

Reinforced soil with geosynthetics – hands-on learning (PBL) using sand and paper

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SUMMARY: An elective module on geosynthetics was designed and made available to Civil Engineering students (5 years' integrated masters). This paper reports a hands-on activity using sand and paper, adopted as part of a problem-based learning (PBL) model and the feedback collected in 2011/2012 using questionnaires. The model and its main features are briefly described, particularly the problem on soil reinforcement with geosynthetics. The students' feedback and some of their outputs are presented to highlight how simple and relatively cheap activities can contribute to learning and create a positive impact on students. The success of the PBL approach is enhanced by managing expectations, as well as giving adequate support and feedback to students.

KEYWORDS: hands-on, active learning, PBL, geosynthetics, reinforced soil, questionnaire

1 SCOPE

Geosynthetics can only be used to their full potential by engineers with an excellent understanding of geotechnical engineering. Therefore, to promote a sound understanding of these materials and their successful application, civil engineers should receive more education on geosynthetics (Giroud 2012). To increase the awareness of the possibilities offered by these materials, a module on geosynthetics was designed and made available to students on an integrated masters in Civil Engineering. This paper reports some hands-on strategies adopted as part of a problem-based learning (PBL) model and the feedback collected in 2011/2012.

The model and its main features are briefly described, particularly the assignment on soil reinforcement with geosynthetics, which included a hands-on activity using sand and paper. The students' feedback and some of their outputs are presented to highlight how simple and relatively cheap activities can contribute to learning and create a positive impact on students.

2 BACKGROUND

The traditional approach used for teaching engineering and science is deductive (Prince and Felder 2006), and has been widely criticised (Mills and Treagust 2003). Such strategies are not suitable to prepare engineering students to current professional challenges, fulfilling innovative and flexible roles and having adequate technical competence. Thus, alternative teaching and learning strategies, such as inductive teaching, project- and problem-based learning, have been used increasingly in the past years.

Hadgraft (1993) reported the application of PBL to civil engineering, describing it as “a way of developing a rounded engineer”, able to perform technically and having excellent communication skills and leadership qualities, while being able to work in team, innovating and taking initiative. The problems should be designed to challenge all students and have a wide range of possible answers, leaving most decisions on design parameters and methods to students (Hadgraft 1993).

Many other authors have been reporting their experiences with PBL in civil engineering, such as Rodrigues da Silva et al. (2012), Ahern (2010), Queen and Albano (2008), Ribeiro and Mizukami (2005) and Johnson (1999). Often,

PBL is used to teach design. In some cases instructors adopt problem-based pedagogical approaches for a complete module or problem-based learning environments for parts of a module (Dabbagh and Dass 2013).

Many of the characteristics and benefits of PBL make it a relevant pedagogical strategy in engineering education (Palmer and Hall 2011), as it allows posing realistic problems while using inductive teaching; additionally, design can be the vehicle for learning.

PBL generally involves (Prince and Felder 2006): teams of students (usually working cooperatively or collaboratively); open-ended assignments replicating real-life situations; definition of solution strategies by students; students' reflective analysis on the approaches used and the corresponding outcomes. A particular feature of PBL is that students "are confronted with an open-ended, ill-structured, authentic (real-world) problem and work in teams to identify learning needs and develop a viable solution, with instructors acting as facilitators rather than primary sources of information" (Prince and Felder 2006). Therefore, in PBL the acquisition of new knowledge is the central point and the solution may be less important than the knowledge gained in obtaining it (Prince and Felder 2006); PBL concerns problem analysis (Kolmos 1996).

3 CASE STUDY

3.1 Module on Geosynthetics

The elective module Application of Geosynthetics in Civil Engineering (AGCE) is part of the 5 years' integrated master in Civil Engineering offered at University of Aveiro (Portugal). The programme corresponds to 300 ECTS (European Credit Transfer System). Each ECTS credit unit represents 25 to 30 hours work including class time, individual study time, preparation of reports, bibliographical research and revision for exams, etc. The AGCE module corresponds to 6 ECTS; its last edition comprised 3 weekly contact hours.

The main goal of the module is to familiarise

future civil engineers with geosynthetics, how to select, conceive and design different types of structures where these materials are included. The syllabus includes: introduction to geosynthetics, constituent polymers and structures; standardization and tests; durability of geosynthetics; hydraulic works; road and railway works; erosion control systems and geotechnical works.

The module aims at developing the following competences:

- Interpret technical datasheets of commercial geosynthetics;
- Identify geosynthetics, namely their type, constituent polymers and structures;
- Identify the functions geosynthetics can perform and select properties associated with their correct performance;
- Define a test program to identify and characterise geosynthetics, depending on the application;
- Apply design methods for given functions and applications;
- Identify the corresponding construction procedures;
- Prepare specifications for the designed geosynthetics;
- Select materials among the commercial available alternatives.

3.2 Problem-based learning (PBL) model

3.2.1 General features

In the PBL approach used students tackled the problems in teams supported by the instructor. The first lesson of the semester included a guided formative activity where students were given samples of geosynthetics and their corresponding technical datasheets, representing a wide range of products and manufacturers. Students analysed the information available and compared it. More than one example of a certain product type was given, chosen to ensure the information available was different. In many cases students were confused with those differences. The aim was to increase their

awareness of the large variety of information available in datasheets. This approach was a success, as students realised they had to really understand the related base concepts (properties, standards and test methods) to be able to distinguish products and the corresponding possible applications.

For the following contact sessions, students were given the problems' brief. The students worked in teams and had no previous information on the corresponding topic. To be able to tackle the problems, students had to identify their learning needs, collecting relevant information, assessing its applicability to each problem. The contact hours were used as workshops, with the instructor acting as a facilitator. These sessions included the use of questioning to promote critical thinking and the ability of students to build an argument.

Two different types of problems were used: summative, marked for assessment purposes; formative, in-class problems used to drive the learning on topics not directly covered on the summative problems. In-class problems are often identified in the literature as PBL environments (as in Dabbagh and Dass 2013).

The summative problems were marked focusing mainly on the choice of methods used, the rationale presented by students, namely on their applicability to the problem, the discussion of results and their comparison. The final solution to the specific problem was less important than the process of getting to that solution and critically analysing it. Thus, the focus was on the process of learning instead of on the final product. Though smaller, the formative problems were tackled in a similar way, enabling a PBL approach for the complete module. Wrap-up moments, to systematise the learning were included, either in the same lecture where the formative problems were used, or after the final sessions on the summative problems (which included oral presentations and discussions).

The assessment comprised two components: mark on the summative problems (70% of the final mark) and final exam (30%) on all topics of the syllabus. To get individual accountability,

besides the exam, each student received an individual mark on the problems, based on the self and peer assessment within the group.

Students were grouped by the author in teams of 3 or 4 using a questionnaire on both marks from previous modules while ensuring compatible availability for group work. Groups were heterogeneous in terms of marks, trying to ensure balanced teams of students.

3.2.2 Previous competences and skills

In 2011/2012 most students taking AGCE had previously attended two modules on Soil Mechanics where project-based learning models were used, including either cooperative or collaborative teamwork (Pinho-Lopes and Macedo 2016). In these models students used laboratory tests and computing and software to tackle geotechnical problems (creating spreadsheets from scratch, validating and testing them and using geotechnical software). Thus, previously most students had the opportunity to develop soft, transferable skills, and competences which facilitated their approach to PBL.

3.2.3 Problems

The main goal of the problems (summative and formative) was to enhance students' learning, by doing, collecting relevant information, using, analysing and criticising it. Students were responsible for choosing appropriate geosynthetics, collecting relevant design methods and checking their applicability conditions, and implementing those methods to design adequate solutions to the problems.

As a starting point, support material was prepared, collected and made available to students with the problems. This included notes, hand-outs, dissertations, journal papers and institutional reports. Most of them were written in English, which for Portuguese students could be an obstacle. Nevertheless, it forced students to get familiarised with technical English and to develop an additional skill. Some students found difficult to analyse and sort out the

relevant information, particularly when there was much available. This way, students were also training the process of finding and identifying trustworthy sources of information. Students helped each other in the group and between groups.

The problems were open-ended, replicated real life situations and the information given was as realistic as possible. In some cases a simple economic analysis was carried out, to increase students' awareness of the impact of costs on the choice of technical solutions. Environmental impacts were also discussed. Questions related with the durability of geosynthetics were dealt within each problem, for example when specifying the geosynthetics and guaranteeing adequate survivability throughout the structure's lifetime. The students were confronted with a holistic perspective of engineering work.

The final stage of the problems included oral presentations of the approaches each team used and the results obtained. The approaches used by the different teams were also compared and their advantages and disadvantages pointed out in brainstorming sessions. The results were analysed and discussed in the larger group. After (typically the following session), the instructor presented a summary of the most relevant points emerging from the learning process, addressing the most common mistakes and misunderstandings, as well providing recommendations and rules of thumb.

3.3 Problem on reinforced soil

The problem on soil reinforcement with geosynthetics used in 2011/2012 included three main parts. The 1st part consisted in building small models of reinforced soil structures in the laboratory. Different structures were to be built by each team using different reinforcement solutions (type of reinforcement, dimensions and density). All structures were to be submitted to the same loading and their performance observed, analysed and compared. If possible, the models should also be loaded to rupture. Such analysis should include:

- observed differences between unreinforced and reinforced models (considering the different solutions defined) and their causes;
- different effects of the reinforcement configurations tested;
- observed failure modes and mechanisms and strategies to prevent them;
- construction procedures used and their influence on the observed behaviour.

The models were built using a granular soil (different for each group) and paper reinforcements, using recycled A4 paper (80g/m²). Students also characterised the materials, soil and paper, using laboratory tests.

The 2nd part of the problem focused on the design of the reinforcement solution for a slope using the method by Jewell (1996). The 3rd part included numerically modelling the structures analysed for the 1st part using the finite element method. If possible the model's behaviour should be analysed, as well as the one of a chosen prototype with similar characteristics, using the same type of soil and a chosen geosynthetic as reinforcement.

3.3.1 Hands-on activity

The hand-on activity focused on building and analysing the performance of small scale models of reinforced soil structures and was inspired by the GeoChallenge described by Cerato et al. (2012). Using the PBL approach, each team of students had to decide which structures to test, for example allowing for different reinforcement solutions, facing elements, while addressing issues related to formwork, stability during construction and loading of the models.

The materials available in the laboratory included plastic containers, sand, pouring material, wooden plates to compact the soil, old and used office paper and scissors (Figure 1).

Students faced several difficulties in the laboratory. The construction sequence had to be realistic, but the small scale of the models, together with the type of containers used, posed some challenges. For example, the transparent

boxes deformed when filled with sand and during loading of the structures. Nevertheless, the containers enabled observing the structures and how the reinforcements affected the response of the structure. The teams tried to come up with solutions to limit the deformation of the containers (Figure 2a, 2b, 2c) and to measure the deformations of the structure during loading (Figure 2e, 2f, 2g). In some cases, when the temporary support was removed the models exhibited localised failures (Figure 2d).



Figure 1. Material available: plastic container, wooden plates for soil compaction and paper (reinforcements).

The models were loaded using dead weights available in the laboratory (Figure 2h). However, stability during loading and when failure occurred also posed some challenges. For the loading phase, the teams had to decide on where to apply the loading and how to register the different responses and compare them.

Figure 3 illustrates some models built by students using different types of reinforcements: sheet (continuous), grid and strip. Different facing solutions had to be adopted, depending on the type of reinforcement.

4 Assessment of the model used

4.1 Research questions

To assess the implementation of the PBL model in the AGCE module in 2011/2012, the following research questions were addressed:

- 1) What was the impact of the PBL approach and of the hands-on activity on the learning?
- 2) What was the students overall impression of the PBL model?

To address these questions, the academic performance of the students was analysed, as well as their feedback.

4.2 Academic performance

In terms of academic performance, the AGCE module is very good as all the assessed students have passed (in all editions of the module). In 2011/2012 there were 11 students enrolled in the module and 10 were assessed. The average mark on the final exam was 14.4 (out of 20). Some students have admitted that, due to the workload associated with other modules and the MSc dissertation, they did not revise extensively for the exam, as its weight on the final mark was relatively low (30%).

The average mark on the summative problems was 17.2 (out of 20). This shows how the students committed their time and energy in tackling the problems very successfully.

4.2 Students' feedback

To address the research questions, the students were asked for feedback on the module. Their opinions and perceptions were collected using a questionnaire. The questionnaire was made available at the end of the semester (after the completion of the assessment) via the e-learning page and answered on-line and anonymously by students. The sample size is small and corresponds to the 6 students (2011/2012) answering the questionnaire (out of 11 students enrolled, 10 of which completed the assessment). Nevertheless, the information collected was found useful and can help making informed decisions for specialised elective modules such as AGCE.

Table 1 summarises some data collected using the questionnaire (Likert scale ranging from 1 to 5). Overall, students accepted very well the module and the PBL approach. The assessment methods were found very adequate for the objectives of the module (Q1c). Although most resources made available were written in English (except notes and hand-outs prepared by the author), the students found

them adequate and easy to understand (Q1a and 1b). The workload and the module complexity were considered adequate (Q2a and Q2b), and

the topic was found very interesting and relevant (Q2c).

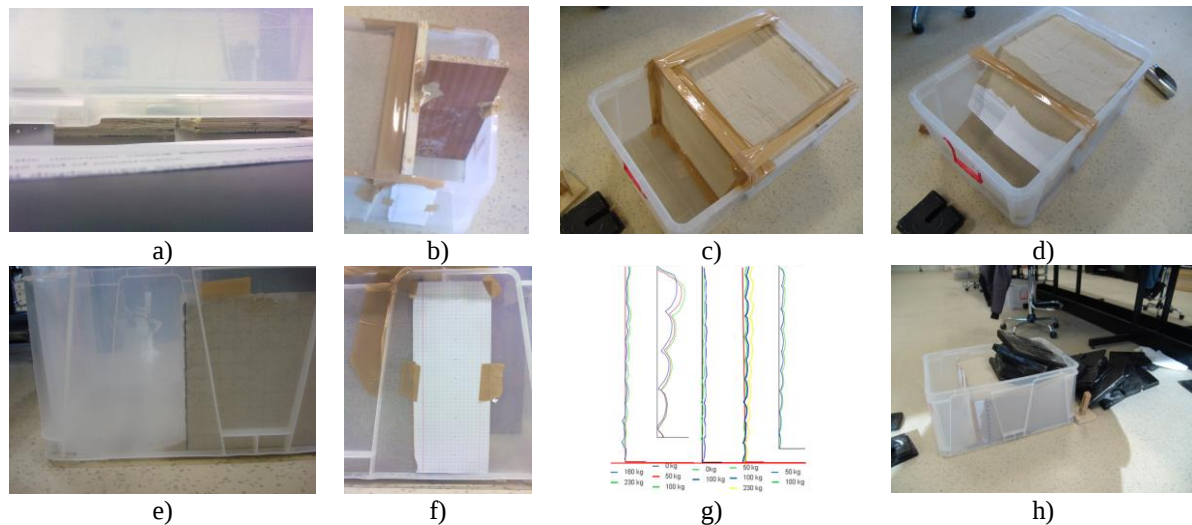


Figure 2. Hands-on activity: a) wooden elements used to limit deformations at the base of the containers; b) and c) temporary support and tape used to limit the deformation of the containers; d) failure of the upper layers of the models before loading; measurement of face deformations using e) a grid and f) a removable reference; g) measured face deformations; h) failure of a model.

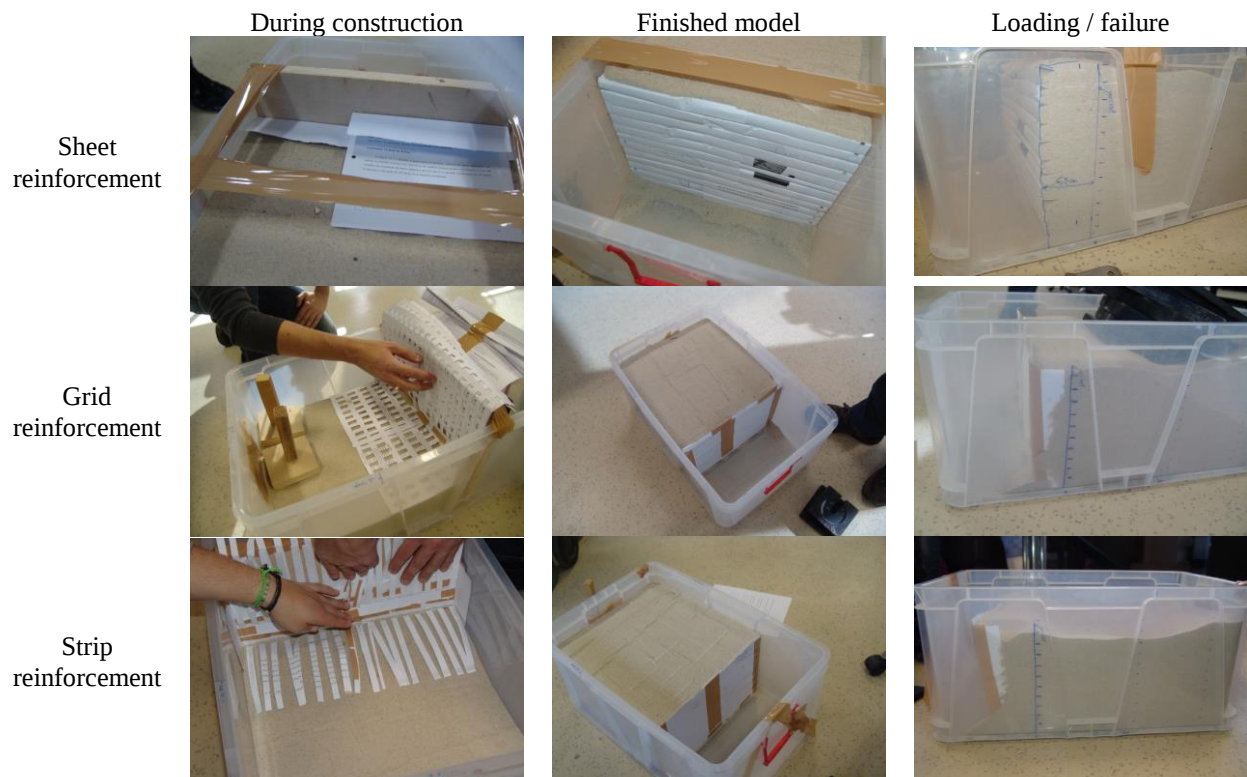


Figure 3. Models built by students using different types of reinforcements: sheet (continuous), which forms the facing; grid or strip reinforcements using an additional facing element.

The groups have functioned very well (Q3a) and the workload was evenly distributed within the teams (Q3b). There are two main reasons for

this. Previously most students had experienced working in groups using project-based learning, having gained relevant skills. As students were

in their final year (5th year of the integrated masters) they generally are mature and very

committed, as they all have chosen to attend this elective module.

Table 1. Summary of data collected using a questionnaire (answers on a 1-5 Likert scale)

Question		Mode	Mean	SD ⁺
Q1	Overall functioning of the module (1- Lower; 5 – Higher):			
Q1a	Adequacy of the bibliography made available	4	4.00	0.63
Q1b	Ease of understanding the bibliography	4	4.17	0.41
Q1c	Adequacy of the assessment methods for the defined objectives	4	4.00	0.00
Q2	Adequacy of the proposed activities for the course contents (1- Lower; 5 – Higher):			
Q2a	Work volume appropriate to the available time	4	3.50	0.55
Q2b	Degree of difficulty /complexity	4	3.67	0.52
Q2c	Interest and relevance	4	4.33	0.52
Q3a	Group functioning (1 – Bad; 5 – Excellent)	5	4.50	0.84
Q3b	Relatively to your team colleagues how much did you work? (1 – Much less; 3 –The same; 5 – Much more)	3	3.17	0.41
Q4	Type of projects proposed (1- Lower; 5 – Higher):			
Q4a	Adequacy of the type of work proposed to the objectives of the module	4	4.33	0.52
Q4b	Usefulness of handling products, analysing and interpreting their technical datasheets	4	3.67	0.52
Q4c	Adequacy of the need to conduct literature review to support the development of the projects	4	4.33	0.52
Q4d	Adequacy of the need to implement various design methods and compare the different results	4	4.17	0.41
Q5	Tools used in the assignments (1- Lower; 5 – Higher):			
Q5a	Importance of the use of IT tools (Word, Excel, Plaxis) in the projects	4	4.17	0.75
Q5b	Usefulness of using different approaches to solve the same problem	5	4.50	0.84
Q5c	Indicate how building the small scale models increased learning in AGCE (1- Lower; 5 – Higher):	4	4.50	0.55
Q6	Do you consider useful (1- Lower; 5 – Higher):			
Q6a	Orally presenting the team assignments in class?	4	4.33	0.52
Q6b	The summary of the main points by the lecturer after the discussion of the assignments?	5	4.83	0.41

SD⁺ - standard deviation

Students appreciated the approach used in the module and found the PBL model adequate to the objectives of the module (Q4a). Searching for relevant information (Q4c) and comparing different approaches to the same problem (Q4d) were also found very adequate. Immediately after the session where students handled geosynthetics and analysed their datasheets the feedback was very positive and the students found the session very helpful. At the end of the semester, when all the problems (either summative or formative) made use of similar information, the perceptions on the relevance of that session were neutral (Q4b).

The use of different IT tools, such as spreadsheets and geotechnical software, was found very important (Q5a). More, combining laboratory work and numerical analysis for the

same problem was found very useful (Q5b). The hands-on activity reported in this paper was identified as contributing significantly for the learning (Q5c).

The wrap-up sessions were also very important for students (Q6b), as well as the oral presentations and discussion sessions (Q6a).

4 CONCLUSIONS

In the AGCE module students carried out literature reviews, used different design methods (available in the literature), compared their results, defined specifications for the materials which were then used to select products available in the market. For the reinforced soil problem, a hands-on activity in which students built small models using sand

and paper, was organised to facilitate and promote the understanding and the application of several concepts. Although the module is offered in the final (5th) year of the programme, it is the first contact with geosynthetic materials and students were very and the specificities on their design and applications. Thus, the AGCE module is ideal for using PBL.

The main goals of using PBL were: to promote the development of problem solving and high order thinking skills of students, as well as critical thinking and capacity of analysis; prepare students to tackle professional challenges, being able to track trustworthy sources of information and keep updated, i.e., to be more self-directed in their learning.

The PBL environment was very informal and contact hours were used as workshops. Although initially students needed more support, they soon became very autonomous. Previous experiences with project-based learning (with cooperative and/or collaborative teamwork) are likely to have played a major role in preparing students for the PBL approach. For the PBL approach to be successful, managing expectations was found essential, as well as giving adequate support and feedback to students throughout the semester.

As this is a specialised module, the number of students enrolled in each year is small. The academic performance of students seems to indicate that the students are acquiring the relevant competences. The data collected using the questionnaire (2011/2012) also corresponds to a small sample. Nevertheless, the model seems to be effective in promoting learning and the development of high order skills. The hands-on activity was very well received and students were very enthusiastic and positive about it. Further implementing this type of activities may prove very successful to engage students and better promote their learning.

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