The impact of online teaching on Geology degree programs during COVID-19: A case study from the University of Barcelona (Spain)

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ABSTRACT

The sudden shift during the COVID-19 lockdown from face-to-face to online teaching clearly impacted degree programmes in Geology characterised by a substantial practical teaching methodology. This study analyses the suitability of online teaching in the degree at Geology of the University of Barcelona by: 1) describing the strengths, weaknesses, opportunities, and threats (SWOT) from the point of view of online teaching and learning, 2) addressing two surveys to teachers and students to explore the consequences of online teaching on learning and gained competencies, and 3) analysing pre-, syn- and post-pandemic academic results. Results show that both teachers and students value the learning resulting from online activities and the acquisition of new skills. However, some perceived that critical competencies cannot be achieved online, such as the field and laboratory work required for professional development. Moreover, students had difficulties maintaining attention and starting discussions, while instructors had difficulties properly monitoring students such as to control exam fraud, due to the lack of the necessary tools.

Online teaching during the pandemic influenced instructors' grading of students and likely led to some leniency with grading, as teachers admit, consistent with the higher student grades and decrease in second-chance examinations in 2019–20. We conclude that in a potential new online or blended teaching scenario, the full acquisition of practical and communicative competencies is a key point that should be accurately managed in Earth Science degree programmes.

Keywords Geology, higher education, online teaching, COVID-19, SWOT analysis

INTRODUCTION

The COVID-19 disruption during the 2019–20 academic year forced a complete lockdown of all universities over the world with a subsequent radical change in the traditional education system (García-Peñalvo et al., 2020; Samson, 2020). Online courses, and later, blended courses, were abruptly implemented and, in most cases, without any previous preparation for teachers or students who were used to face-to-face (F2F) classes (Gonzales & Keane, 2020; Day et al., 2021; Díez-Gutiérrez & Gajardo, 2021). Despite this change, there is a consensus that online teaching was the most effective way to mitigate the impact of COVID-19 on education (Dampson et al. 2020; Gyamerah, 2020).

In the geosciences, the impact of the COVID-19 lockdown could be greater than in other disciplines because, in addition to traditional lectures, Earth Sciences degrees require laboratory sessions and field classes (King, 2008) to gain analytical, observational, and practical skills. The use of specific instruments (microscopes, magnifying glasses, stereoscopes, laboratory equipment, etc.), and hand samples (minerals, rocks, or fossils) available either in the classroom or in the field, are of key importance in Geology degree programmes. Similarly, field work enables students to train their 3D visualization skills

(Hannula, 2019), which are essential for the interpretation of the landscape and geological processes, as well as for the characterisation of geological bodies and the spatial relations between them. Fortunately, during the lockdown a large number of active and imaginative resources were designed to replace the basic school laboratory equipment and field work —from virtual field trips, videos, TV programmes, smartphone apps or podcasts, among others, with new and revisited websites with a myriad of activities being implemented (King, 2020; Pokhrel & Chhetri, 2021). Many newly developed virtual field trips and other resources are now available in the literature (Bond & Cawood, 2021; Rader et al., 2021; Barth et al., 2022; Bursztyn et al., 2022; Paz-Álvarez et al., 2022) and on websites (e.g. Geología en Acción, n.d.; NAGT, 2022). In the specific field of mineralogy and petrology, optical mineralogy tutorial videos were shared, showing multiple examples that cover a range of characteristics in thin sections (Kohn, 2021). In the field of geodynamics, examples of 3D faults at different scales around the world (Carena, n.d.), videos for practising stereonet plotting (University of Liverpool, n.d.), or videos showing general principles or data acquisition using geophysical instruments (IRIS, n.d.) were made available. In addition, some publishers provided free access to key textbooks to support learning and teaching worldwide in order to help ease the sudden change to remote learning and working during the pandemic (Springer Nature, n.d.).

A broad literature about online teaching during COVID-19 lockdown has been published over the last two years (see Pokhrel & Chhetri, 2021, and references therein); however, fewer studies are focused on geosciences degrees (Samson, 2020; Day et al., 2021) and just a few of those deal with geology programs (Gonzales & Keane, 2020, 2021). In order to fill this gap and to analyse the suitability of virtual teaching and learning methods in geology courses, we present a case study of the degree of Geology offered by the University of Barcelona (Spain) after the pandemic experience. Specifically, the objectives of the study are: 1) to describe the strengths, weaknesses, opportunities, and threats of online teaching in the degree of Geology (University of Barcelona), 2) to present the results of the teaching staff and student surveys regarding their impressions about online teaching carried out during the academic years 2019–20 and 2020–21, and finally, 3) to analyse the effects of online and blended teaching on academic results, together with surveys' results.

BACKGROUND

Learning outcomes in geology programs

Most of the Geology degree programs in Europe follow the guidelines described in the Tuning Educational Structures in Europe (2009) project, which highlights the points of reference and convergence expressed in terms of learning outcomes and competencies to be obtained by the student. Understanding of Earth systems deals primarily with the study of materials, processes and history of this and other planets in order to learn from the past, understand the present, and predict and influence the future. Earth Sciences offer a distinctive education by providing a systematic multi- and inter-disciplinary approach to complex natural systems. Most would agree that students develop a satisfactory understanding of Earth Sciences with significant exposure to field-based learning and teaching (Elkins & Elkins, 2007; Kelso & Brown, 2009; Petcovic et al., 2014).

Field training embraces a wide range of spatial and temporal analytical skills, and encourages undergraduates to use their powers of observation, analysis, and imagination to make decisions in light of uncertainty. In the field, students are required to take notes, make sketches, take photographs and samples and to make measurements, and often to write a short report which is assessed along with the field notes. The Tuning Educational Structures in Europe (2009) project highlights the fact that Earth Sciences develop intrinsic ways of thinking, such as: 1) the awareness and understanding of the temporal and spatial dimensions of Earth processes and 2) the ability to integrate field and laboratory evidence with theory following the sequence from observation to recognition, synthesis, and modelling, which are not transferable to many other disciplines. In this sense, if practical work in laboratories and in the field is necessary for the acquisition of some specific competencies, how suitable is online or blended learning in the Earth Sciences in higher education?

The degree of Geology at the University of Barcelona is taught at the Faculty of Earth Sciences, which is the second largest Faculty of Earth Sciences in Spain (*ca.* 80 instructors) after the University Complutense of Madrid (*ca.* 103 instructors). In 2020–21, at the Faculty of Earth Sciences, there were 175 students; 36% were female, 60% were 20 years old or younger and 94% of our students were from Spain. The degree has a total of 240 credits (ECTS — European Credit Transfer System) similar to other First Cycle Bachelor degrees in Spain, but different from the 180 ECTS model followed by many other European countries (Tuning Educational Structures in Europe, 2009). The curriculum consists of introductory level, namely, basic courses (60 credits, 1st year), required courses (150 credits, 2nd, 3rd, and 4th year), elective courses (18 credits, 4th year) and the compulsory final project (12 credits). Although the academic year is structured in semesters (from September to January and from February to June), more than 50% of the courses taught continue for the whole academic year (September to June) because they are the equivalent of 9 to 12 credits (see University of Barcelona, n.d.a). Teaching activities in the degree of Geology (University of Barcelona) are traditional, fully F2F, and consist of theoretical and practical classes—computer, laboratory, and field practices—and assessments. This degree has about 60% of its courses with computer and laboratory practices, while 80% include field work. This has probably been the main limitation of online teaching in geology over the world, as it is difficult to establish an appropriate learning pathway for the acquisition of such practical skills.

Academic adaptations during COVID-19

The COVID-19 pandemic and all the restrictions imposed had a major impact on the teaching method. The 2019–20 academic year began as usual, and on March 12th 2020, due to the lockdown, all F2F activities were suspended until the end of the academic year. From March 13th onwards all teaching activities (theoretical and practical classes, field trips, and assessments) were done online and started following the general guidelines for online assessment in higher education published by the Spanish Network of University Quality Agencies (REACU, 2020a, 2020b), the National Agency for Quality Assessment and Accreditation (ANECA, 2020), and the Ministry of Universities (González et al., 2020; García-Peñalvo et al., 2020).

In the degree of Geology (University of Barcelona), the radical change did not affect the development of the courses for the autumn semester, and the impact on the development of annual courses was variable, and approximately 65–70% of the activities were carried out normally. The maximum impact took place in the compulsory and elective courses of the spring semester, which could only normally develop 25–30% of their scheduled activities. It should be noted that the most affected teaching activities were field trips and exams, which are usually concentrated in the last weeks of the semester. The most extreme cases were found in two elective courses consisting of an intensive one-week field course, scheduled for May and June. COVID-19 restrictions also affected the 2020–21 academic year. Computer and laboratory work, exams and field trips were scheduled F2F because they involved small groups and outdoor activities. However, only half of the theoretical classes were initially scheduled F2F despite the fact that they were indoors and implied a larger number of students. Later on, the progression of the pandemic forced all theoretical classes to be held online from November 2020 until the end of the academic year.

METHODOLOGY

Research design

Several qualitative and quantitative research methods were used in this study. The qualitative methods involved the use of SWOT analysis (see next section), while the quantitative ones included the analysis of student grades, both prior to and after the use of online teaching, and the development and deployment of surveys to both geology instructors and undergraduate students in order to assess their perceptions of online instruction. The authors develop and oversee academic responsibility at the faculty of Earth Sciences, and thus have in-depth knowledge of the students, the course curricula, the competencies, the legislation, and the quality indicators needed for degree accreditation. As seen in Figure 1, the SWOT analysis was the starting point to prepare the questionnaire of the surveys; meanwhile the recompilation and the analysis of the grades were conducted with the purpose of understanding potential changes to the grades, from pre- to post- pandemic, and to contrast them with the surveys' results. Our study also benefited from a previous online survey focusing on the perceptions of the teaching staff entitled, "Online teaching during the alarm state at UB" (in Catalan) (IDP, 2020) launched in July 2020 by the University of Barcelona.

SWOT analysis

SWOT analysis is an established method that aims to identify the strengths (S) and weaknesses (W) of an organisation and the opportunities (O) and threats (T) in the environment with the purpose of formulating strategies to build on the strengths, eliminate the weaknesses, exploit the opportunities or counter the threats (Dyson, 2004). The SWOT analysis was originally developed for business marketing, organizations or other entities (Proctor, 1992; Dyson, 2004; Chermack & Kasshanna, 2007; Helms & Nixon, 2010; Nekoueizadeh et al., 2016). Moreover, it has been successfully applied to other topics such as health, social work (Westhues et al., 2001; Sharma, 2005), revisions to undergraduate business curricula (Kuiper & Thomas, 2000), strategy formulation for vocational education (Lee et al., 2000), instructor peer review (Thomas et al., 2014), field work (Munge et al., 2017), and for assessing the impact of online teaching in higher education settings (Hightower et al., 2011; Ali et al., 2019; Santandreu Calonge et al., 2022; He, 2022).

The SWOT tool is used in this study merely as a description of the strengths and weaknesses (internal factors) and the opportunities and threats (external factors), rather than as a strategic development process (see Goodstein et al., 1993; Dyson, 2004). We focus on the pros and cons of online teaching in the degree of Geology from the points of view of teaching and learning. As a starting point, we used the results of the previous online survey at the University of Barcelona, which was addressed to the entire academic staff of the university (883 respondents, representing 15.5%). Only the 20 responses from the academics at the faculty of Earth Sciences were considered for our purpose. The adopted approach was an informal discussion where each of the authors proposed a factor for each issue based on our perceptions as instructors. Firstly we addressed the online teaching experience and later the learning experience of the students. After a process of reflection, we created a table that summarized the SWOT results from the point of view of teaching and learning for each issue, ranked by importance. Finally, a small group of students, who were in their last year, reviewed the students' SWOT analyses.

Instructors and student surveys

We used surveys (Evans & Mathur, 2005; Bryman, 2016) with both closed and a small number of open-ended questions addressed to instructors and students of the degree of Geology at the University of Barcelona. The surveys were designed to provide a better understanding of the effects of online teaching on the geology students' knowledge and competence gained. The questions raised were specific for each of these two groups, resulting in two independent surveys. All the questions were proposed, debated, and agreed upon by the research team. The final surveys are divided into five sections in order to make it faster and easier to answer and collect valuable results. Surveys were created using Microsoft Forms, an online software with a user-friendly interface that is widespread in the University community (see Supplemental Material).

The 32 questions for teachers (22 closed-ended questions and 10 open-ended questions) were divided into five sections including: 1) general questions about the courses taught during the pandemic lockdown (n = 9); 2) online teaching (n = 8); 3) online examinations (n = 7), 4) final degree project (n = 6), and 5) a question regarding the achievement of the specific competencies of the bachelor's degree (n = 1). In addition, a final open question, "supplementary comments" was created to allow participants to clarify, justify, or introduce new arguments related to the online teaching experience. Within closed-ended questions, five needed a "yes/no" response, one was a single multiple-choice question, six included matrix tables with checkboxes, and ten were "choose all that apply". Most of the open-ended questions were formulated to expand responses of previous multiple-choice or multi-select questions. One open question was related to the online platform (e.g., Zoom, MS Teams, Google Meet or BBCollaborate) used by instructors since the lockdown. It is noteworthy that, prior to the lockdown, institutional platforms had not been officially implemented. The electronic survey was sent out using an e-mail invitation on a listserv of current students' and instructors' databases and was open from late March to the end of April 2021. The median time taken to complete the survey was 11 minutes. It yielded 40 anonymous responses, representing a survey participation of ~ 50% of Geology degree instructors (versus the 22% gathered by the previous survey at the University of Barcelona). Even though 40 responses are fewer than desired in terms of statistical analysis, it is acceptable considering the limited number of instructors in Geology degree programmes in Spain.

For students, 14 questions were asked (9 closed-ended questions and 5 open-ended questions), divided into the same five sections as those surveyed for instructors, and with the same final open question. Within closed-ended questions, two needed a "yes/no" response, one was a single multiple-choice question, three included matrix tables with checkboxes, and three were "choose all that apply". Most of the open-ended questions were formulated to expand responses from previous multiple-choice or multi-select questions and one open-ended question was related to the positive or negative aspects of online assessments. The electronic survey was opened from late April to mid-May 2021, and yielded 81 responses, representing survey participation from about 50 percent of the geology degree students. The median time taken to complete the survey was 8 minutes.

Both surveys were disseminated by email to all instructors and students from 2nd to 4th year. We analysed the frequency of responses respectively for the 22 and 9 closed-ended questions and we used the open-source software Orange v 3.27 to find the most repeated words in open-survey questions. Herein we have classified all the open-ended responses and included their main results in the predefined five categories.

Analysis of the academic grades

The analysis of academic results considered the grades from all courses (basic, required, and elective) obtained by students from the degree of Geology. The three academic years prior to the pandemic crisis (2016–17, 2017–18, and 2018–19) have been considered as a reference. The 2019–20 academic year was affected by the lockdown and the suppression of all F2F activities during the spring semester, and the 2020–21 academic year was characterized by a blended learning experience with all theoretical classes being held online. Grades for all courses throughout the analysed period are publicly available at the University of Barcelona (n.d.b).

The grades for the degree of Geology, as with all Spanish universities, are numerical with a scale ranging from 0 to 10. These numerical values are grouped into a series of descriptors: Fail (0 to 4.9), Sufficient (5 to 6.9), Good (7 to 8.9) and Very Good (9 to 10). The Excellent grade is an honourable mention that is only awarded to a maximum of 5% of the total number of students enrolled in a course and requires a grade between 9 and 10. In our analysis, students who qualified with Excellent have also been included in the category Very Good.

The evolution of the yield rates (related to the percentage of students who pass a course in relation to the total number of students enrolled) of the basic and required courses throughout the considered period has been analysed in detail. Elective courses, often with few students enrolled, and the final project were not analysed because in both cases the yield rates are always above 90% and often reach 100%. Moreover, in the analysis of yield rates, those courses not affected (or minimally affected) by the lockdown during the spring semester of the 2019–20 academic year have been separated from the rest.

RESULTS

SWOT analysis

The following is a synthesis of the results of the two SWOT analyses, the first focused on the teaching point of view (instructors) and the second on the learning point of view (students) (Table 1). The main result of both SWOT analyses is that Geology degree teaching during the pandemic was strongly limited by the lack of practical training activities for students. This mainly affected critical capacities such as field work, instrument skills (use of lenses, microscopes, stereoscopes, laboratories, hand specimens, etc.), and image analyses, such as maps, seismic profiles, etc.

Teaching point of view

The most important strength derived from the COVID-19 pandemic was the collective adaptation to the new situation. In this regard, the sudden lockdown and associated restrictions forced instructors (in a positive way) into rapid reaction in order to adapt themselves to the new circumstances (new online tools, methods, communication channels, etc, some completely unknown for most of them). Moreover, the online work enhanced the coordination of teaching teams and in addition to the autonomous work of the students.

Regarding opportunities, the situation was seen as an opportunity to learn new ways and tools to improve instruction and to review and renew old teaching content. The classrooms were equipped with new remote teaching interactive tools (video presenters, digital whiteboards, recording systems, digital image collections of thin sections or of hand specimens, etc.), which nowadays remain fully implemented in the classes. Online teaching reduced the expenses of many students who stayed home and were thus able to follow the courses on a lower budget (no need to rent an apartment near the university, no commuting expenses, etc.). Most of these new technologies and changes also impacted the professional skills of the students and instructors concerning communication, technology, or pedagogy. Finally, the new situation required teaching staff and students to better manage their time, which is also a necessary skill for a geologist.

The main weakness from the teaching point of view was the insufficient and inadequate training in online technologies and teaching during pre-pandemic times. Moreover, the new situation led to a significant reduction of interaction between instructors and students in online activities (for example, difficulties in visualizing the faces—and thus, the emotions—of the students while teaching), the difficulty to maintain students' attention in online classes, and the lack of tools to detect plagiarism. An additional weakness pointed out was the lack of hands-on teaching, both in the laboratory and in the field, which may result in the difficulty of teaching/learning some of the most characteristic and basic skills of the degree programmes in Geology. An increase in the time devoted to preparing teaching activities compared to pre-pandemic teaching was also highlighted as many new tasks had to start from zero to replace the onsite class with new online activities.

The key threats mentioned were the decrease in the teaching quality, the increase in the stress of instructors due to being constantly connected with students and the potential permanent substitution of field work by online activities. Other potential threats considered were the difficulty in following students in a personalized way, the increase in plagiarism or the cost of online teaching from home in terms of internet connections, equipment, and air conditioning.

Learning point of view

The most important strengths that students attained from online classes were an increase in their computing skills, more flexibility of studying hours, higher accessibility to learning materials because of their online location, and their capacity to adapt to the new situation. Regarding opportunities, key points included the possibility to follow online activities independently of the location and the better accessibility of online activities for disabled persons.

On the contrary, the most important weakness of concern to the students were: 1) lack of specific computing skills, 2) lack of computing tools such as high-speed internet, poor equipment, access to specific software with campus licenses, etc., 3) lack of field or lab practicum, 4) lack of social interaction and reduced teamwork training, and 5) lack of the incentive to follow online teaching. Regarding threats, a loss of F2F interaction with classmates and the institution, an increase in distractions, and a loss of concentration to follow teaching activities, were highlighted.

Teaching staff and student surveys

General questions

According to the survey results, nearly all academics (93%) were involved in online teaching during the lockdown. Forty-five percent of them participated in the required courses from the 2^{nd} to 4^{th} year, 17% in the 1^{st} year and elective courses, and 46% supervised at least one final degree project. Fifty-one percent participated in theoretical sessions, 26% taught practical classes and 23% instructed field courses. The most extensively used online platforms during the lockdown were those provided by the University of Barcelona (BBCollaborate and Moodle). At the same time, 34% and 48% of the students attended the 1^{st} year courses and the 2^{nd} to 4^{th} year compulsory courses, respectively. Fourth-year elective courses were followed by 10%, and 10% carried out the final degree project during the lockdown.

Both groups (79% of instructors and 72% of students) stated that the lockdown, restrictions and associated virtual teaching methodology caused them some mental health issues, with stress and anxiety being the most common. This kind of result concerning health has been reported in other studies (Gilsbach et al., 2021; Lee, 2020; Wang & Wang, 2020) and remains outside of the scope of our study.

Online teaching

The most striking result after the online teaching experience of academics is that field and F2F practical training cannot be replaced by online education. This is especially overwhelming for field activities in which 81.1% of the surveyed staff considered online teaching as an obstacle to achieving the competencies of the degree.

There are several factors of online teaching that have negatively affected the development of online lessons. Lack of eye contact (i.e., students usually switch off their cameras) and the difficulty of starting debates are the ones with high negative impact according to 90% of teachers. Similarly, 85% of students consider the difficulty of maintaining attention and initiating class discussions to be the worst factors of online teaching. Other factors identified by the academics as weaknesses associated with online lessons include: 1) impoverishment in the transmission of values (e.g., rigor, honesty, and collaboration), 2) non-achievement of general and specific competencies (e.g., teamwork and communication skills), and 3) excessive workload to prepare teaching materials, which affected their research activity. By contrast, 80% of teachers contemplated online teaching as a good opportunity for improving technological tools and virtual environment skills. In addition, almost 60% of the academics stated that students completed the contents of the course, and also recognised that the costs of working at home during the lockdown were irrelevant.

Instructors and students considered that part of the theoretical lessons could be done using online platforms without affecting the competencies plan. However, 50% of instructors and up to 79% of students believe that practical teaching cannot be taught online. Exceptions were exercises using technology with or without geological-specific software (geographical information systems, data interpolation, statistical and seismic software, among others). In such cases, blended teaching could be an option for more than 40% of teachers and students. During the lockdown, field work was replaced by activities using Google Earth (22%), field and rock sample images (30%), and videos (23%).

Online examinations

Concerning those questions related to the perception of teachers and students about the results of the online exams during 2019–20, 62% of academics perceive that the grades were higher, whereas the majority of students (53%) identify them as being lower. Seventy percent of instructors felt uncomfortable with the online assessment carried out during lockdown and believe that the results of the online exams do not properly reflect the knowledge of the students.

The most important issues reported by teachers about online examinations were connectivity problems and the complexity of controlling fraud in online assessments. In addition, the development of online exams, especially those which required the identification of rocks and minerals, was also considered a negative impact of online assessment. However, 50% of academics considered the positive aspect of the possibility of automating the procedure of designing and correcting exams.

Final degree project

Forty-six percent of the teaching staff supervised a final degree project during the lockdown. Half of them complained about the difficulty in interacting with students, the longer execution time of the project, as well as adversities in obtaining experimental data. These observations were similarly highlighted by the students.

After their unexpected online experience dealing with final degree projects, 70% of instructors consider that it could complement the classical F2F procedure. According to them, online supervision could improve the follow-up of the projects, as it is easier to arrange meetings (fewer timetable limitations, reduced mobility costs, and broken barriers to accessing departments and personal offices) and to share results and new ideas. Furthermore, the other 30% contemplated online supervision as a time-consuming approach and considered field work and laboratory activities essential for the successful final degree projects.

Specific competencies of the degree of Geology

More than 50% of instructors consider that most of the competencies of the degree of Geology (Table 2) cannot be achieved virtually or that they at least require significant modifications and efforts. According to instructors (and also reported by students), the specific competencies that are unfeasible to acquire by means of online activities include: 1) practical (hands-on) experience while working with various types of rocks, structures, landscapes, and other natural processes, 2) the ability to collect, process and interpret data from the field and other sources in a rigorous way, such as to analyse them in the laboratory or classroom, and to document the results in a report, 3) the skills necessary to independently carry out research in the field of geology, and 4) the capacity to observe and understand the environment.

There is a striking disagreement between instructors and students regarding the achievement of certain specific competencies, by means of virtual teaching. In particular, students consider “Comprehensive knowledge of the Earth system and understanding of its characteristics, processes, history and materials” as one of the least affected (80%) competencies by virtual methodology, whereas 78% of instructors believe that this competence cannot be achieved virtually or should require modifications and significant efforts. Furthermore, both groups agree when considering that the competence “Knowledge of the applications of geology and the role that it plays in society” is easily achieved through online teaching (Table 3).

Analysis of academic results

Figure 2 shows the evolution of the final grades for each course of the degree of Geology from the academic year 2016–17 to the academic year 2020–21. According to these results, the percentage of Fail marks decreased in all academic years from the 1^{st} to the 4^{th} year, from values up to 30% to less than 3%. There is always a high number of students in the 1^{st} year that account for Fail marks, because the 1^{st} year is selective, and therefore only those students who pass all the courses within two years at most are allowed to continue.

For a given year (1^{st}, 2^{nd}, 3^{rd}, or 4^{th}) the distribution of the marks is quite consistent throughout the analysed period in this study. Only some changes are observed for the academic year 2019–20 (for the 1^{st} and 2^{nd} years), where the percentage of students who failed the course increased. Despite being also affected by the COVID-19 pandemic, no significant changes were observed in the grade distribution for the 3rd and 4th years of 2019–20. The behaviour of the academic year 2020–21 is similar to those before COVID-19.

Concerning yield rates, most of the courses affected by the COVID-19 pandemic show a clear increase of this indicator during the academic year 2019–20 and a clear decrease during the academic year 2020–21 (Fig. 3). This applies to most courses although there are some exceptions: 1) Chemistry (1st), Mathematics (1st) and Metamorphic Petrology (3rd) do not show any significant changes between the different academic years; 2) Biology (1st) and Crystallography (1st) show a continuous yield rate decrease since 2018–19; 3) the yield rate of Basic Geology (1st) and Geological mapping II (3rd) decreases in 2019–20, and increases in 2020–21 up to values similar to or higher than values of prior years (Fig. 3).

There is a set of courses not affected by the COVID-19 pandemic during 2019–20 academic year that only show minor changes in their yield rates because their activities were almost 100% completed when the lockdown started. Geological Mapping I (2nd) and Subsurface Geology (4th) yield rates show a continuous increase since 2016–17, because they were not affected by the lockdown. However, for three courses of the 3rd year (Geophysics, Igneous Petrology, and Geochemistry), the yield rate behaviour is similar to that observed for most of the courses affected by the pandemic in 2019–20.

Additionally, during the academic year 2019–20 the number of second-chance examinations was 105, lower than the 130 and 169 second-chance examinations done in the pre- and post-pandemic years, respectively.

DISCUSSION

The suspension of classes due to the pandemic lockdown brings us the unique opportunity to test the advantages, disadvantages, and challenges of synchronous online or blended teaching in Geology degree programs. Some considerations must be addressed regarding the suitability of online teaching in those Geology programs strongly based on practical classes, as an adaptation to virtual education in the future is highly feasible (Bettinger & Loeb, 2017). Considering that learning outcomes and earned competencies by students are factors to be taken into account to scaffold the validity of online methodology, we discuss two essencial competencies from the SWOT and surveys results that the students must achieve (practical and communicative) and consider the advantages or disadvantages of online teaching for the particular case of the degree of Geology (University of Barcelona).

Practical competencies

One of the most remarkable results of our surveys is the alignment between instructors and students when considering the loss of the field work and the lack of specific instruments as major weaknesses (Table 3). Many previous studies have pointed out the importance of field work as it is essential to the education of future geologists (e.g., Drummond & Markin, 2008; Mogk & Goodwin, 2012; Petcovic et al., 2014). However, less attention has been paid to the use of specific methods or instruments (e.g., microscopes) in the classroom that are fundamental to the analysis of earth materials (Gunter, 2004; Michels et al., 2016).

The lockdown occurred at the worst possible time, at least for students, since the main field work is carried out during the spring season (Senger et al., 2021). To solve this problem, one alternative was the preparation of field sessions by means of 3D virtual excursions (Bond & Cawood, 2021; Bursztyn et al., 2022; Paz-Álvarez et al., 2022). Nevertheless, in the field, students use their own observations and simple tools to make descriptions and eventual interpretations, while instructors help them by fostering discussions and designing activities to test their observations (Kastens et al., 2009). The

COVID-19 pandemic put an immediate stop to onsite discussions about outcrops and inhibited the opportunity to integrate the variety of scales, dimensions and complexity that field work offers (King, 2020). Following the Tuning Educational Structures in Europe (2009) ideas, in the Earth Sciences curricula programs, students ought to practise their sense of observation and analysis for understanding the temporal and spatial dimensions in the field. In this regard, Earth Sciences require a high level of spatial ability thinking and, therefore, digital tools could certainly assist students during online teaching to help visualise geological structures or to improve the comprehension of geological cross-sections, even though the computer monitor image is two-dimensional (Kali et al., 1997). King (2008) considers that computer animations provide a valuable new tool for the development of this spatial ability. However, virtual field excursions cannot completely replace the onsite field work. On the one hand, field-based skills such as defining the grain size of a rock, evaluating the hardness of a mineral, or measuring the orientation of structures cannot be virtually performed because handling rock samples or geologist's compass by hand is a very useful physical practice. On the other hand, the ability to properly understand how rock structures interact with three-dimensional topographic surfaces, or how different rocks crosscut among them, requires specific visual training that depends on the level of each student. In our experience, virtual field work works most effectively as a complementary tool, as previously pointed out by Senge et al. (2021).

Other important skills acquired in the field are aspects related to the social dimension (see Bali & Liu, 2018; Means & Neisler, 2021). Interpersonal relationships are prevalent in the field, teamwork and group discussions among students are very frequent and clearly increase successful learning. However, online courses are also viewed as offering fewer opportunities for interaction with other learners and the instructor (Platt et al., 2014; Bali & Liu, 2018). Petcovic et al. (2014) showed that, for a large majoriy of instructors, knowledge and skills learned in the field could not be learned in the classroom, as the strong cognitive and emotional component experienced outdoors is an important factor that indoor classes often neglect.

In relation to specific methodologies and/or instrumentation used in the classroom, the overall physical resources in our institution are only accessible in the laboratories or in specific spaces, similar to many other universities. Geoscientists use a broad range of tools to study a diversity of Earth systems problems (Kastens et al., 2009). Rock, mineral, and fossil collections are unique and unreproducible. Students do not have at-home microscopes, magnifying glasses, stereoscopes, or any other laboratory and/or field equipment, since they are economically unavailable as previously pointed out by Dolphin et al. (2019). Certainly, this lockdown has stimulated and forced the innovation of technological infrastructure in our faculty, while online resources have been fully implemented for the first time. Virtual courses show images of geological materials under the microscope with different magnifying glasses, or with polarized light; and there is work in progress on interactive digital platforms that support online and blended experiential learning environments (Jeffery et al., 2021). However, according to our survey results, no virtual context can adequately replace the handling of a microscope. In the same sense, virtual courses have displayed a great variety of hand samples of minerals and rocks moving in all directions of space. However, without weighing the sample, experimenting with its magnetism, lustre, or even its taste, it becomes unthinkable that students can properly classify it.

The COVID-19 pandemic has motivated self-diagnosis for online teaching but, following our experience and the results, we assert that the virtual context must only be employed as a complementary tool for practical classes rather than as a substitute.

Communicative competencies

Instructors have agreed that communication was a clear weakness for online courses, especially in lecture classes with more than ten students. According to the surveys results, a student behind a screen is generally not engaged in the whole lecture, rarely talks, the interaction among students is effectively absent, and open debates are practically nil. These results agree with previous studies of online education (Bettinger & Loeb, 2017; Bali & Liu, 2018; Dietrich et al., 2020). In this sense, we must also consider an instructor's lack of experience and skills within synchronous teaching, and some new and extended skills should be required in the future (Moorhouse, 2020). Both the limited technology formation and the poor online teaching experience of instructors result in a decrease in the spontaneous interaction between instructors and students (Le et al., 2022). Video conferencing has been a very useful tool for maintaining fluid contact with individual students or small groups by following their advances and solving their specific problems. However, the learning experience of public speaking or the opportunity to imitate the body language of the instructor are aspects that are difficult to replace. In addition, the lack of visual control makes it difficult to identify students that need additional help or who are at risk of being detached from the guidance of the course. This fact has also been observed in other institutions (Huang et al., 2020; Stevanovic et al., 2021; Iqbal et al., 2022; Le et al. 2022).

Student-student interaction, through discussion with their peers, is a key factor in the learning process (Boyle et al., 2007; Goad & Jones, 2017; Le et al., 2022). During the pandemic this exercise had not been facilitated, and thus, the opportunities to connect with peers from a social and/or academic point of view were reduced. Klyce and Ryker (2022) emphasize the importance of this basic competency, and its value for job development.

Several strategies can be used to increase student-student or instructor-student communication, such as the use of high-quality pre-recorded videos to present subject content, followed by short synchronous meetings focused on performing more interactive activities, well-designed online discussions, evaluation or mentoring tactics (Goad & Jones, 2017; Le et al., 2022).

Advantages or disadvantages of online or blended teaching in the degree of Geology

The results discussed above indicate that online teaching had significant side effects on the acquisition of practical and communicative competencies. Similarly, some important points can be highlighted in terms of the use of online or blended teaching in the degree of Geology at the University of Barcelona.

Firstly, it is generally admitted by the participants in this study that virtual methodologies were especially useful during the COVID-19 lockdown, when it was impossible to carry out practical classes and field work. In this regard, both the teaching staff and students point out the use of new tools and methods as key benefits of online teaching implemented during COVID-19. These results are in line with those previously reported in the literature for diverse disciplines (Goad & Jones, 2017; Dietrich et al., 2020; Huang et al., 2020; Stevanović et al., 2021). Secondly, instructors equally admit that the teaching of geology requires physical experience that no virtual methods can replace. Field work is a key point in geoscience practicum education and is considered fundamental by the scientific community (e.g., Petcovic et al., 2014) and students (e.g., Boyle et al. 2007) (see discussion above). Thirdly, the analysis of academic results show that the average grades during the pandemic lockdown were higher than in previous years (Fig. 2). This point was also highlighted in the SWOT analysis from the teaching point of view (Fig. 3). During the pandemic all exams were done online by using a wide range of systems of evaluation that varied from multiple-choice tests to short answers, oral expositions, mathematical calculations, exercises and map interpretations. Independently of the used method, the

Fail marks decreased specifically in the 1st and 2nd years by 12% (Fig. 2). These results are significantly different from Samson (2020) who describes low grades during the lockdown and correlates those results with low participation in distance learning. In our case, the reasons for this behaviour could be diverse. On the one hand, the teaching staff admitted that they were more lenient with the students, probably as a result of personal empathy and the consequent lack of strictness due to the situation, which involved stress and common academic difficulties. On the other hand, the University of Barcelona did not implement a system to guarantee that online exams were equivalent to face-to-face exams. Therefore, we may consider that the students could have shared their answers or consulted with textbooks or class notes during the exam. The studies of Chirumamilla et al. (2020) and Pokhrel and Chhetri (2021) report the same instructor concern about cheating in online exams. During COVID-19, there was clearly a bias in the grading compared to the following year, when the exams returned to F2F format and the grades returned to their baseline pre-pandemic level.

The threats reported in this study about an online or blended scenario must be considered in order to counter them (Table 1). For instructors the fear of a decrease in teaching quality is the main concern. Iliya and Ifeoma (2015) assert that teachers need adequate motivational support in order to sustain their efforts and professional conduct. If the instructor's workload for class preparation is high and adequate technological support provided by faculties or universities is not available, it is very likely that motivation would be greatly diminished and, subsequently, teaching quality would suffer. Academic and quality policies should consider ensuring strategic initiatives such as increasing technological investments and employing or reviewing new models of education.

LIMITATIONS

Our study must be considered in the context of some limitations. On the one hand, it is only based on the results of two surveys performed at the time, and follow-up data including a post-pandemic analysis are still lacking. It whould be interesting to know what online teaching tools are currently being used. On the other hand, the number of answers from instructors is certainly limited in terms of statistical analysis although it is remarkably higher in the context of Geology in Spain. The next step would be to survey a greater sample size, including all universities and departments in Spain that offer a degree of Geology.

Finally, any future research should address the impact of virtual learning on students that started the degree during COVID-19. In oher words, will the student cohort that finishes their studies during 2022–23 be credited with the same level of knowledge and competencies as pre-COVID students?

CONCLUSIONS AND RECOMMENDATIONS

The disruption of the COVID-19 pandemic forced the implementation of online courses (or blended courses later) into the traditional system of teaching in higher education institutions. In the field of geosciences, degree programmes like Geology at the University of Barcelona replaced face-to-face teaching with online teaching. The pandemic offered the opportunity to evaluate the suitability of online teaching environments by means of a SWOT analysis, two surveys addressed to teaching staff and students in order to understand the perceptions of the effects of online teaching on the geology students' competencies acquisition, and the analysis of pre-pandemic academic results until present.

This study shows the great impact of online or blended teaching on the degree of Geology for two specific and critical competencies (practical and communicative) that students must achieve by the end of their studies. Results indicate that teaching staff and students consider the lack of specific instruments and the loss of field work as weaknesses of online teaching, as students could not practise their sense of observation and analysis for understanding the temporal and spatial dimensions in the field. The practical field and laboratory work necessary for professional development is thereby not guaranteed.

Our data indicate that communicative competencies are also threatened in online teaching, as students behind a screen rarely talk. Uniquely, smaller classes can effectively work by properly maintaining attention and establishing debates. We suggest implementing practical workshops and training for teachers in order to improve the management of a successful classroom.

In terms of opportunities, both the teaching staff and students valued the learning of new methodologies and the acquisition of new online skills during the pandemic. However, the lack of tools for plagiarism detection or for designing online exams were the main barriers for instructors. Probably for that reason, along with some leniency during the pandemic period, the 2019–20 academic year was more academically successful than other years.

Finally, once the COVID-19 pandemic has ended and we have returned to the previous F2F teaching ecosystem practices (to borrow a term from Hodges et al., 2020), some considerations should be taken into account. In spite of the stressful experience for the sudden adaptation of online teaching, institutions should rethink how to improve the blended learning-teaching ecosystem in the future. The adequate and full-acquisition of practical and communicative competencies are key points that should be managed in any practical degree programme, such as Geology. Regarding practical recommendations related to our results, we suggest investing in the creation of virtual libraries (regional field trips, an inventory of outcrops, recorded classes, self-corrected exercises, petrographic tours of thin sections, etc), defining the best student-instructor ratio to work online and clarifying the role of teachers and students in online teaching.

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FIGURES

Figure 1. Scheme of the methodological approach followed in this paper to assess the impact of online teaching on the Geology degree program at the University de Barcelona (UB). This assessment was completed by quantitatively analysing the academic grades and via the exploitation of the surveys on online teaching, which have been defined following the qualitative SWOT analysis performed by the authors (see text for more explanation).

Figure 2. Evolution of the final grades distribution in terms of Fail, Sufficient, Good and Very Good for 1st, 2nd, 3rd and 4th year students of the degree of Geology from the academic year 2016–17 to the academic year 2020–21.

Figure 3. Evolution of the yield rate for the basic and required courses of the degree of Geology directly (A) and indirectly (B) affected by the COVID-19 pandemic during the academic year 2019–20, from the academic year 2016–17 to the academic year 2020–21. Elective courses and the final project are not considered.