy of the students that are present at the laboratory.

In this circumstances, it will be frequent that at least one of the human agents will have to leaves the usual residence and this option might become problematic under conditions of extreme restrictions to circulation (however, for studies performed in places away from human conglomerates, for example for fieldwork, it could be possible to overcome this issue).

Interaction with humans will in principle allow developing any kind of study usually performed in the field or in the laboratory. Besides the problem of communication of commands, there is the major issue of observation at several scales and azimuths. Human flexibility allows using other complementary tools like satellite imaging.

Remotely controlled electronic systems dispense the presence of humans on the studied site (field or laboratory). In principle, this option could be implemented in ways compatible with total human confinement (excluding the need for some human interventions for equipment maintenance). However, there is the question of the distance range for controlling the electronic devices (but we can expect that this will improve significantly in the future). These electronic systems could have several enhancements coupled such as different wavelengths (e.g. for scheelite observation). This is a sector that might grow in the coming years as the necessary technology becomes more accessible.

The first step in performing fieldwork is to define the framework for the terrain survey, namely an initial recognition of the objects that will be studied, which might be modified according to the results of these preliminary data (e.g., further, more detailed studies, of constituents of these objects).

There are already several examples of the use of autonomous electronic systems in terrain studies. We can refer to the study by Kromer et al. [2] concerning the monitoring of mass movements in rock slopes with a land station equipped with a time-lapse camera system. One can also find examples of the use of aerial vehicles in terrain studies related to slope stability [3-5].

One of the challenges for autonomous electronic systems will be to perform some hand tests used for characterizing geological samples such as described in [6]. Perhaps it will be possible to use electronic systems that perform physical tests on-site on the studied rocks and soils. Similar considerations will apply to sample collection.

Regarding laboratory work, students could go to the laboratory at specific times to perform the requested studies and collaboration between institutions would help to overcome travelling issues. In practice, restrictions on the number of students that could be in the laboratory at the same time and the need for the instructor presence could make this excessively costly.

For hand samples, besides the study of samples in the institution spaces, it will be, in principle possible to send the samples to the students' domiciles and afterwards teaching staff can interact with them remotely.

However, some properties of minerals cannot be taught by procedures where the students are physically removed from the samples; for example, taste (the students will lose the “chance” of tasting sylvite) and smell.

Performing studies of hand samples solely by electronic systems seem to be a significant challenge, not only due to the potential difficulties in handling the samples but especially for some of the properties that are frequently used in the study of hand samples of minerals and rocks. This will be the case, namely, for those that involve the manipulation of the samples such as surface hardness, or for organoleptic properties (taste, smell). While, in principle, it should be possible to simulate these data based on the senses through neurological stimulation of the pertinent regions of the brain, besides the technical difficulties, this will certainly raise serious ethical issues. Nonetheless, in principle, any of these properties could be replaced for some kind of instrumental test.

In the case of microscopic studies, it will be harder, but not impossible, at least in principle, to send the physical items to the students, especially petrographic microscopes, which are costly and delicate equipments. It will be exceedingly difficult in practice to distribute them among the usual number of students. But this option might be possible for some students under special circumstances (in a more inclusive perspective). And one can hope that, if there is a market for them, it will be possible to obtain cheaper, sturdier, and more portable microscopes. It will be useful to remember that the first petrographic microscopes were handmade and used solar light (so, this will be a way to promote the use of renewable solar energy and a, albeit small, contribution to decarbonization). There are already publications with instructions for how to make a kind of petrographic microscope [7], albeit without the possibility of obtaining interference figures. While, certainly, it will be a very steep challenge to prepare conditions were students could mount their own petrographic microscopes, the long-term benefits could be enormous. Furthermore, the changes required to prepare sturdier, portable, solar light-based, petrographic microscopes will be much less dramatic than the change from room-sized to pocket-sized computers that happened in less than a century and the change that the first two authors saw during their lifetime from "the" computer in "a" lab to computers in our pockets.

It will be even harder, of course, to send to the students equipments like X-ray diffractometers where safety issues are much direr (impossible at present and it does not seem viable to promote "home-made X-ray diffractometers", namely for safety reasons).

Remotely operated instruments like microscopes or X-ray diffractometers are currently a question of implementation details. An example of a computer-controlled petrographic microscopy can be found in Fueten [8].

The assessment of the potential relevance of these remote procedures in teaching Earth Sciences should consider, also, their eventual impact on future professional activities. Remote operations could contribute to exploration and monitoring studies in isolated and hardly accessible locations, under conditions that limit the movements of people in general and especially in terms of those with temporary or permanent restrictions.

The discussion presented here about the traditional geological studies can be extended to surveys of objects located out of Earth. The teaching perspective could contribute to valuing space missions with the transmission of observation and analysis in real-time. Additionally, the training and investment in the development of remote procedures for the study of geological bodies can contribute to implementing exploration and exploitation operations of other astronomical bodies (in this case by interaction with remotely-controlled electronic systems, at least for the immediate future – but see below). The present relevance of the issues concerning other celestial bodies might be illustrated by the existence of proposals for protection for the geological objects in them, as shown in the publication on exogeoconservation by [9] and will converge with general questions about possible terraforming operations. The possibility of Mars colonization in the relatively near future has been widely discussed by one of the leading companies, see, e.g., [10] and this should be a significant incentive for the developing of these techniques in Earth Science teaching.

The use of remote electronic systems is an area where it seems that some companies are ahead of academic teaching as some other examples help to illustrate [11,12]. This might prompt questions on whether universities are failing one of their main purposes (to prepare students for the workplace).

4. Final considerations

Remote teaching procedures seem presently viable with reasonable investments and in a relatively expedite manner when they are based on interactions with other humans (there will be variable options in terms of the position of students and teaching staff according to the objects and techniques involved).

Besides the more technical details related to observation and communication, one should also consider potential ethical issues (especially in terms of privacy) for distanced lectures using spaces where other students are present.

There are several issues concerning the use of interactions with electronic systems, including the financial costs required by the use of such systems. However, one should consider the many benefits that could be derived from the use of these electronic systems, not only for working students but also in terms of inclusivity. Furthermore, this creates an opportunity for geological teams to collaborate with informatic ones since it could also contribute to the development of electronic solutions with the potential to be implemented in other situations. In a similar fashion to what has happened with other technological solutions (e.g., cars, computers, phones, and also already for drones), one can expect that the development of opportunities for the use of these electronic systems will make them both better and less costly.

While all the procedures discussed here will potentiate the future professional relevance of the students, the use of remotely controlled electronic systems will be especially useful for remote and inaccessible locations and any situation where human access is restricted. This will also include potential operations in extraterrestrial locations.

Universities should consider seriously these remote teaching techniques, looking at groundbreaking examples coming from companies in order to better prepare their students for future professional settings.

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