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Use of ICT to implement an active learning strategy in soil mechanics courses at undergraduate level

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Article

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Abstract

Nowadays engineers are constantly dealing with more complex problems, uncertainty, incomplete data, and demands of customers, governments, environmentalists, and public. This requires technical skills as well as skills in human relations. So, during their academic background it is necessary to incorporate more skills, social and technological, into their base knowledge. This can be accomplished introducing Information and Communication Technologies (ICT) in Higher Education (HE). Several studies show that the use of ICT in teaching promotes participation, engagement, collaboration, and student interaction, making them more active participants and responsible for their learning. In addition to these advantages, ICT allow to give equal importance to learning processes and to the contents, as the activities offered by ICT allow to the students develop communication skills, teamwork, finding and evaluating information, access, and manipulation of large amounts of data, work with other technologies, update and refine existing skills and knowledge. It was in this context that Guided Exercises emerged. A Guided Exercise permits students to relate models and help them to solve a complex exercise step by step. This strategy was used in two consecutive courses of an undergraduate degree in Civil Engineering, Soil Mechanics I and Soil Mechanics II at the University of Aveiro, Portugal. The results show that students considered the strategy useful for the understanding of the concepts covered in the course. Analysing the students' academic performance, it can be concluded that those who used this methodology had a better approval ratio. This paper presents data to support these statements.

1. Introduction

This paper reports our experience in implementing a strategy called "Guided Exercises" in two courses of the Civil Engineering undergraduate study programme at the University of Aveiro, Portugal. The main objective of this strategy is to ensure that students solve exercises autonomously, in a more organised manner, and that the quality of their autonomous study can be continuously monitored throughout the semester.

Students' autonomous work is stimulated through the proposal to solve exercises on the guided form. These were implemented through Moodle quizzes, where automatic evaluation and feedback on the answers allow students to understand where and why they failed. We can see this process as a cycle where students do autonomous work (with guidance), which allows them to assess their knowledge, check what they did wrong, and then they can repeat the process in other exercises, week after week. Some preliminary studies (Macedo et al., 2020; Oliveira et al., 2018) have already been done and they showed that students considered that the "Guided Exercises" strategy was important for student learning. The main objective of this paper is to demonstrate that there is a direct relationship between students' use of the Guided Exercises strategy and their approval ratio at the end-of-semester exam. The influence of this strategy in the performance obtained was also analysed.

This paper is organized as follows. In this introductory section we contextualize: i) the advantages of Information and Communication Technology (ICT) as a tool for promoting autonomous work in Higher Education (HE); ii) the topic of Blended Learning is addressed; iii) the most relevant features of the Moodle, a Learning Management System (LMS), which has served as a platform for the implementation of Guided Exercises; iv) the Guided Exercises strategy is presented. Section 2 reports our case study, namely describing the course in question and its teaching and evaluation methodology. Section 3 evaluates the methodology identifying the research methodology. Section 4 elaborates on the presentation, analysis, and discussion of the results of our study. Finally, Section 5 presents some conclusions and paves the way for future work.

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1.1 ICT in Higher Education: a brief approach

Information and Communication Technologies (ICT) are playing an important role in our more demanding, dynamic, and technological society (UNESCO, 2002). The awareness of the enormous potential of ICT-based tools for the construction of knowledge, for autonomous and joint study indicates a new culture emerging: the digital culture. The creativity, competitiveness and innovation are characteristics inherent to ICT, which show the development based on information and knowledge.

In education, there is an ever-increasing need to combine a better, faster and effective qualification of professionals for the labour market with the eagerness to attract and motivate students (Tinio, 2003). As far as Higher Education Institutions (HEIs) are concerned, there is an additional challenge to encourage students to develop their individual skills more autonomously and to stimulate their continuous and permanent training.

Scoz & Ito (2013) argue that the various aspects related to the modernization of Higher Education (HE) involve the development of nationwide assessment systems as well as the use of ICT for improving teaching and learning.

The use of ICT is causing significant changes in the teaching and learning process, as it has several advantages over traditional teaching methods. As early as 1996, Smith (1996) stated that ICT facilitates the immediate exchange of information, the adaptation of information to different learning styles, and encourages autonomous study. The integration of ICT aids constructivist learning in which students interact with other students, teachers, information sources, and technology (Gredler, 2000). ICT also gives tools that facilitate access to people, content, strategies, activities, guidance, and opportunities to apply new strategies that make learning a personal process. Technology allows students to choose how, when, and where to participate in the learning process and to gather a variety of learning resources, including people, places, and materials to which they would otherwise never have access (New Media Consortium, 2007).

Nowadays, students' interests are different, and so are their habits. The use of computers, internet and social media has changed the way students interact with the world. There are several studies that have been carried out with the objective of characterizing the habits of Internet/ICT use by HE students. One of those studies, conducted in Portugal by Rosalina Babo et al. (2012), showed that most students access the Internet several times a day, that they are connected on average 1-3 hours a day. In the same study it was shown that the students who spend more time online are those who are enrolled in "technology" related courses. Furthermore, the main reasons for students to use the Internet were identified as (Rosalina Babo et al., 2010): i) to research work/study; ii) to access documents in their LMS (e.g., Moodle).

In this scenario, ICTs are used widely in several dimensions of HE, whether face-to-face or distance learning environments, such as the Moodle platform - "Modular Object-Oriented Dynamic Learning Environment" (Moodle, 2023).

Teachers play a crucial role in the integration of ICT. In 1998, Sarmento et al. (1998), said that "The widespread use of ICT by younger teachers is also a sign of confidence". Evidently, with this new way of managing education, particularly in HE, teachers are faced with a new paradigm, since teaching today is not simply knowledge transmission (Angadi, 2014). Teachers soon began to interact in the construction of knowledge and became researchers on how to use new technologies in teaching (Zhao & Cziko, 2001). According to the literature, because of organizational, curricular, extracurricular and policy changes in HE teachers are required to continuously acquire new skills. They need to be able to adapt content objectively and clearly, to make it attractive and enjoyable. Nevertheless, many teachers still do not take advantage of the potential of ICT to promote higher quality teaching/learning (Barolli et al., 2012; Cubukcuoglu, 2013).

1.2 Student's autonomous study

The amount of autonomous study by students in HE began to be clarified more objectively and more quantitatively with the introduction of the European Credit Transfer and Accumulation System (ECTS) in 1989 under the Erasmus program, and later with the request of the Bologna Ministers in the Bucharest Communiqué in 2012 (Bucharest Communiqué, 2012). This was a call by the Ministers to institutions to further bind study credits to students' learning outcomes and workload and to integrate the achievement of learning outcomes in assessment procedures. In accordance with the ECTS Users' Guide (Bucharest Communiqué, 2012), workload is an estimate of the time a student normally needs to complete all learning activities (e.g., lectures, seminars, practical work, individual and group research, report writing, projects...), and individual study required to attain the defined learning outcomes.

Today, there is a better estimate on the amount of time a student should allocate to autonomous work. However, the quality of autonomous work is difficult to quantify and guarantee (Holmes, 2018). It is important to note that the student is now the centre of the educational process, where they are expected to play an active and critical learning role. This is important, because we want students after their graduation to be prepared to enter the labour market, where such autonomy is requested. On the other hand, there is the danger of the student feeling abandoned. In fact, the tendency is to simplify all this by decreasing the number of classes and "force" (the idea would be more "motivate") the student to achieve the outcomes proposed through autonomous work.

Many students who attend HE become disoriented or even lost during their academic path (Neri de Souza, 2006). One of the reasons for this scenario has to do with their schooling because the demand for autonomous work in primary/secondary education is often very low and when they enter HE the students are faced with a new reality where autonomous work is preponderant (Neri de Souza, 2006). Note that in HE the number of hours allocated to autonomous work is higher and consequently the number of contact hours with the teacher is lower than in high school.

Autonomous study implies the mobilization of many student skills, such as: i) knowing the objectives they need to achieve; ii) knowing and recognizing what has been taught; iii) defining/planning tasks and work priorities; iv) knowing how to use information resources, selecting bibliography, and making summaries, knowing how to work in groups, etc. Since freshmen do not yet possess these autonomous work skills, it is essential to find ways of monitoring their evolution, i.e., the skills students acquire during their study.

In this context, it is very important that teachers make different kinds of materials and support tools available to students, be willing to answer their questions, and assess their skills and knowledge regularly along the way (especially those acquired through autonomous work).

But how can autonomous work in HE be defined? According to Bonham (1992, p. 192), "[…] independent study is a process by which a student acquires knowledge on their own and develops the ability to question and critically evaluate". Knight (1996) further completes this definition by stating that "[…] independence is not the absence of guidance but the outcome of a learning process that enables students to choose the guidance they need to achieve their goals". Finally, Thomas (2014) states that "[…] in general, autonomous study is done outside of contact hours but contributes to specific learning outcomes. This learning is carried out by students, alone or with other students, without direct participation from teachers".

Nevertheless, it is extremely important for teachers to support and guide students throughout the semester. It is also important to assess students' competencies at different moments (and in different areas) so that students can receive timely and relevant feedback on their study methodology and effort (Young, 2002).

1.3 Blended learning

Learning can take place in different modalities. A distinction is often made between face-to-face classroom learning and virtual learning, as well as asynchronous and synchronous learning (Chaeruman et al., 2018). As information and communication technologies (ICT) have become more sophisticated, popular, and widely used, the need for their integration into the various teaching modalities has increased. In recent years there has been a significant increase in the use of these types of technologies blended with traditional classroom teaching. In higher education, the blended approach is highly desired because of its flexibility and individualization, which allows teachers to propose, in each situation, the most advantageous training solutions for their students, to give them the opportunity to adapt the learning process to their own needs and specific stages of life (Barnett, 2014; Lencastre & Coutinho, 2015; Müller & Mildenberger, 2021). It is increasingly evident that blended learning can overcome several limitations related to online learning and face-to-face teaching (Alammary et al., 2014). Some examples are hardware capabilities, computer skills, lack of interpersonal interaction, delayed feedback (online learning) and need to travel to some location, low flexibility to create individual learning paths, and higher costs (face-to-face teaching) (Gherheș et al., 2021).

Originally, the term blended learning was used as the link between the traditional classroom and distance learning supported by a computer. More recently, due to the increasing spread of the Internet and the ease of use of LMSs, blended learning represents a diversity and variety of combinations (Lencastre & Coutinho, 2015).

Allen et al. (2007) employs the online proportion of a learning environment as a differentiation criterion for the four modalities: traditional, web-facilitated, blended/hybrid and online learning (Table 1).

According to Allen et al. (2007), the classification of a course into: traditional; web-facilitated; blended/hybrid; and online learning, depends on the percentage of the course that is delivered online. Thus, according to the authors a course to be considered a blended learning approach must have between 30% and 79% of the course content delivered online. With this classification, the term Web-facilitated is introduced for face-to-face courses that have up to 29% online content (see Table 1).

Table 1. Course classifications according to Allen et al. (2007).

Proportion of Content Delivered Online	Type of Course	Typical Description
0%	Traditional	Course without the use of online technology – content is delivered orally or in writing
1 to 29%	Web Facilitated	Course which uses web-based technology to facilitate what is essentially a face-to-face course. Uses a Learning Management System (LMS) or web pages to post the syllabus and/or assignments
30 to 79%	Blended/Hybrid	Course that blends online and face-to-face delivery. Substantial proportion of the content is delivered online. Typically uses online discussions, but also has some face-to-face meetings
80+%	Online	A course where most or all the content is delivered online. Typically have no face-to-face meetings

It is clear that the use of ICT is an essential condition for the implementation of teaching modalities that have an online component. In recent years there has been a marked growth in technological solutions (LMSs, video conferencing platforms, audience response systems, among others) that make it easier for teachers to implement strategies with an online component, a situation that has been enhanced by the COVID-19 pandemic.

1.4 Learning Management Systems (LMS) - Moodle

Engineering education faces new challenges since students are different and teaching methodologies have not adapted or evolved in accordance, or at least not at an adequate pace. Today's students are dependent on the Internet, and HEIs must take advantage of this fact to promote teaching and learning. The teacher's role has changed (or it should change), and other types of learning environments have emerged, trying to make the most of the potential that ICT has to offer as facilitators of teaching/learning. In this context, most HEIs have been providing LMS platforms for more than a decade.

LMS platforms are web-based software applications that support learning content, allow interaction of and with students, have assessment tools, and allow producing learning progress reports (Kasim & Khalid, 2016). The most popular open-source LMS platforms are Moodle, Sakai, and Atutor. Blackboard, SuccessFactors, and SumTotal are examples of non-open-source LMS platforms and are more commercial. The LMS platform we will look at in more detail will be Moodle, since it is the most widely used platform in HE and it is the one used in the institution under study in this chapter.

Moodle (Modular Object-Oriented Dynamic Learning Environment) was originally developed by Martin Dougiamas and was first made available online in 2002 (Grant et al., 2018). It is used in 242 countries by over 411 million users, featuring more than 47 million courses and 158,300 sites (Stats Moodle, 2024). In Portugal, there are 2,316 registered sites (Stats Moodle, 2024). Moodle allows for the creation of web-based courses and content and is designed to provide educators, administrators, and students with a single robust, secure, and integrated system for creating personalized learning environments and experiences. It is worth noting that Moodle is open source, which is quite appealing to HEI with ICT courses and programming skills.

From the perspective of the teacher, Moodle is user-friendly (at a basic level) and offers an enormous amount of functionality (see Figure 1). Essentially, interaction

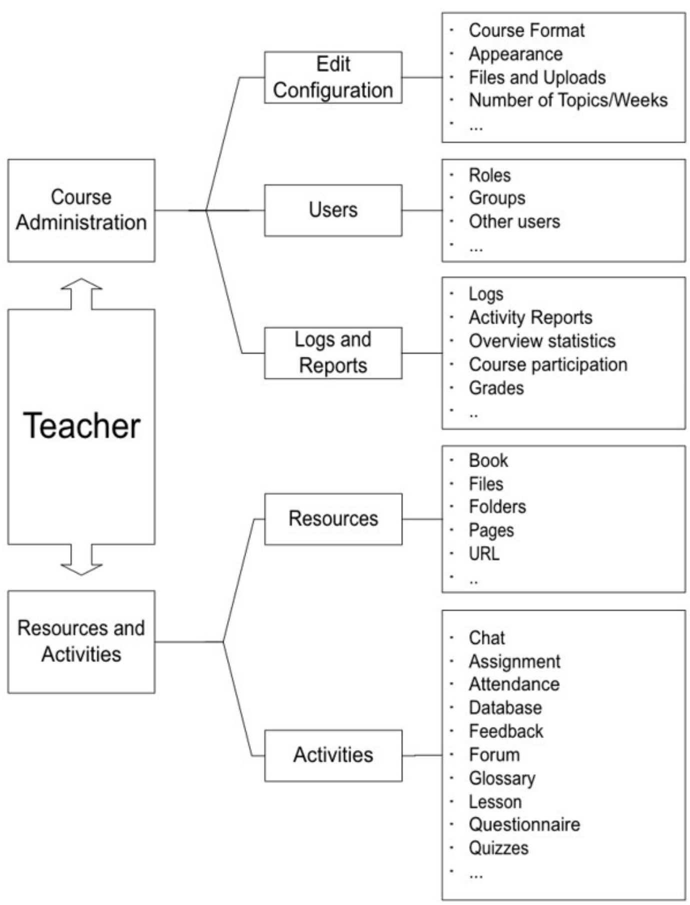


Figure 1. Moodle features in teacher perspective.

with Moodle can be divided into two main blocks: Course Management and Resources and Activities (Büchner, 2016; Henrick & Holland, 2015; Nash & Moore, 2014).

In the Course Administration section, teachers can perform all activities related to the formal part of the course. This includes defining course Format, Appearance, Files and Uploads where teachers can define if they allow uploads and the maximum file size, number of topics or weeks, enrolling students/teachers, assigning roles, creating workgroups, defining assessment criteria, reviewing student grades, and generating various types of reports.

Resources and Activities are the key functionality for interaction between teachers and students, as well as direct interaction among students. In Resources, teachers can provide all supporting content such as slides, exercises, books, lab guides, and sample exams. Activities can include chat rooms, forums, quizzes, lessons, among others.

Moodle has several interesting features, namely (Lustek et al., 2019; Meikleham & Hugo, 2020; Kasim & Khalid, 2016; Olmos et al., 2015):

- Makes it easy to look up content, as it is available online, can be accessed anywhere/anytime, which potentially increases student motivation (especially for working students);
- Allows for automatic evaluation and grading of students, through tests/quizzes, giving them immediate feedback;
- Allows the teacher to monitor students' activity more easily (for example, it is possible to check the records of when and how many times a student has logged in, what he/she has consulted, which activities/resources he/she has been in, how long he/she has been in each activity/resource);
- Allows easy administration of assignment/report submission, submission deadlines control and version control (for example, you can check deadlines, date and time of file submission...).

Studies indicate that the interactivity provided by tasks/assignments in Moodle has led to more active students, with greater motivation and willingness to learn (González et al., 2013). Furthermore, the integration of online components into traditional classes has been shown to substantially improve communication between students and teachers, increase access to Internet resources, and increase student satisfaction (Chung & Ackerman, 2015).

1.5. Guided exercises

One of the problems that science and engineering teachers face is the difficulty that their students have in solving exercises. To develop students' problem-solving skills, a strategy called "Guided Exercises" was implemented through a collaboration process with a researcher in didactics from the Research Centre on Didactics and Technology in the Education of Trainers (CIDTFF) at the University of Aveiro. It was found that during the studies conducted in the scope of this collaboration, students exhibited a behaviour similar to what is described in the literature (e.g., Heller et al., 1992; Heller & Hollabaugh, 1992; Saul, 1998), where they only focused on finding the formula to solve the exercise without seeking to understand the concepts and/or models related to the physical situation of the exercise. According to Saul (1998), students may be able to solve traditional exercises or typical end-of-chapter exercises in textbooks, but this does not indicate that they have understood the underlying physical situation or that they can make connections between physical concepts and real-life situations. To address this problem, Heller et al. (1992) and Heller & Hollabaugh (1992) started by studying the mechanisms used by students to solve end-of-chapter exercises. When students work together in groups to solve these exercises, the discussions that take place within the group often revolve around questions like "Which formula should we use?" rather than "Which physical concepts and principles should be applied to solve the problem?" In that study, it was estimated that about two-thirds of students use the approach of "Which formula should I use?" when solving end-of-chapter exercises. Therefore, it was concluded that typical exercises from textbooks do not promote high-level cognitive discussions among students.

In response to the identified problems, a strategy called "Guided Exercises" was conceptualized. This is an active learning strategy that aims to promote the application of knowledge and reasoning in exercise solving by combining conceptual questions with calculations. A Guided Exercise can be created, for example, based on a typical end-of-chapter exercise. In this type of exercise, students are usually only asked to perform calculations. To perform these calculations, students need to mobilize and relate models and reasoning. Therefore, a Guided Exercise breaks down the typical exercise into several questions that students must answer in a logical sequence. Thus, before performing each calculation, students must answer a question about the concept/phenomenon associated with that calculation. This methodology is in line with a study conducted by Hegde & Meera (2012). In their work, the authors argue that the first step in problem-solving is to identify the applicable physical principle to the situation. The same authors found a weak association between students' conceptual structure and physical principles, which acts as a major obstacle in problem-solving. Most of the time, the physics terms in the exercise statement trigger the search for an equation, and if there is an inability to do so, it can hinder the complete resolution of the exercise. The goal of this type of exercise is for students to not only apply formulas but also associate those formulas with the underlying concepts. By applying this strategy, students can understand the models and reasoning required to solve these "typical exercises" and later apply this knowledge to new situations.

This strategy, Guided Exercises, promotes the learning of complex content and requires active student participation in their own learning process, starting with an in-depth analysis and providing increased cognitive flexibility through the sequence of various questions. This participation demands reflection, knowledge maturation, and cognitive flexibility (Spiro & Jehng, 1990). With this strategy, the aim is for students to understand, reflect upon, and apply the covered content.

The feedback provided by Guided Exercises can be of different types. We can classify the feedback into three types: I and II. Type I feedback is given when students choose a response option and simply find out if it is correct or incorrect. Type II feedback provides students with indications of where they went wrong and how they can improve if they choose the wrong option, without revealing the solution. If they choose the correct option, they receive an encouraging message.

2. Case study

The pedagogical practice described in this paper was implemented in two courses of the 3rd year of the actual bachelor's in Civil Engineering of the University of Aveiro: Soil Mechanics I and II. In each academic year, these courses are taught consecutively in the 1st and 2nd semester to a group of students that is practically the same. The courses, Soil Mechanics I and II, have been the object of transformative pedagogical practices since the school year 2007/2008. These practices, the authors' reflections, and the results of the evaluation of their implementation have been shared in several national and international forums, like conferences, workshops and scientific papers. In a first transformation, a project-based learning model was implemented (using a cooperative, and collaborative models), described in detail by Pinho-Lopes et al. (2011) and Pinho-Lopes & Macedo (2016). Since 2015/2016 the strategy named "Guided Exercises" was implemented (Macedo et al., 2020; Oliveira et al., 2018). This is the strategy object of study in this paper. In 2019/2020 immediate feedback sessions were introduced (similarly to Pinho Lopes & Powrie, 2020). In consequence of the COVID-19 pandemic context, in 2020/2021 flipped learning was implemented in these courses using a hybrid model (Pinho-Lopes & Macedo, 2022).

The SMI course is an introductory course where the fundamental concepts and basic proprieties of Soil Mechanics are presented. Considering that the behaviour of Civil Engineering constructions is significantly affected by the mechanical and hydraulic properties of the soils where they are implanted, their study is essential for subsequent application in the design of Civil Engineering structures. The SMI program is grouped into four distinct chapters: (1) Physical properties and soil identification; sedimentary and residual soils; (2) Stress state in soils; capillarity; (3) Water in soils; seepage and (4) Compression and consolidation of clay soils.

In the second semester, SMI contents are complemented in SMII. In this course, the fundamental concepts and basic properties of soils are now used as the basis for the application of concepts, theories and methods commonly used in civil engineering for the conception and design (using the Eurocodes) of several types of geotechnical structures. For that it is fundamental to understand how the structures and/or their components are somehow conditioned by the mechanical behaviour of the soil masses where they are implanted. For this reason, the course starts with the study of soil shear strength and stress-strain relationships. The content also covers the field tests generally used to characterize the mechanical behaviour of soils. The contents are grouped in the following four chapters: (1) introduction to soil shear strength; shear strength and stress-strain relationships in sands and clays; (2) lateral earth pressures; earth retaining structures; (3) stability of slopes and embankments and (4) in situ sampling and testing.

Both courses have presential classes. In relation to the weekly contact hours, both have four hours of classes (in two different days) and one hour of tutorial class. In SMI one lesson is theoretical–practical and the other is practical. In SMII both lessons are theoretical–practical. Each course has 6 ECTS units, which correspond a total of 162 hours work, assuming that each ECTS represents 27 hours work (value adopted by the University of Aveiro). Such workload includes class time, individual study time, preparation of reports, elaboration of projects, bibliographical research, and revision for exams.

As stated, in the beginning of 2007/2008 academic year the two courses on Soil Mechanics (SMI and SMII) were fully redesigned to include project-based learning (PjBL). Triggered by Bologna Process and its requirements, teachers decided that was the right moment to adjust their courses to adopt student-centred learning models, complementing the traditional teacher-centred model. The implementation of this strategy is described in detail by Pinho-Lopes et al. (2011) and Pinho-Lopes & Macedo (2016).

After the first editions of the PjBL implementation, it became clear that there were some limitations. The most relevant one was that students worked more cooperatively than collaboratively. Thus, it was found that within each team, students tended to divide tasks and only focused on their specific task, not communicating with their peers. This led to a compartmentalization of knowledge that was evident in the exam results. Therefore, many times each student developed the relevant knowledge and skills in the part of the project they were working on and knew little about the other subjects (Gredler, 2000). To address this limitation, a complementary strategy was used - Guided Exercises - which was implement for the first time in 2015/16 in SMII.

The aim of Guided Exercises was to improve the teaching-learning process while keeping the students in the centre of the procedure (Oliveira et al., 2018). Supported by ICT, namely the LMS available in the UA (Moodle), one or two Guided Exercises per chapter of the syllabus were prepared and made available to students. The use of

Moodle allows to give immediate feedback to students in two different ways. The first is through the grade, simply formative, obtained by the students when they finish each exercise. The second, through short comments, previously prepared by the teachers, to the answers given by the students to certain questions. These comments can be suggestions for reading certain chapters of the support manual, indication of which is the correct answer, or simply messages of encouragement. The Guided Exercises were available in two moments. Firstly, at the end of each chapter and for a period of 15 days. During that time students had unlimited attempts to the Guided Exercise. Later, during the exam period, all Guided Exercises were available again to help students with revision. Students' participation was voluntary and did not have any influence on their final grade.

Since the second semester of 2015/2016 the strategy Guided Exercises is available to students. However, due the COVID-19 pandemic was necessary to prepare different teaching approaches to deal with the lockdown periods. Thus, in the second semester of 2019/2020, it was necessary to use emergency remote teaching to continue teaching activities. The teachers and students had to learn quickly how to use new technologies, such as video conferencing platforms like Zoom and MS Teams, to maintain the synchronous moments of teaching. The consequent additional workload led to a concentration of students' attention on the tasks that actually counted for their assessment. For this reason, there was a considerable decrease in the use of Guided Exercises, since these were not considered for assessment, serving only as formative purposes.

In the academic year 2020/2021 a blended learning model was implemented. The lessons learned during the previous semester, and the constraints impose by the UA due the pandemic, motivated the teachers to implement a new strategy fully supported by UA's Moodle, the flipped classroom. Traditional classes have given place to online ones implemented with the following structure. First, a video lesson (< 15 minutes) where each content is expose. Then, a short exercise or conceptual question with immediate feedback and finally a short summary with the main ideas. These online classes should be seen prior to the synchronous moments, which were used to conduct discussions with students and resolution of exercises promoting deeper learning. More details can be found in Pinho-Lopes & Macedo (2022). With some adjustments, due to return to face-to-face model, this strategy was also used in 2021/2022. Again, during these two academic years a reduction in the use of Guided Exercises was observed.

3. Methodology

The implementation of the strategy Guided Exercises in SMI and SMII courses was assessed using two different approaches. The first one was the preparation of a questionnaire, distributed to the students in the end of each semester, to collect the students' perceptions about the strategy and to identify if there was a need to adjust it. The second one was the analyses of the students' academic performance through the study of the existence of a correlation between the use of Guided Exercises and obtaining a passing grade on the final exam, carried out by all students individually. The aim is to examinate if Guided Exercises promotes learning in students. This second approach is the study object of this paper.

In the second semester of 2015/2016, after the first experience of implementation of the Guided Exercises, a questionnaire was prepared. The questionnaire was composed by 17 closed questions using a Linkert Scale (1 totally disagree to 5 – totally agree) and 3 open questions. The first was aimed to understand why students used Guided Exercises. The other two intended to identify at least one positive and one negative aspect on Guided Exercises. The intention was to obtain information to support the incorporation of some adjustments in the strategy to meet the expectations of the students.

The study we intend to do in this paper is to understand whether the use of Guided Exercises promotes learning in students and whether this can be measured and correlated with the grades obtained on a final exam.

To do this it was necessary to establish criteria that would allow to divide the students into two groups: those who used the "Guided Exercises" strategy and those who did not use the "Guided Exercises" strategy.

There were two criteria used:

- They did more than 75% of the Guided Exercises made available;
- The grade obtained in these Guided Exercises was greater than or equal to 10 (on a scale up to 20).

The usage rate of the Guided Exercises by the students was obtained at the end of each semester by consulting the Moodle utilization history.

To verify the existence of a correlation between the use of Guided Exercises and the obtaining a passing grade on the final exam, several statistical tests were used. For this purpose, was used a computer software, IBM SPSS Statistics software, version 26. The first statistical test used was the chi-square test of independence. This test allows to find out if two variables are related. In this case it is intended to understand whether solving Guided Exercises is related to passing the final exam. A complementary test to the chi-square test was performed, which was Cramér's V test. This test allows us to measure the strength of association between two nominal variables giving a value between 0 and 1 (the classification is: i) > 0.5 - high association; between 0.3 and 0.5 - moderate association; iii) between 0.1 and 0.3 low association and finally iv) between 0 and 0.1 - little if any association).

These two tests can be complementary since the chi-square test is a test of statistical significance while Cramer's V test is a test of substantive significance. Put in other words, with the chi-square test one answers the question "Is there a relationship between using the Guided Exercises and a student passing the final exam?" while with Cramer's V-test one answers the question "How strong is this relationship?"

4. Results and discussion

The surveys conducted with students between 2015/2016 and 2018/2019 on their perceptions on Guided Exercises allowed to identify a set of evidence on the added value of its use. Thus, in that period Guided Exercises were available to 89 students assessed on the courses. In total, 64 students (near 75% of the assessed students) answered the questionnaire made available at the end of each academic year. The results obtained allow to highlight several aspects (Macedo et al., 2020):

- Guided Exercises were important, to understand the contents covered in class, to their learning process and were a different way of studying;
- Guided Exercises helped students to understand the steps that must be taken to solve an exercise, helped them to understand the reasoning behind that problem and the majority tried to solve the exercises without guessing the corrected answer by trying several times and checking if the answer is corrected;
- Students considered that Guided Exercises were better understood than traditional, the feedback given helped them to understand their difficulties and oriented them to solve other exercises.

From the open questions, the results showed that students used Guided Exercises for study (59%), revise contents (42%) and guide them through an exercise (16%). Regarding the positive and negative aspects, as positive aspects they pointed that Guided Exercises helped them to better understand what was asked in the exercise (38%), to study during the semester (25%) and to organize their answers (22%). As negative aspects students said that they would like to have more Guided Exercises (33%), Guided Exercises should be shorter (28%) and Guided Exercises should be always available (27%). The results of these surveys are described in detail by Macedo et al. (2020).

Regarding the statistical analyses between the use of Guided Exercises and the students' academic performance, the results are presented below.

The sample with all students (academic year 2015/16 to 2021/22 of the two courses: Soil Mechanics 1 and 2) has 199 students. The criterion for using exam grades as the element for comparing the two groups of students is because exams are the element of assessment carried out under similar conditions.

The results can be summarised in the following Table 2.

From the analysis of these results, it can be stated that the number of students who did not do at least 75% of the Guided Exercises made available was 135 (67.8%). Of these 135, 56 (41.5%) were approved in the exam.

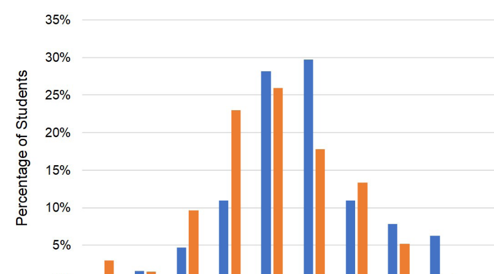
On the other hand, 64 students (32.2% of the total number of students) did more than 75% of the Guided Exercises, and of these, 38 (59.4%) were approved in the exam.

To perform a deeper analysis to the academic performance between the two groups of students, their grades in the final exam were compared by analysing the relative frequency of the grades obtained by each group of students (Figure 2).

Analysing Figure 2, it is not only in terms of approval rate that there are differences between the two groups of students. As it can be seen, the group of students that did Guided Exercises obtained higher grades. For example, the percentage of students who obtained grades between 10 and 12 (on a scale of up to 20) was almost two thirds higher (30% vs 18%) for students who did Guided Exercises.

The same conclusion can be drawn by looking at the normal distribution of the grades of the students in the two groups (Figure 3). There is a clear deviation to the right of the normal curve for students who did 75% of the Guided Exercises.

Thus, it may be concluded that Guided Exercises seem to have a positive effect for the approval in the final exam. The chi-square test was used to check whether these results are statistically consistent. The value obtained was 5.578 with a significance level of p=0.023 (<0.05), which



	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20
Did at least 75% of GE	0%	2%	5%	11%	28%	30%	11%	8%	6%	0%
Did not do at least 75% of GE	3%	1%	10%	23%	26%	18%	13%	5%	1%	0%

Figure 2. Grades distribution between the two groups of students analysed (all students).

Table 2. Results of approval rate in the final exam vs the use of Guided Exercises (GE) for students from academic year 2015/16 to 2021/22.

	Approved		Failed		Total
	Number of cases	%	Number of cases	%	Number of cases
Total	94	47.2	105	52.8	199
Did not do at least 75% of GE	56	41.5	79	58.5	135
Did at least 75% of GE	38	59.4	26	40.6	64

shows that the number of students who passed the exam is related to the Guided Exercises. For these data, Cramer's Statistic is 0.167 that represents a low association between doing Guided Exercises and be approved in the final exam. This low association may be related with the introduction of new distance learning methodologies. As previously mentioned, from the second semester of the academic year 2019/20 and due to the Covid pandemic, new distance learning strategies have been introduced. Thus, students were eventually encouraged to use other strategies and Guided Exercises naturally ended up being less used. Therefore, we chose to present another study with a smaller sample (with 89 students) from the course units of Soil Mechanics I and II from the academic years between 2015/16 and 2018/19. This sample is prior to the Covid pandemic and therefore the students' focus was more on the only online strategy available which was the Guided Exercises.

The results are summarised in the Table 3. In terms of the exam grades a similar analysis to the one realised for all academic years was carried out (Figure 4 and Figure 5). The first major difference between these results and the results obtained when considering all students (199) is that now the percentage of students who did and did not do the Guided Exercises is almost equal (46 students - 51.7%) did not do the Guided Exercises and 43 students did the Guided Exercises (48.3%).

The second major difference is in the impact that the Guided Exercises had on approval in the final exam. Of the students who did not do Guided Exercises only 26.1% passed. This compares with 48.8% (almost double) of the students who did Guided Exercises and passed the final exam. Again, these results have statistical validation. The result obtained for the chi-square test was 4.930 with a significance level of p=0.03 (<0.05) which shows that the number of students that were approved in the exam is related to the use of the Guided Exercises strategy. When Cramer´s V test is applied, a value of 0.325 is obtained, indicating a moderate association between doing Guided Exercises and be approved in the final exam.

Similar to the previous analysis conducted for all students, a deeper analysis of the academic performance between the two groups of students was performed for those who attended the courses in the period between the academic years 2015/16 and 2018/19. Their grades in the final exam were compared by analysing the relative frequency of the grades obtained by each group of students (Figure 4) and their normal distributions (Figure 5).

Regarding academic performance, the trends observed for all students are the same as those seen above when considering the sample of students who attended the courses

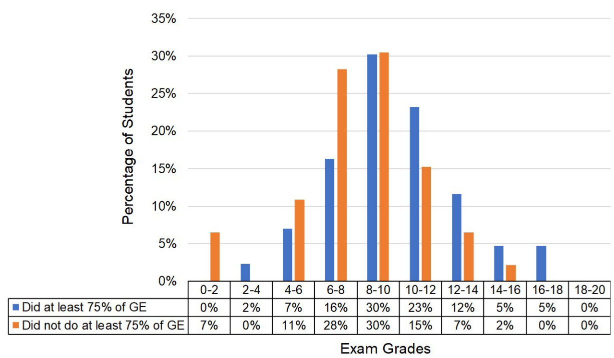


Figure 4. Grades distribution between the two groups of students analysed (2015/16-2018/19).

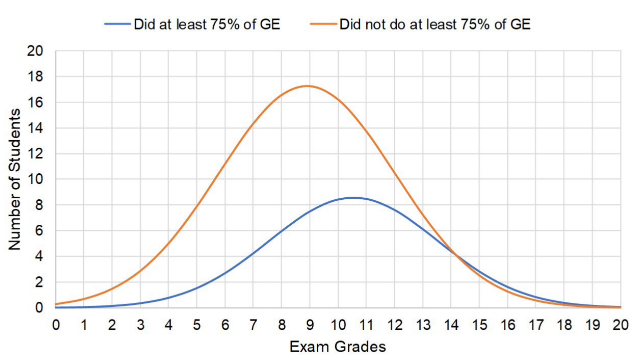


Figure 3. Normal distributions of the exam grades between the two groups of students (all students).

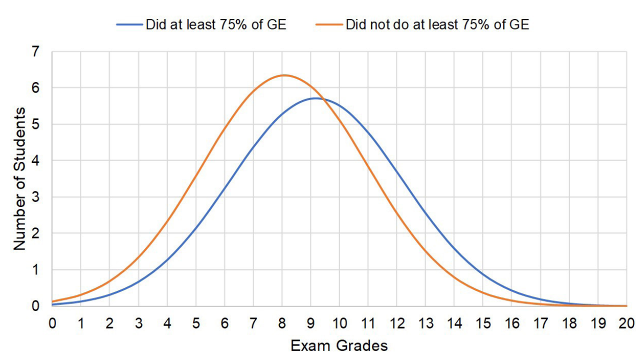


Figure 5. Normal distributions of the exam grades between the two groups of students (2015/16-2018/19).

Table 3. Results of approval rate in the final exam vs the use of Guided Exercises for students from academic year 2015/16 to 2018/19.

	Approved		Failed		Total
	Number of cases	%	Number of cases	%	Number of cases
Total	33	37.1	56	62.9	89
Did not do at least 75% of EG	12	26.1	34	73.9	46
Did at least 75% of EG	21	48.8	22	51.2	43

between the academic years 2015/16 and 2018/19. It is clear that students who did at least 75% of the guided exercises obtained better academic results than those who did not.

All the previous analyses revealed that the use of the learning strategy Guided Exercises have a positive influence both in the approval rate and students' performance in terms of the obtained grades in the final exam.

This active learning strategy can easily be applied, with the necessary adaptations, to other courses in the areas of engineering and exact sciences, e.g. (Urbano et al., 2014). For the success of the strategies some principles should be followed. As reported by students (Oliveira et al., 2018) the length of the exercises should not be too long, the number of exercises available should be enough to cover all the syllabus, be available throughout the semester on the LMS platform and if possible be used in the classroom. Another important aspect is the immediate feedback provided. More important that knowing what questions students got wrong, specific feedback should be provided on each question to guide them to the content they need to revisit. The results obtained from the use of this strategy over the years have revealed that the level of engagement is essential to its success. The use of other strategies and the fact that it is not compulsory in terms of assessment has resulted in a decline in its use in recent years. However, the variety of strategies and resources allow students to have a more flexible and personalised learning environment for which Guided Exercises contribute.

5. Conclusions

In this paper was presented and discussed an experience in implementing an active learning strategy called "Guided Exercises". The strategy is implemented in two consecutive courses on Soil Mechanics (Soil Mechanics I and II) of the Civil Engineering undergraduate study programme at the University of Aveiro, since 2015/2016.

The main motivation for developing and using this strategy in these courses was the necessity to find a solution to one of the problems identified during the implementation of the PjBL. It was found that students tended to compartmentalize content (Pinho-Lopes & Macedo, 2016), and it became necessary to find a teaching-learning strategy that could minimize this issue. With Guided Exercises students could test their understanding of the contents in a more organized and systematic way. Supported by ICT, the Guided Exercises can be used to mobilize knowledge to solve complex problems.

The strategy was assessed using two different approaches, a questionnaire, and an analysis of the relation between the use of Guided Exercises and approval ratio at the final exam. From the first one, it can be concluded that students considered the strategy useful to understand contents and the necessary steps that must be taken to solve a complex problem. They also considered it important for their learning process and a different way of studying.

The results obtained by analysing the grades at the final exam and the use of Guided Exercises strategy by students revealed that there is statistical evidence showing that using Guided Exercises influences the approval ratio. When analysed the period on which the strategy was used in a more systemic way (between 2015/2016 and 2018/2019) the approval ratio of students that used Guided Exercises was almost the double than the students that did not used it. This conclusion is supported by the results of the statistical tests performed, demonstrated by the fail rate which is smaller among the students who did at least 75% of Guided Exercises (40.6% against 58.5% when all students are considered and 51.2% versus 73.9% when are considered only the students that attended the courses in the period 2015/16 to 2018/19) and corroborated by the statistical tests performed which revealed significant statistical differences.

The level of engagement also plays an important role in the success of this active learning strategy. During the period in which students used the guided exercises more (2015/16 to 2018/2019), their influence on the results was greater, as evidenced by the results of Cramer's V test. The obtained value was 0.325, compared to the value of 0.167 obtained for all students.

Since COVID-19 pandemic the use of Guided Exercises had a significant reducing in its use by students, due the introduction of other online strategies. The diversity of strategies and resources provides students with a flexible and personalised learning environment, to which Guided Exercises significantly contribute. The next main challenge is to find a better equilibrium between the different active learning strategies available. One way to achieve this equilibrium is to incorporate all the strategies in more integrated way, for example using a gamification approach.

Future civil engineers face many challenges, and the field of geotechnical engineering education plays a relevant role in their preparation. Challenges such as technological advancements, interdisciplinary approaches, sustainability, innovation, lifelong learning, globalization, and cultural diversity require students to develop a set of both hard and soft skills to address them. In this context, students will increasingly have to use digital tools, be challenged to develop soft skills, and adapt to learning environments tailored to an increasingly diverse student profile where personalization plays a crucial role. As showed in this paper, the Guided Exercises strategy can help promote the use of digital tools and contribute to personalised learning.

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Declaration of interest

The authors have no conflicts of interest to declare. All co-authors have observed and affirmed the contents of the paper and there is no financial interest to report.

Authors' contributions

Joaquim Macedo: conceptualization, methodology, investigation, data curation, visualization, writing – original draft, validation, writing – review & editing. Paulo C. Oliveira: conceptualization, methodology, investigation, data curation, visualization, writing – original draft, validation, writing – review & editing.

Data availability

The datasets generated analysed during the current study are available from the corresponding author upon request.

List of symbols and abbreviations

p Probability value, p-value
CIDTFF Research Centre on Didactics and Technology in the Education of Trainers
ECTS European Credit Transfer and Accumulation System
GE Guided Exercises
HE Higher Education
HEIs Higher Education Institutions
ICT Information and Communication Technologies
LMS Learning Management System
PjBL Project-based learning
SMI Soil Mechanics I
SMII Soil Mechanics II

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