VIRTUALIZATION OF GEOLOGY AND CRYSTALLOGRAPHY TEACHING RESOURCES: TOWARDS AN IMPROVED (VIRTUAL) LEARNING OF MINERALS, ROCKS, AND FOSSILS

Suset Barroso-Solares[1], Victor Alonso-Gomez[2], Alejandro del Valle[1], Jesus Medina[3], A. Carmelo Prieto[1], Javier Pinto[1]

[1] Archaeological and Historical Materials (AHMAT) Research Group, Condensed Matter Physics, Crystallography, and Mineralogy Department, Faculty of Science, University of Valladolid, 47011 Valladolid (SPAIN)
[2]Department of Physics, University of Valladolid, Campus Universitario Duques de Soria, 42004 Soria, (SPAIN)
[3] Condensed Matter Physics, Crystallography, and Mineralogy Department, Faculty of Science, University of Valladolid, 47011 Valladolid (SPAIN)

Abstract

Our society and, in particular, the high-education system have faced severe challenges since the starting of the COVID-19 pandemic around February-March 2020. The safety restrictions that limited or eliminated face-to-face teaching required the fast development of new virtual teaching strategies. Trying to turn a crisis into an opportunity, these quickly adopted strategies should evolve into fully-developed resources that complement and improve traditional teaching, as well as substitute face-to-face teaching without a significant impact on the students' learning opportunities. However, knowledge fields that require of field practices or to be in contact with actual samples present additional challenges to develop efficient virtualization strategies.

In particular, the direct observation and manipulation of samples of minerals, rocks, and fossils are essential activities in the study of Geology-related subjects. Moreover, in crystallography studies, the students should be able to relate the analyzed dynamic and static structures with the actual materials. Accordingly, in both cases, the absence of face-to-face practical classes with access to minerals, rocks, and fossils collections is a high-impact drawback for the students.

With the aim to overcome this situation, the Crystallography and Mineralogy area of the University of Valladolid has recently started a teaching innovation project to develop a fully accessible virtual collection of minerals, rocks, and fossils. In addition to the traditionally employed datasheets and pictures, this collection includes photorealistic three-dimensional reconstructions of the samples obtained by photogrammetry. This collection includes models developed by other Universities with the same interests, as well as new models developed within this project. The virtual collection is also complemented by detailed information and additional pictures or videos from the samples, also including resources for self-evaluation activities.

Herein, the design and development of this project are described, with a particular emphasis on the impact of the developed resources on the teaching of diverse Geology and Crystallography subjects. Finally, the efficiency and success of this project are evaluated from the feedback provided by the students who can take advantage of these resources, taking their opinions into account to propose further improvements.

Keywords: photogrammetry, vibrational structure, evaluation.

1 INTRODUCTION

The educational disruption caused by the COVID-19 pandemic has been particularly significant in those branches of knowledge in which the development of practices, whether laboratory or fieldwork, is a cornerstone of the training provided.

In the field of Geology, it is essential that students come into contact with samples of minerals, rocks, and fossils. This need, common in all the geology-related subjects, takes on relevance in the case of a Qualifying Master's degree such as the Master required in Spain to be a teacher in high school and vocational training with the speciality of Biology and Geology. The responsibility of the professors of this Master is not limited to preparing future Geology teachers, in which an essential aspect is a minimum of practical training, but also to provide them with the best information and preparation for the overcoming of the competitive examinations that they will have to face for the exercise of their professional activity. Both aspects are intrinsically related, as a high-quality teaching program of a qualifying Master should be able to provide the knowledge and skills required to access and develop the corresponding professional activity.

For this purpose, it should be noted that a test of notable difficulty in these competitive examinations is the *visu* exam, in which samples of minerals, rocks, and fossils must be visually identified. Therefore, it is not possible to conceive of adequate and quality training that does not include practical content by interacting with samples of such materials.

On the other hand, in the field of Crystallography, the direct experimentation in the laboratory with mineral samples allows the students to establish significant relationships between the actual analysed materials and their static and dynamic structures determined by diverse experimental techniques (e.g., Raman spectroscopy, FTIR spectroscopy, X-ray diffraction). However, on numerous occasions, the samples and databases available are not as representative as one might wish. As a consequence, it is possible to find students capable of quickly identifying the Raman spectrum of a particular material, but without having any clue about the aspect of that material, a situation that evidence a lack in the development of meaningful learning.

These scenarios pointed out the need for virtual resources capable of complementing and enhancing the provided trained on Geology and Crystallography related subjects and, particularly, on the abovementioned Qualifying Master. Moreover, the availability of such virtual resources would improve the preparation for potential scenarios of mandatory virtual teaching.

With this aim, the use of photorealistic three-dimensional models, obtained by photogrammetry, is proposed. The realism currently achieved by the photogrammetry technique can provide high-quality interactive models accessible from any device (e.g., computers, tablets, smartphones), being probably one of the best alternatives to the manipulation of actual samples. This approach has already been implemented by universities such as The University of Queensland (Australia) or West Virginia University (USA), while The Geological Society of America and other institutions have proposed the use of photogrammetry models as a promising tool for the training of Geology-related subjects.[1]–[3]

However, this approach has scarcely been developed in Spain, missing the opportunity to improve the resilience of the high education system to situations such as the COVI-19 pandemic, as well as to create a unique and powerful resource for the preparation of the Geology teacher's competitive examinations. Moreover, the potential combination of the crystallographic static and vibrational structures with three-dimensional models to provide a contextualized training has not been previously explored. Aiming to overcome these challenges, in the course 2020-2021 the professors of the Mineralogy and Crystallography area of the University of Valladolid started a teaching innovation project entitled "Virtualization of geology and crystallography teaching resources: towards an improved (virtual) learning of minerals, rocks, and fossils", that has been financed by the University of Valladolid (Spain).

Herein, the preliminary results of this innovative project are presented, documenting the available resources and developed approaches.

2 METHODOLOGY

2.1 Samples selection

A total of 35 samples, comprising minerals, rocks, and fossils, of the collection of samples employed in the practical training of Geology-related subjects were selected for the first stage of this project. The list of samples can be found in Table 1. For each of these samples, a detailed datasheet with information and diverse available and developed three-dimensional models are prepared.

Table 1. Samples included in this project.

Number	Minerals	Rocks	Fossils
1	Goethite	Andesite	Trilobite
2	Malachite	Sandstone	Ammonites

3	Barite	Basalt	Orthoceras
4	Quartz	Bauxite	Goniatites
5	Muscovite	Limestone	Leptolepids
6	Pyrite	Conglomerate	Phrynosoma
7	Calcite	Quartzite	Shark Teeth
8	Aragonite	Diorite	Fossilized fern
9	Lapis Lazuli	Phyllite	Belemnite
10	Azurite	Gabbro	Turritella
11		Gneiss	
12		Granite	
13		Granodiorite	
14		Pegmatite	
15		Pumice	

2.2 Photogrammetry models

A dedicated photogrammetry setup was developed, including a lightbox, diffuse annular lighting, an automatic rotatory platform, and a camera Canon 2000DK. Photogrammetric reconstructions were obtained using Agisoft Metashape Standard Edition (Educational Licence). The developed models were uploaded to the Sketchfab platform. Moreover, already high-quality available models developed by other educational or research institutions were reviewed, selecting the most representative to extend the developed collection.

3 RESULTS

The following subsections detail the advances of the project in the development of the new training resources, which have been recently available for the students. Future works will discuss the medium and long-term impact of this project on the training and performance of the students.

3.1 Development of samples datasheets including three-dimensional models

One of the first tasks of the project was to select the relevant information to be included in the new datasheets, taking as an example and updating, when necessary, the teaching material developed in the last decades by the Crystallography and Mineralogy area. Then, it was decided to develop the new datasheets in a PDF format instead of on a web-based platform. This decision was made to allow the resources to be useful even without an internet connection.

Accordingly, in each datasheet, it was incorporated one three-dimensional model available directly on the PDF file (all the employed and developed models are licensed under Creative Commons Attribution). Moreover, links to additional available models on the Sketchfab platform are provided on each datasheet. In this way, access to at least one model is ensured even without an internet connection, while additional resources are easily available if an internet connection is available.

A total of 35 datasheets have been developed in this stage of the project, including more than 70 three-dimensional models. An example of the developed datasheets is shown in Figure 1.

Figure 1. Example of the datasheet of Andesite. On the left side, a high-quality picture is included, whereas the interactive three-dimensional model is placed on the right. It should be noticed that the texts are currently only available in Spanish. The developed resources will be translated to English in future stages of the project.

Moreover, information about the static and vibrational structure of minerals (i.e., X-ray diffractogram, Raman and FTIR spectra) is being included in the corresponding models. An example of the final expected result can be found in Figure 2.

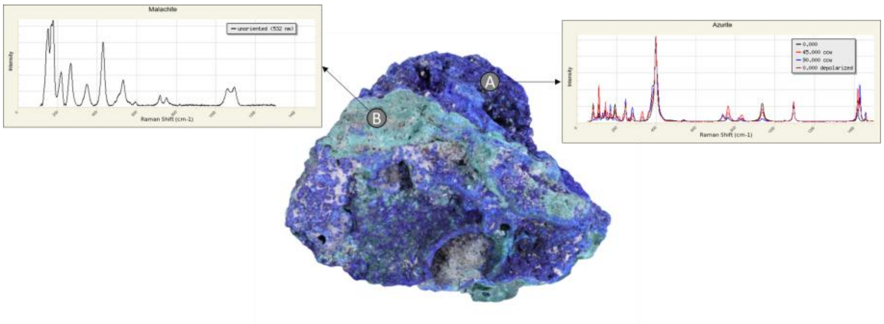

Figure 2. Example of an annotated model of Azurite and Malachite. The initial model is available as "Azurite and malachite #15106 07-29-2020" (https://skfb.ly/6VYOH) by rocksandminerals and licensed under Creative Commons Attribution (http://creativecommons.org/licenses/by/4.0/). Raman spectra are obtained from the RRUFF Project (https://rruff.info/)

3.2 Development of self-evaluation activities

The availability of tens of high-quality three-dimensional models allowed not only to produce teaching resources but also to incorporate new self-evaluation activities to improve the students training. In a first step, self-assessment Moodle questionaries were developed, including a bare three-dimensional model (i.e., without annotations, labels, or legends) and three options to identify the correct name of the sample shown in the model. The first attempts employing these questionaries clearly shown the advantages of this approach. Instead of a plain picture, the possibility of interacting with the model, appreciating the volume of the sample, having a clear idea of the textures and shapes make a notorious advance in the students training. Then, it was possible to create questionaries with an increasing level of difficulty. The questionaries with the greater difficulty provide among the potential answers similar materials, being necessary to pay attention to fine details of the studied sample. An example of this first type of questionaries is shown in Figure 3.

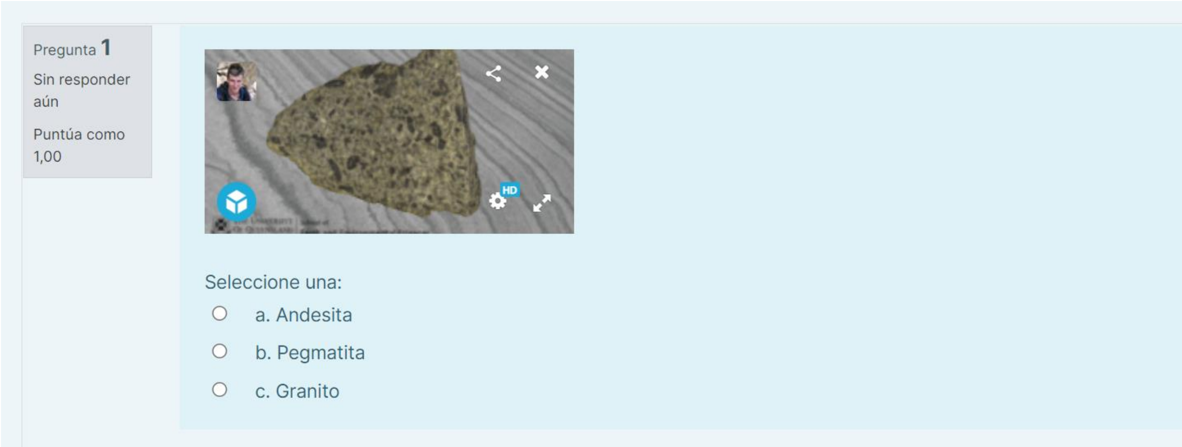

Figure 3. Example of a self-evaluation questionary showing diverse choices for the sample that should be identified. It should be noticed that the texts are currently only available in Spanish. The developed resources will be translated to English in future stages of the project.

Moreover, as mentioned in the introduction, the preparation of the *visu* exam included in the competitive examinations for future Geology teachers is one of the main objectives of this project. Accordingly, a simulation of this exam was implemented in the Moodle platform of the University of Valladolid. In this case, a random three-dimensional model is shown on each question, and the students should write down the name of the corresponding mineral, rock, or fossil. This feature has been recently implemented, receiving very positive feedback from the students. One of the main advantages of this approach is that this virtual practical training is not limited to the available collection of samples in a laboratory, classroom, or museum, being possible to substantially enlarge the samples that the students can observe and identify while preparing for their exams. An example of a question of this simulation of the *visu* exam is shown in Figure 4.

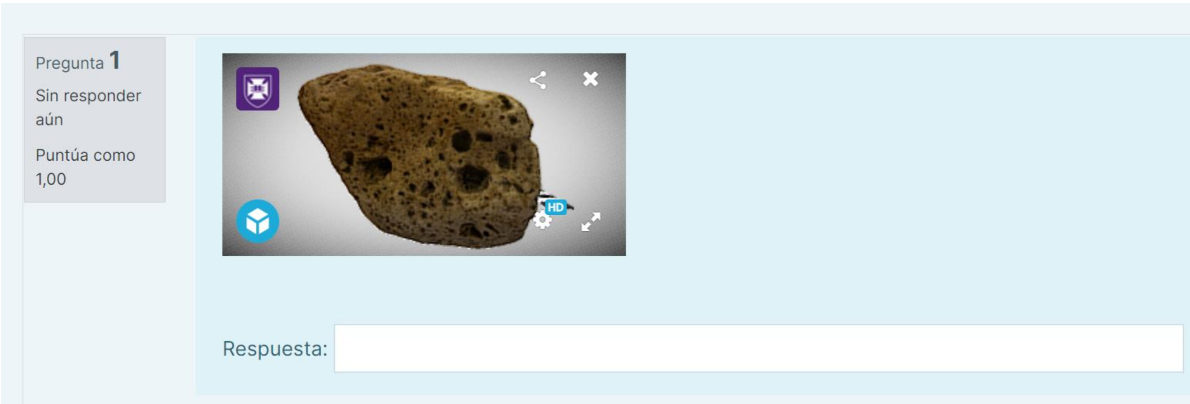

Figure 4. Example of a question of the simulated visu exam. It should be noticed that the texts are currently only available in Spanish. The developed resources will be translated to English in future stages of the project.

4 CONCLUSIONS

The development of this innovative teaching project has evidenced the potential of the proposed techniques (e.g., photogrammetry) to provide high-quality virtual resources for the practical training in Geology-related subjects. Particularly, the wide availability of available three-dimensional realistic models, and the possibility to develop new models of specific samples, make the generation of virtual collections of minerals, rocks, and fossils a remarkable teaching resource. Although it is still too early to evaluate the impact of this project on the students training, the positive feedback received indicates the value and appropriateness of the new resources developed.

ACKNOWLEDGEMENTS

Financial assistance from the University of Valladolid (PID2021_117) and Junta de Castile y Leon (VA210P20) is gratefully acknowledged.

REFERENCES

[1] G. D. M. Andrews, G. D. Labishak, S. R. Brown, S. L. Isom, H. D. Pettus, and T. Byers, "Teaching with Digital 3D Models of Minerals and Rocks," *GSA Today*, vol. 30, no. 9, pp. 42–43, 2020.

[2] I. Díaz Martínez, P. Citton, S. De Valais, and E. García Ortiz, "La fotogrametría se convierte en una poderosa herramienta para la conservación y difusión del patrimonio paleontológico," *Rev. PH*, p. 20, 2018.

[3] D. G. De Paor, "Virtual Rocks," *GSA Today*, vol. 26, no. 8, pp. 4–11, 2016.