Project-based learning in consecutive modules on Geotechnics: Foundations

Apprentissage basée aux projets en modules consécutive aux Géotechnique: Fondations

J. Macedo and M. Pinho-Lopes

1 University of Aveiro, Aveiro, Portugal
2 University of Southampton, Southampton, United Kingdom
3 University of Aveiro, Aveiro, Portugal (unpaid leave)

* Corresponding Author

ABSTRACT Three conditions of effective learning have been reported: active learning by doing, cooperation and teamwork in learning and learning through problem solving, essential to promote creativity and innovative capacity. Project-based learning can help to promote such skills in engineering programs as it allows recreating professional reality and relating fundamental theories and skills of an engineer. High-level thinking and sound judgment is developed through accumulated authentic professional experience by engineers. For engineering students a similar process can be triggered by a teaching environment which enables simulating and stimulating such skills. To prepare better professional and enhance students’ employability Civil Engineering students of University of Aveiro, Portugal, have undertaken several modules on Geotechnics where a project based learning model has been used. These group projects included open-ended realistic scenarios tackled using different tools (spreadsheets and software). This paper refers to a module on Foundations. A collaborative project-based learning model was implemented. Students’ perceptions on the added value of the project were collected using a questionnaire and are discussed. Most students had attended two modules on Soil Mechanics where a similar learning model was used, but initially they had negative reactions to it. Students report a severe workload; however their estimates match the expected working hours. The model has been evolving in order to optimise the learning and address the students’ feedback.

1 INTRODUCTION

Civil Engineering students of University of Aveiro, Portugal, have undertaken several modules on Geotechnics where a project-based learning model has been used. Such models were firstly implemented in 2007/2008 on two modules of the 3rd year of the integrated master in Civil Engineering: Soil Mechanics I and Soil Mechanics II. Their implementation, the projects used and reflections on its impact on students have been previously discussed by Pinho-Lopes et al. (2011), Pinho-Lopes (2012a, 2012b) and Pinho-Lopes & Macedo (2013, 2014).

This paper refers to a subsequent module on Foundations and Retaining Structures (4th year), where a similar approach has been used.
The redesign of the modules was triggered by two main reasons: the implementation of the Bologna Process which enforced a significant change on traditional learning models based on the transmission of knowledge; and the necessity of prepare the students for the innovative and flexible role of engineers in today’s society.

The introduction of the project-based learning model on the modules allowed the promoting of high order thinking and problem solving skills through the using of realistic projects, adapted to the students’ level of knowledge. Such skills are critical to the engineers when they resolve geotechnical problems because to solve them they routinely use critical thinking and engineering judgment (Pierce et al., 2013).

Effective learning has been promoted by including active learning by doing, cooperation and teamwork in learning and learning through problem solving, as suggested by Nordstrom & Korpelainen (2011).

The ultimate goal of using these approaches is increasing students’ employability, preparing better professionals.

2 CASE STUDY

The module on Foundations and Retaining Structures was redesigned in 2011/2012 to include project-based learning. The module was updated to include projects trying to replicate realistic situations where the students worked in teams. On the following sections the module is set into the context of the course and of the other modules on Geology and Geotechnics.

2.1 Course and modules on Geotechnics

The Civil Engineering course in University of Aveiro (UA), Portugal, is an integrated master totalling 5 years (10 semesters), corresponding to 300 ECTS (European Credit Transfer System).

In years 1 to 4 of the course all modules are compulsory (usually corresponding to 6 ECTS) and on the 5th year students take three elective modules (6 ECTS each) and a M.Sc. dissertation (42 ECTS). For the elective modules students have a significant number of options available.

Within the course there are 2 compulsory modules on Geology and 3 on Geotechnics (Table 1). The goal all this group of modules is to provide all students with a solid knowledge on Soil Mechanics and on Geotechnical Engineering, with a good geology background.

<table>
<thead>
<tr>
<th>Module</th>
<th>Year</th>
<th>Semester</th>
<th>ECTS</th>
<th>Scientific area</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Geology</td>
<td>Y1</td>
<td>S1</td>
<td>6</td>
<td>Geosciences</td>
</tr>
<tr>
<td>Engineering Geology</td>
<td>Y2</td>
<td>S2</td>
<td>4</td>
<td>Geosciences</td>
</tr>
<tr>
<td>Soil Mechanics I</td>
<td>Y3</td>
<td>S3</td>
<td>6</td>
<td>Civil Engineering</td>
</tr>
<tr>
<td>Soil Mechanics II</td>
<td>Y4</td>
<td>S4</td>
<td>6</td>
<td>Civil Engineering</td>
</tr>
<tr>
<td>Foundations and Retaining</td>
<td>Y5</td>
<td>S5</td>
<td>6</td>
<td>Civil Engineering</td>
</tr>
<tr>
<td>Structures</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Year; * Semester

2.2 Modules on Soil Mechanics

Since 2007/2008 the two modules on Soil Mechanics (I and II) were completely redesigned to include project-based learning. This involved using cooperative or collaborative approaches. Their implementation, the projects used, some reflections on its impact on students and strategies to improve them have been previously discussed by Pinho-Lopes et al. (2011), Pinho-Lopes (2012a, 2012b) and Pinho-Lopes & Macedo (2013, 2014).

On those modules, besides tackling traditional text books problems using hand calculations, students undertook group projects using computing and specific geotechnical software (further described by Pinho-Lopes 2012a). The main goal was to help students develop soft skills and become familiar with typical numerical tools currently used in Geotechnics, while developing high order thinking and problem solving skills. For the projects students were asked to create their own spreadsheets from scratch. Students were guided into critically analysing results obtained using different approaches to increase their awareness to common misinterpretation of data generated using both spreadsheet and other software.

The groups for the project work were assigned by the teaching team and this has proved to be one of the major issues for students. Most students are not willing to work with people they do not know well and prefer to work with their friends. Adding to this, some conflicts within the group, different perspectives and ambitions for their marks often constitute additional challenges for students.

Pinho-Lopes & Macedo (2014) have identified some strategies to try and overcome such issues.
However, the success of the project-based learning model depends essentially on the attitudes of students. Convincing them of the relevance of the project-based learning model for both their academic and professional success, is crucial. Although an increased workload associated with the projects and the nature of the groups can be discomforting, it will better prepare students to face similar challenges in a professional life work environment.

2.3 Module on Foundations and Retaining Structures

The module on Foundations and Retaining Structures corresponds to 6 ECTS and the usual number of students per school year is 50 to 70. The weekly contact time is 4 hours for groups of up to 45 students simultaneously. The module aims at developing understanding and designing foundations and retaining structures, namely using the Eurocodes. The syllabus is grouped into: 1) Introduction; Types of foundations and retaining structures; Properties relevant for the design; Design philosophy; Eurocodes; 2) Ground characterization and investigation; 3) Shallow foundations; 4) Deep foundations; 5) Retaining structures.

By the end of the module the following learning outcomes should be achieved: Distinguish between shallow and deep foundations; Identify field and laboratory tests to use for the characterisation of the ground; Assess relevant parameters to use in the design of foundations and retaining structures, using test results; Apply methods described in the structural eurocodes for the design of foundations and retaining structures; Define an optimised solution for a certain problem; Design shallow foundations; Design deep foundations; Understand the constructive methods associated with the different solutions; Use computing and software to solve problems related with foundations and retaining structures; Ability to work in teams; Communication skills (oral and writing).

2.3.1 Project-based learning model

The project-based learning models comprised: Traditional lectures, to introduce the relevant concepts, in-class discussions and questioning; Tutorial sessions (included in the contact time), where students used hand calculations to solve problems linked to the each aspect of the syllabus; Compulsory team projects; Individual marks on the team projects, obtained using the students’ self and peer-assessment.

The team projects were prepared using a collaborative model. As such, the team as a whole was responsible for all the work, having to better organise and distribute tasks. So, without intervention of the teaching team, students need to distribute the work that must be done by each member of the team. The final submission consists of a written report summarising all the work developed. The final mark of each student is obtained by applying a weight to the team’s mark, based on the students’ self and peer assessment within the group (according to Felder & Brent (2007)).

2.3.2 Group formation and assessment

The groups were formed by the teaching team using the answers of the students to a questionnaire on the marks for previous modules and on their time availability to work on the project. With their answers, the teaching team organised heterogeneous and balanced groups, each including students of different levels and with compatible schedules.

The assessment included two different elements: team projects, and tests. During the semester each group prepared two team projects, and each student took two tests. For students failing, there was a second assessment (without any penalty) – a final exam, in which the weight of the individual mark on the projects was kept. The relative weight of the two assessment elements for the final mark was: 70% for the tests (average of the two) and 30% for the individual mark on the team projects. The threshold mark was 8 (up to 20) in each assessment element.

Thus, individual accountability was promoted using both the tests, which covered all subjects of the syllabus, and the individual marks on the projects.

2.3.3 Team projects

The team projects were open-ended assignments, which aimed at promoting critical thinking and engineering judgments by students. Realistic geotechnical cases were used for the projects, though adapted to their level of knowledge.

The team projects consisted in the analysis and design of foundations, using the Eurocodes, for different case studies, previously assigned to the groups.
The terrain was different to all groups and the selection of geotechnical properties for the soils had to be based on engineering judgements on results of in situ tests. Most projects included creating spreadsheets to compute, compare and analyse results. Additionally, numerical tools currently used by engineers when studying geotechnical problems were used. With those tools the students were challenged to analyse different situations where retaining structures and different types of foundations were used, checking the changes in the behaviour of such structures when some geotechnical parameters were modified. The aim was prepare the students to use these tools while promoting their critical judgment of the results achieved. With this the teaching team sought promoting high order thinking and problem solving skills. Students were also encouraged to use the spreadsheets they prepared and the software available (which enabled validating the spreadsheets) to derive solutions for the problems proposed in class. Such tasks were additional opportunities to develop the skills referred.

3 ANALYSIS AND DISCUSSION

3.1 Assessment

To evaluate the success and impact of these models on students’ learning, the teaching team has been collecting students’ feedback during the semester, monitoring their academic performance, and using questionnaires at the end of the semester.

During the semester students were asked to give an informal opinion on the model (orally and written, anonymously). A statistical analysis of the number of students enrolled, who attended, were evaluated and obtained a passing mark was done. The questionnaires used are part of the quality assessment system (SGQ) of University of Aveiro, created to both monitor and improve the quality of teaching. Such system is directed on all the modules each student attends.

3.2 Results

Table 2 summarises the data on the academic performance of students. In 2011/2012, the first time this model was used, 75% of the students undertook the assessment tasks and 77% of them obtained a passing mark. In 2012/2013 that number increased considerably to 98%. Two reasons can be pointed out to explain this difference. On one hand, most students repeating the module in 2012/2013 after failing it in 2011/2012, passed to module. Thus, when they attended the module for the second time they were already more familiar with the contents. On the other hand, although there were changes on the teaching team, the project-based learning model was kept. Students were more aware of what was expected from them.

Table 2. Academic performance of the students.

<table>
<thead>
<tr>
<th>Edition</th>
<th>NES</th>
<th>NSA</th>
<th>Pass</th>
<th>Fail</th>
<th>Quit</th>
<th>Final Mark (up to 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Average</td>
</tr>
<tr>
<td>2011/2012</td>
<td>76</td>
<td>57</td>
<td>44</td>
<td>11</td>
<td>2</td>
<td>10.93</td>
</tr>
<tr>
<td>2012/2013</td>
<td>76</td>
<td>60</td>
<td>59</td>
<td>1</td>
<td>0</td>
<td>12.27</td>
</tr>
</tbody>
</table>

NES Number of enrolled students
NSA Number of students assessed
SD Standard deviation

For the final marks, the results were also better on the second year of implementation of the model. An increase of about 12% was observed. The distribution of the final marks in each academic year can be observed in the Figure 1 and explains that result.

Figure 1. Distribution of the final marks.

It must be noted that the projects were different on both editions, which can have contributed to the trend observed.

The module on Foundations and Retaining Structures was assessed by the students using the SGQ platform. Table 3 shows the ECTS estimated by students for the module, and Table 4 summarises their answers on the module.
Table 3. SGQ results - ECTS estimated by students.

<table>
<thead>
<tr>
<th>Edition</th>
<th>NES</th>
<th>NVA</th>
<th>Estimated ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Average</td>
</tr>
<tr>
<td>2011/2012</td>
<td>68</td>
<td>40</td>
<td>5.62</td>
</tr>
<tr>
<td>2012/2013</td>
<td>76</td>
<td>35</td>
<td>6.32</td>
</tr>
</tbody>
</table>

NES - Number of enrolled students (eligible to SGQ)
NVA - Number of valid answers
SD - Standard deviation

The number of ECTS credit units estimated by students is similar to the number of ECTS assigned to the module (6 ECTS). With this result is possible to say that the workload of the module using the project-based learning model is suitable to what is expected from the module, despite the students’ opinion that the module is too laborious and complex, requiring many hours of work to obtain a pass mark (answers to question P17, Table 4).

Table 4. SGQ results for Foundations and Retaining Structures module (answers’ scale from 1, lowest, to 9, highest).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Average</td>
<td>SD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011/2012</td>
<td>40</td>
<td>5.26</td>
<td>1.68</td>
<td>6.11</td>
<td>1.69</td>
<td>6.15</td>
<td>1.88</td>
<td>7.03</td>
<td>1.56</td>
<td>5.67</td>
<td>1.96</td>
<td>6.36</td>
<td>1.68</td>
</tr>
<tr>
<td>2012/2013</td>
<td>35</td>
<td>6.59</td>
<td>1.02</td>
<td>6.49</td>
<td>1.66</td>
<td>6.71</td>
<td>1.81</td>
<td>7.18</td>
<td>1.93</td>
<td>6.74</td>
<td>1.93</td>
<td>6.59</td>
<td>1.68</td>
</tr>
</tbody>
</table>

NVA - Number of valid answers
SD - Standard deviation
P7 - Coordination of the different components (theoretical, practical, theoretical-practical, laboratory, …)
P8 - Adequacy of the recommended study elements and bibliography
P9 - Adequacy of the proposed activities (practical cases, homework) to the module and its objectives
P10 - Adequacy and modernity of the equipment (laboratory, computer rooms, etc.)
P11 - Inclusion of information in PACO (virtual secretary) and e-learning
P13 - Adequacy of the assessment method
P14 - Development of the comprehension skills on the themes covered
P15 - Articulation between the activities carried out in the module and the competences previously acquired
TTG - Total of groups P7-P15, except P12
P12 - Global functioning of the module
P16 - Degree of difficulty of the module contents
P17 - Workload /time necessary for obtaining pass mark

Analysing the answers to the questions about the module (SGQ) it becomes clear that the students’ perceptions were different in the two editions. In the first academic year of the model implementation the reaction of the students was rejection and suspicion. Usually when the students start the academic year they have some expectations about the modules functioning based on the previous years. In the Foundations and Retaining Structures module this wasn’t different and the redesign of the module with the inclusion of the project-based learning model that the students already knew from the previous modules on Soil Mechanics (I and II) generated the reactions mentioned above. In the second year the results of the SGQ survey show an increase of the values assigned by the students to almost all the items questioned. The exception was the degree of difficulty of the module contents (P16).

When redesigning the modules on Soil Mechanics the authors registered similar reactions from students, as reported in previous publications.

Additionally, this module, the projects and the support given to students while developing them were updated between the two editions, to take on board the students’ comments on the module in 2011/2012. The effectiveness of such changes is reflected on the answers to the questionnaire.

Overall, students answering the questionnaire considered that the assessment system was adequate (P13) and the different components of the module were well coordinated (P7). The resources available were found adequate (P8 – P11), which allowed the development of the comprehension skills (P14).

Finally, the informal feedback collected indicated that the groups’ formation, the workload, the use of specific software and the assessment method were the students’ main concerns. However, they also considered that the implemented model has advantages in their preparation for “real life” and for their future role as civil engineers. Similar feedback was obtained for the modules on soil mechanics (as reported by Pinho-Lopes et al. (2011) and Pinho-Lopes & Macedo (2013, 2014)).
3.3 Acceptance of the model

One of the most difficult aspects that the teaching team had to deal with, as already reported by Pinho-Lopes & Macedo (2014) for the Soil Mechanics modules, was the group formation. The students prefer work with their friends and so they reject working with people they don’t know very well. In some cases this generated conflicts within the groups it was necessary to implement relevant strategies to overcome such situations, overcoming conflicts and equipping students with tools to deal with problems. The strategies used are described in Pinho-Lopes & Macedo (2014) and follow suggestions of Felder & Brent (2007).

Another aspect that the students always refer as a problem is the workload. However their answers to the SGQ questionnaire show that the number of working hours they report is adequate. The number of ECTS estimated by students is close to the value assigned to the module (Table 3).

The use of specific software that needs some time to learn how it works is always referred as problem, although the teaching team tried to overcome it by providing students with specialised training.

Nevertheless, the project-based learning model has been well received by students for the module on Foundations and Retaining Structures, as well in all the other modules where it has been implemented.

4 CONCLUSIONS

The aim of using the project-based learning model used was to promote effective learning by students. For this, different learning styles were addressed and students were challenged to adopt deeper approaches to subjects relevant for their professional or personal development. Advancing students to higher development levels was intended too. In the last years the authors have carried out the implementation of such strategies in several modules on Geotechnics in the Civil Engineering program at UA.

For the module on Foundations and Retaining Structures, despite the initial reaction of rejection and suspicion students were generally successful. Their final marks are not very high but the added value of the projects is often evident for students when they tackle their M.Sc. dissertation or when they start their professional lives.

Students answering the questionnaires considered the module to be adequate and, although they report a severe working load, it matches what is expected from the module.

Some issues have been raised by the students that attended the different modules where this model has been used. However, according to students’ perceptions and to the overall judgement of the authors, the strategies adopted were useful and successful in promoting and facilitating the construction of knowledge and in developing competencies by students. Although students consider these approaches important for their preparation for the future professional life, it is necessary continue to show them the benefits to their professional and personal development of these student centred learning approaches. With more commitment students the model acceptance can be higher and their final results can be better.

REFERENCES


