Implementation of a blended learning strategy for geotechnical courses

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ABSTRACT: Higher education learning environments have transformed significantly over the past few decades. While traditional lectures remain prevalent in theoretical courses, creating varied learning methods that resonate with the newer generation of students, particularly those who have experienced post-COVID-19 education, is crucial. To tackle student motivation and attention issues, the flipped learning model places students at the core of the educational process, offering multiple solutions to educators, mainly when supported by learning management systems. The Geotechnics@Home initiative aims to improve blended learning and facilitate the flipped classroom approach. Students engaged in virtual classes at their own pace, which allowed in-person sessions to focus on practical applications, lab investigations, and project work. Key components of this teaching project are outlined, along with preliminary findings regarding students' academic performance. Although extending this platform to more courses and involving additional students is imperative, the preliminary results are encouraging. In the first year of implementing the platform, there was an increase in the number of evaluated and approved students. Furthermore, students' performance resulted in a smaller disparity between the best and worst results.

Keywords: Blended learning, Flipped learning, Soil mechanics, Learning management systems, Students' performance

1 Introduction

The COVID-19 pandemic has impacted every sector of society, including education. The numerous lockdowns experienced by many countries have accelerated the integration of digital technology in education, enabling students at all levels to continue their studies (Sathish et al., 2020). However, the shift to distance learning comes with considerable challenges, such as technological infrastructures, digital literacy, and pedagogical adaptation. Students need to develop focus and self-control, while teachers face difficulties creating engaging online content (Al Lily et al., 2020). In online learning environments, instructors evolve from teachers to facilitators. They emphasise student engagement and encourage self-motivation by supplying all necessary materials at the start of the class or course. They need also be organised and provide clear instructions on navigating the available resources. This approach fosters student collaboration and helps them develop their own understanding of the course materials (Bailey and Card, 2009). The migration to online learning environments has also allowed the enhancement of different learning approaches, transitioning from teacher to student-centred methodologies (Sathish et al., 2020), prioritising students' well-being, academic success and inclusive educational practices while highlighting the need for continuous professional development of teachers (Sato et al., 2024). Online learning in higher education offers numerous benefits. For students, it allows them to pursue advanced degrees while staying in their current jobs, offering a range of international institutions and courses to choose from (Hosseindoost et al., 2022). Additionally, they can access a wealth of information through educational platforms (Arkorful and Abaidoo, 2015). From the institution's perspective, online learning can help alleviate operational challenges. However, notable drawbacks include the diminished interaction between students and instructors and an excessive dependence on technology (Chang, 2016).

Blended learning (b-learning) combines various teaching methods that cater to different learning methods (McSporran and King, 2005). This approach utilises a pedagogy that leverages the advantages of both in-person and online education (Osguthorpe and Graham, 2003). The focus is on achieving a balanced integration of digital access to information and direct human interaction. It's crucial for b-learning to emphasise and merge the strengths of these two different educational environments (Osguthorpe and Graham, 2003). Moreover, b-learning is most effectively utilised in the Flipped Classroom learning methodology. In this approach, students assume responsibility for their learning as they access lesson materials before attending class (Capone et al., 2017). According to these authors, teachers facilitate the proper understanding of the lesson by involving students in activities or projects where they can transfer the acquired knowledge into competencies.

This communication presents a case study at the Polytechnic University of Coimbra, Portugal, where a blended learning methodology was implemented for the Soil Mechanics course of the Civil Engineering degree. No more theoretical classes are scheduled. Students only attend theoretical-practical and laboratory courses. All the theoretical material was uploaded to the school’s learning management systems (Moodle® Platform), and students attended virtual lessons at their own pace and rhythm, according to a previously presented timeline. During the practical and laboratory classes (face-to-face lessons), geotechnical challenges or problems are proposed to students so that they can apply the learning outcomes of the virtual lessons. The success of this initiative is evaluated through students’ final grades. The outcomes achieved encourage the development of a collaborative e-learning geotechnical space for students enrolled in several undergraduate studies.

2 Blended learning and flipped learning enhanced by learning management systems

2.1 Literature review

Blended learning is rapidly becoming popular in higher education (Talan and Gulsecen, 2019). A fundamental component of b-learning is the diverse communication methods that connect students and teachers. When students enrol in a b-learning course, they become part of a community that encourages the exchange of questions and answers, as well as active discussions and critical debates with both peers and instructors through written communication. Garrison and Kanuka (2004) state that written communication greatly enhances synthesising skills, reflection, and accuracy. Moreover, to effectively participate in the online part of the course, students need to develop skills to navigate various activities, which boosts their self-motivation (Bevell et al., 2020). As summarised by Platonova et al. (2022), b-learning can significantly enhance academic performance and student satisfaction and decrease student retention rates.

The instructional design of a blended learning course is vital for ensuring high-quality learning. The face-to-face and online elements differ in terms of time, scope, and significance, which fluctuates from one course to another based on their specific requirements (Santos, 2018). During the design phase of a blended course, it's essential to clearly define objectives, establish assessment methods, outline content sequences, devise teaching strategies, and select the most fitting tools (Masie, 2006). This comprehensive approach is crucial for effectively addressing training needs. Masie (2006) highlights four key factors that blended course organisers should consider for success: (i) actively participating in blended learning experiences to understand the challenges students face; (ii) acquiring proficiency in all technological tools that may be used in the course; (iii) ensuring access to the appropriate technological resources; and (iv) gaining practical experience with blended learning and mastering the related technologies.

The increasing demand for technological integration in higher education is leading to new learning methods (Chi et al., 2018). In this context, traditional education can be enhanced through information and communication technologies (Fetaji et al., 2019). Methods that blend face-to-face and online lessons and activities are becoming more prevalent. Within this framework, the flipped classroom approach is starting to change the educational paradigm. The flipped classroom approach is defined as inverting the learning activities that usually occur inside and outside the classroom (Lage et al., 2000). This method strongly emphasises technology (Chi et al., 2018), as the time typically allocated for direct instruction is moved online, allowing face-to-face sessions to focus on engaging and dynamic activities. The benefits of this methodology include (Schmitt & Cequea, 2020): i) facilitating the application of higher-order thinking processes according to Bloom's taxonomy; ii) enabling students from diverse disciplines to gain various knowledge, skills, and attitudes that contribute to societal development; iii) encouraging students to take greater ownership of their learning, thereby enhancing course effectiveness; and iv) utilising in-person time for active activities and group discussions, facilitated by the instructor educator.

The defining feature of the flipped classroom is its active learning approach, where classroom time is devoted to discussing previously studied materials, such as videos and texts, instead of traditional teaching methods. This shift allows for student participation and critique (Wang, 2019). The emphasis is on learning instead of teaching, fostering greater interaction between students and instructors (Mok, 2014). As noted by this author, class time is utilised for problem-solving, addressing questions, developing critical thinking, and enhancing collaborative exercises. In this context, it's important to emphasise the definition by Bishop & Verleger (2013), who describe the flipped classroom as an educational approach comprising two elements: engaging group learning activities and individualised computer-based instruction conducted outside of it.

Although the flipped learning methodology offers several benefits, Zhang et al. (2021) note that it isn't ideal for every course. Specifically, subjects that require reasoning, conceptual understanding, and systematic approaches, like language, history, and various liberal arts, are not well-suited for flipped learning. Conversely, this approach proves advantageous for disciplines that involve abstract reasoning and logical clarity, including mathematics, physics, and chemistry. Due to their foundations in mathematics and physics, engineering courses can also be included in this last group.

From a student’s perspective, flipped learning boosts engagement, motivation, and academic performance. Similar to other pedagogical methodologies with proven results in teaching geotechnical subjects, such as co-creation (Ribeiro et al., 2024), this active learning approach fosters student responsibility and promotes a deeper comprehension of learning objectives. Additionally, students learn at their own pace and learning style. Pre-class activities help alleviate anxiety, encouraging students to participate in discussions as they are already familiar with the material (Mayasari, 2024). From a teacher’s viewpoint, the educator will guide on the side rather than being a sage on the stage (King, 1993). Rather than simply teaching knowledge, the teacher takes on the role of a facilitator or coach, encouraging students to construct their own understanding. Additionally, it is essential to transform learning environments to prioritise student engagement (Mazur, 2013).

While flipped learning offers several benefits, some researchers argue that its full potential is not achievable solely through learning management systems (LMS) (Rhode et al., 2017). LMS platforms are essential for broadening access to education, offering various tools for content sharing, interaction, and collaboration among students and educators. They also enable educators to monitor and report students' progress throughout the course modules. Indeed, many students face challenges accessing various learning platforms and navigating the information available. Additionally, educators may find it challenging to create effective pre- and post-class materials, such as practical activities and assessment tools, overseeing numerous course information banks and securely maintaining student databases (Pozo-Sánchez et al., 2022). The authors conclude that the flipped learning approach is advantageous and significantly improved when integrated with an LMS platform, optimising the overall learning process.

Several online LMSs are available, one of them being the Moodle® platform. Moodle is an acronym for Modular Object-Oriented Dynamic Learning Environment and presents three main advantages: i) It is an open-source platform for creating learning communities and designing online environments that support education, allowing any user to modify and adapt the environment according to their own needs; ii) It enables the publication and accessibility of resources in various formats, allowing content management, which makes it easier for teachers to make content available in different formats and to define when and how students interact with it; iii) It includes diverse functionalities such as participation, communication and collaboration tools, course and user administration, evaluation, and activity tracking, among others. Compared to other LMS, the Moodle® platform offers several benefits: i) it operates without commercial purposes; ii) it features a straightforward and user-friendly interface for easy navigation; and iii) it demonstrates a high level of versatility in integrating new functionalities.

2.2 Learning Management System at the Polytechnic University of Coimbra

The Polytechnic University of Coimbra provides two online platforms for its students: NONIO and Moodle. NONIO serves as an academic management tool where students can enrol in courses or modules, submit requests to administrative services, obtain various documents, and check weekly timetables and evaluation dates. Additionally, it allows instructors to share course materials and upload assignments. However, NONIO is not categorised as a virtual learning environment because it lacks synchronous or asynchronous communication capabilities for interactions between students and teachers, functioning primarily as a file management system. The second platform is Moodle, a learning management system introduced earlier. Regardless of minor variations between Moodle versions, when students log into the platform, they select their pathway through their degree, the academic year, and the semester, eventually reaching the course they wish to enrol in and accessing the available information and prepared activities.

The Civil Engineering degree at the Engineering School of the Polytechnic University of Coimbra comprises thirty-six courses, with twelve each academic year and six per semester. The curriculum features four geotechnical courses: Geotechnics (fall semester of the 2nd year), Soil Mechanics (spring semester of the 2nd year), Foundations 1 (fall semester of the 3rd year), and Foundations 2 (spring semester of the 3rd year). These four courses establish the foundational geotechnical education, which is further expanded upon in the Master's in Civil Engineering. Besides these courses, students have the option to select additional geotechnical courses from the Master's in Sustainable and Smart Cities, the Sustainable Cities Management Degree, as well as the Civil Protection Technical Course and the Civil Construction and Public Works Technical Courses, among other education offer. While the syllabus length may vary based on the specific degree characteristics, it addresses topics that are, to varying extents, included in the syllabuses of the four fundamental courses. For teachers, the structure of Moodle leads to the dissemination of information across various courses, necessitating the management of multiple Moodle pages that occasionally feature similar content.

3 Geotechnics@Home project

Geotechnics@Home project is an ongoing project based on online activities developed during the COVID-19 pandemic. In Portugal, two lockdowns were imposed on the population to prevent and control the spread of disease and safeguard the national health system. Both lockdowns affected the spring semester, and most classes had to be substituted by online synchronous and asynchronous moments. As a result, several online Soil Mechanics lectures were prepared and proposed to students. These lectures have been revised and adapted for integration into a blended learning model, utilising flipped learning methodology boosted by Moodle features.

Geotechhnics@Home is designed to enhance, not replace, the official course page on Moodle platform where teachers provide updates and all the relevant information on ongoing geotechnical courses. This learning tool aims to support all geotechnical studies by offering essential knowledge in the field. It functions similarly to a Soil Mechanics and Geotechnical Engineering textbook, leveraging the advantages of a digital environment. Regardless of the lecturers' teaching method, students can always use the platform to either engage with required module lectures or just complement the topics discussed during in-person classes. The first option positions this project as a b-learning platform, facilitating a flipped learning approach. Conversely, if the teacher opts not to utilise the platform, students can independently engage with it as an e-learning tool, selecting the material they wish to explore further. Whatever the reason for using the platform, feedback to the student is always guaranteed either by the lecturer responsible for the course or by any other geotechnical lecturer with access to the platform.

The platform also monitors student activity for various reasons based on usage stage. Currently, tracking occurs through task completion criteria and badges. These criteria motivate students to participate in all activities, which is crucial during the initial phases of their experience. For instance, they help develop habits in using asynchronous communication methods like forums and chats, which are vital in blended or online learning environments. However, many students often hesitate to utilise these tools. To encourage participation, completion criteria require students to engage with a certain number of posts or replies. Other conditions may prevent students from progressing on the platform until specific tasks or grades are achieved, ensuring a structured learning path while allowing students the freedom to explore their interests and make choices. Badges work as rewards for achievements and intend to keep students motivated.

As part of a flipped learning approach, students are invited to follow the pre-established virtual lectures. These lectures replace the traditional teaching of theoretical content at the beginning of classes or whenever new concepts are introduced. Scheduling topics in advance allows students to manage their theoretical study time independently and at home (or elsewhere), ensuring they have the necessary knowledge/skills when practical application is required. This approach allows face-to-face class time to focus entirely on solving exercises, working on projects, conducting lab investigations, and engaging in other activities. It should be noted that this methodology does not involve teachers utilising synchronous moments for theoretical explanations. Instead, teachers promote sharing knowledge gained during self-study, facilitating student interactions and offering guidance to enhance understanding. The process should prioritise asynchronous communication to support the active construction of student knowledge.

3.1 Getting started with the platform

In a blended learning model, getting started with the platform is essential for engaging all students enrolled in the course. The proposed activities should enable students to familiarise themselves with the platform, connect with participants, and level all the students in information and communication technology skills necessary for effective platform usage. The more students immerse themselves in the platform, the higher their chances of retaining information and maintaining motivation. Several activities can be proposed: newsletters, forums for quick presentations, a global glossary that will be continually updated with students' information, and various submission tasks (Figure 1).

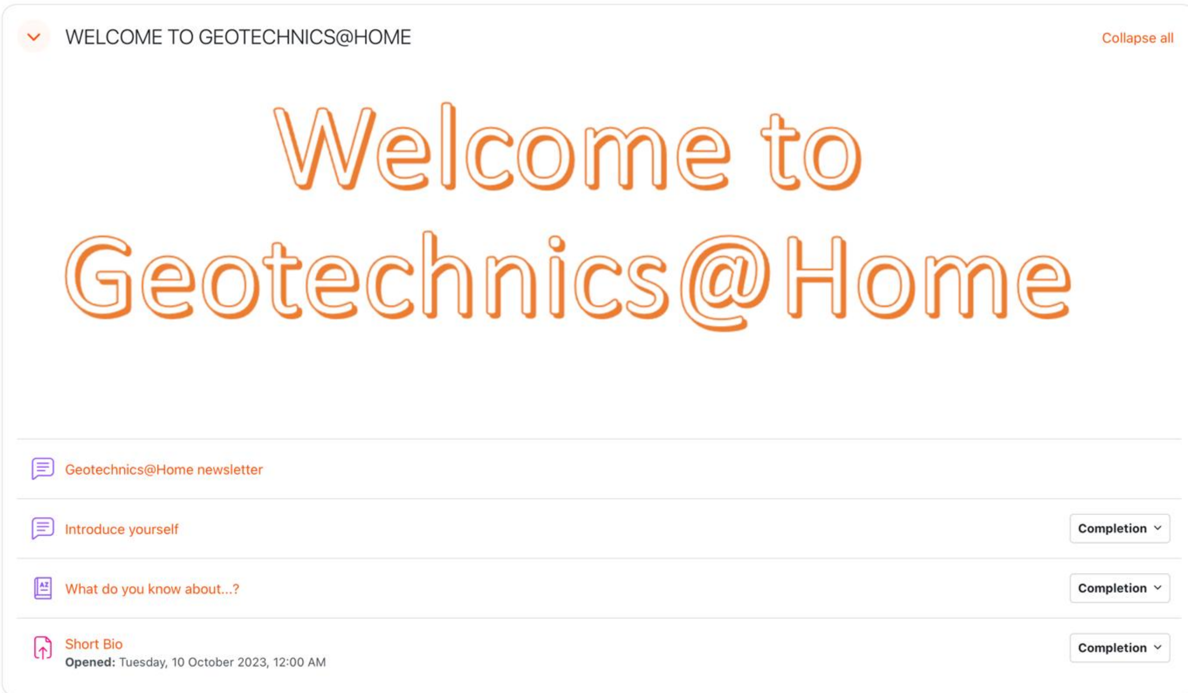

Figure 1. Getting started with Geotechnics@Home: homepage

At this point, including the course's general information is essential. Students must be able to access all pertinent details, such as the course description, intended audience, prerequisites in skills or knowledge, syllabus, learning objectives, teaching methods, resource and technology needs, communication tools, and assessment procedures. The schedule and timetable must also be communicated to the students at the beginning of the course, especially when using the platform is an integral part of the course's teaching methodology. Students will embark on an autonomous study journey and must be guided throughout. This information should be compiled into a single, interactive document, and its completion must be mandatory to ensure that all students understand what is expected of them, when, and how. For instance, utilising the resource book of the learning management platform is advisable. To maintain student motivation, engaging activities should be created to boost awareness and curiosity about upcoming topics. As Geotechnics@Home welcome session, it was chosen the lecture Enigma of the Leaning Tower of Pisa, given by Professor Burland in 1998 (Burland, 1998) (Figure 2). These activities should be optional but can lead to badges students earn throughout their blended learning journey.

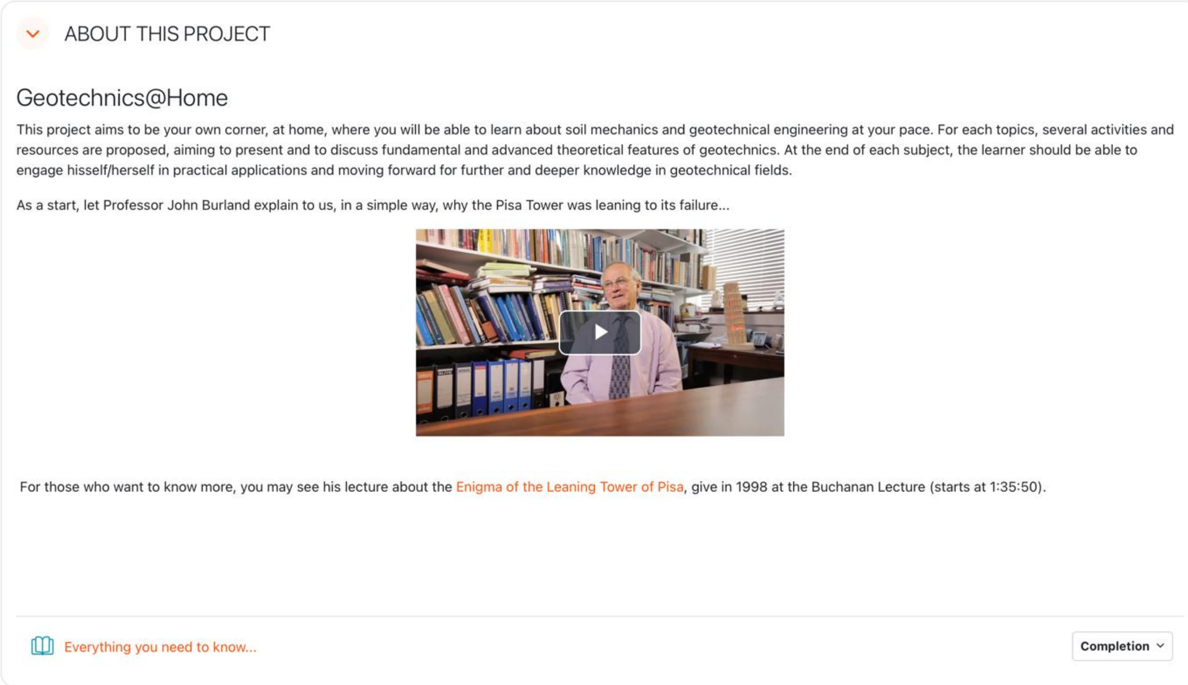

Figure 2. Getting started with Geotechnics@Home: about the project

3.2 Students' Corner

A key component of this project is the ongoing contact between teachers and students, and this unique space has been created to promote the sharing of ideas, doubts, and other useful information. Student's Corner comprises three features:

1. Attendance and summary: This Moodle activity is most effective when the platform is utilised in a flipped learning model. Consolidating all information in one location aids students' progress. Students remain informed about what has been accomplished and what is planned for the face-to-face class.
2. Cybercafe: Geotechnics@Home hosts its official chat platform where students and teachers can discuss any topic, whether related to geotechnical engineering or not. This casual environment fosters user interaction, enhancing their sense of belonging to the platform community.
3. GeoHelp: It is the project's global forum. Students should direct any questions or concerns regarding the platform, its integration with courses, or active learning methodologies to this forum. It is a collaborative space where both teachers and students can respond to posts. For personal matters, students can always contact teachers via private messaging, meetings during office hours, or any other communication method.

3.3 Main lectures

Geotechnics@Home is built on top of the foundational lessons. Every class follows a similar format (see Figure 3): i) a lecture on the topic, ii) a dedicated forum for questions, and iii) a self-evaluation test. As illustrated in Figure 4, the lectures follow a standard framework. The welcome page offers a concise overview of the topic and outlines the four main sections of the lecture (Revisions, Lecture, Written documents, Self-assessment). To complete a lesson, students must engage with all activities and achieve a passing grade in the self-assessment section. This requirement is crucial primarily when the platform supports flipped learning strategies. In a more open usage, students can directly access the lecture content.

There is no hierarchy among lessons on the platform. Introducing such a limitation would restrict users from accessing their preferred lessons. Access conditions for lesson topics arise only when they are divided into various issues, either due to their complexity or the number of subjects addressed. This conditional access ensures coherence in content presentation. The revision chapter includes questions to confirm that students have the requisite knowledge to fully understand the material presented. If students cannot answer the revision questions, they are encouraged to revisit a specific lesson.

All lectures have been uploaded to YouTube, but the channel is private. Access to the videos is restricted to the link in the Lecture chapter of the main lesson. In an earlier version of the Geotechnics@Home project, the video lectures were directly embedded in the Moodle platform. While this approach offered better data and content protection, it overloaded the institutional servers hosting Moodle. The video durations range from under 7 to 30 minutes, averaging 20 minutes. The streaming platform serves solely to visualise the lesson. Feedback or other interactions are not provided. Any issues, questions, or concerns must be reported in the dedicated lesson forum.

The final two chapters of the lesson are Written Documents and Self-assessment. The Written Documents chapter offers links to suggested and supplementary reading materials. While the platform includes essential bibliographic details for various courses, users can always access a direct link to the main course page. The Self-assessment section features questions designed for students to evaluate themselves. It's important to highlight that, in contrast to the Revision chapter, which requires students to answer all questions correctly to proceed, this Self-assessment allows students to navigate through different questions and receive a final grade. If the grade is positive, the lesson is marked as complete. Conversely, if the grade is negative, students are encouraged to review the lesson before attempting the self-assessment again.

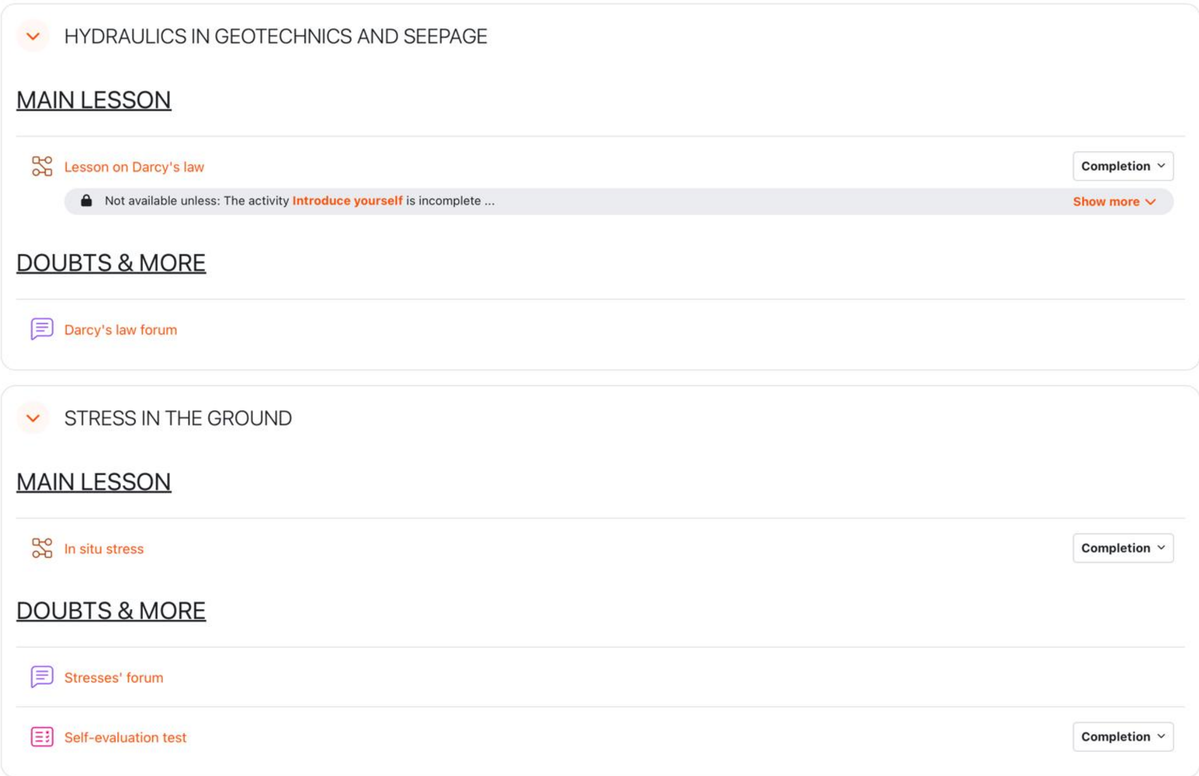

Figure 3. Geotechnics@Home main lessons: general structure

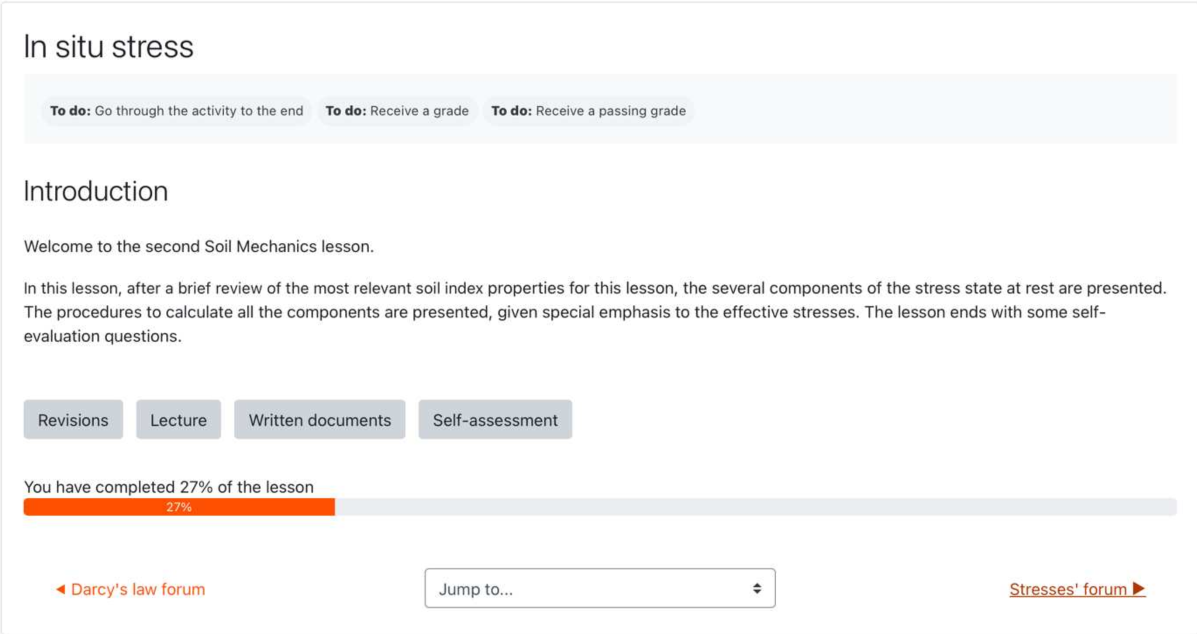

Figure 4. Geotechnics@Home main lessons: example of the In situ stress lesson

In the lessons, any questions or doubts should be posted in the doubt forum. This forum encourages collaboration, allowing both students and teachers to respond to inquiries. Teachers also play a supervisory role, ensuring that student responses are accurate and, if needed, providing supplementary information or explanations. Students are finally given the opportunity to undertake self-evaluation tests. These tests are automatically generated from a pool of questions from a database. This question database has been continuously updated since the first COVID-19 lockdown in 2020 and contains dozens of questions. It features both open-ended (long or short) and closed questions. Nearly 20 closed question types are available, including single and multiple-choice, true/false, numeric, matching, sorting, drag-and-drop to text or image, fill-in-the-blanks, and dropdown boxes, among others. Each self-evaluation test presents 20 randomly chosen questions in a shuffled order, with the answer options also displayed randomly. The time for answering is restricted; the platform automatically concludes the attempt and saves the students' responses, allowing each student only two attempts at the self-evaluation test. The initial attempt serves well as a self-evaluation activity. Afterwards, students will receive feedback and a grade from the teacher. It's important to mention that the platform does not offer automatic feedback due to the open-ended questions, which require human review. Following the feedback, students have a chance for a second attempt, which may consist of either another self-evaluation or a final grade for the lesson topic, depending on how the platform is used pedagogically. In an e-learning context, where students navigate the platform independently, the grade serves as an informational tool for the student. When Geotechnics@Home is used to enhance flipped learning, the final grade's role as an assessment will vary according to the course syllabus and learning agreement, which must be communicated to and accepted by the student in a distance learning methodology.

4 Results: Students' performance

Geotechnics@Home debuted for students enrolled in the Soil Mechanics course during the 2023/2024 academic year. This marked the first implementation of the flipped learning active learning approach in the course. Although it is premature to make definitive conclusions, analysing the students' performance reveals promising data that advocates for the continued use of this methodology and further development of the platform and its implementation in other courses. Table 1 summarises academic results since the current lecturer assumed responsibility for the course. Due to differing evaluation conditions, the academic year 2019/2020 has been omitted from this summary. During the COVID-19 lockdown, assessments for students occurred remotely rather than in person, as done in previous years. Aside from the evaluation and approval percentages for students in the 2020/2021 academic year, the overall results for the 2023/2024 academic year, the implementation year of the platform, are better across all domains. Higher, lower, and average grades are either improved or comparable when only the approved students are considered. Additionally, when comparing the second highest and lowest grades, student performance was as good as in prior years, or even better, leading to a smaller disparity between the best and worst results.

Table 1. Final grade evolution in the last 6 years

	2023/2024	2022/2023	2021/2022	2020/2021	2018/2019	2017/2018
Students evaluated	76%	69%	60%	81%	47%	85%
Students approved	92%	89%	78%	100%	100%	82%
Higher grade	17	15	14	15	16	17
Lower grade*	11	10	10	10	11	11
Average grade*	14.7	13.4	11.7	11.5	13.6	14.7
2nd higher grade*	16	15	14	13	14	17
2nd lower grade*	13	11	10	10	13	11
Amplitude	3	4	4	3	1	6

* The values presented were based solely on the sample of approved students.

6 Conclusions

Geotechnics@Home is more than a course Moodle page. It aims to be a learning platform for all the geotechnics-related courses taught in the Institute of Engineering of the Polytechnic University of Coimbra. This project has been implemented and developed to enhance electronic and blended learning, supporting active learning methodologies like flipped learning. The first impressions clearly show that this initiative helps students to achieve better academic results and, of course, to develop the necessary skills for their profession. To confirm and improve the encouraging results of this initial implementation, the platform should be used in additional courses and engage more students.

The project will soon include Experience points (XP) and different user levels, leveraging Moodle's gamification elements, in addition to continuously updating courses and lectures to improve the platform's adaptability and applicability. Gamification's advantages in remote learning settings are well acknowledged and ought to be further maximised. In relation to the lectures, new platforms like VideoAnt and Hypothes.is should be used to improve video interactivity and make reading tasks easier.

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Since 2004, Luis Araújo Santos has been an adjunct professor at the Coimbra Institute of Engineering, part of the Polytechnic University of Coimbra. He teaches geotechnical courses in various undergraduate and graduate programs. With a strong academic background in geotechnical engineering and environmental studies, he has focused on researching granular soils and geomaterials through the use of unconventional testing equipment. His research and teaching have recently focused on waste management and industrial and mining waste valorisation in transportation and geotechnical engineering applications. His passion for teaching and pedagogy has driven him to participate in numerous training courses in higher education pedagogy, focusing specifically on active learning methodologies and co-creation project facilitation. He recently completed a postgraduate course in distance learning and earned several micro-credentials in online education. His combined scientific and teaching skills have enabled him to successfully implement less conventional learning approaches in soil mechanics and environmental classes.

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