This is an Accepted Manuscript of an article published by Taylor & Francis in
EUROPEAN JOURNAL OF ENGINEERING EDUCATION on 19/06/2015, available online:
http://www.tandfonline.com/doi/full/10.1080/03043797.2015.1056099

Project-based learning in Geotechnics: cooperative versus collaborative teamwork

Margarida Pinho-Lopes

Faculty of Engineering and the Environment, University of Southampton, Southampton, United Kingdom

Department of Civil Engineering, University of Aveiro, Aveiro, Portugal (unpaid leave)

E-mail: M.Pinho-Lopes@soton.ac.uk

Alternative e-mail: mlopes@ua.pt

Joaquim Macedo

Department of Civil Engineering, University of Aveiro, Aveiro, Portugal

E-mail: jmacedo@ua.pt

About the Authors

Margarida Pinho-Lopes is a PhD in Civil Engineering. She was an Assistant Professor in the Department of Civil Engineering, University of Aveiro, Portugal, between 2006 and 2013, and a Senior Lecturer at University of Brighton, UK, between July 2013 and January 2015. Presently she is a Lecturer in Geomechanics at University of Southampton. She teaches or has taught Soil Mechanics (undergraduate) and Foundations and Bearing Structures (graduate) and Application of Geosynthetics in Civil Engineering (graduate). She does research into Geotechnics, particularly into the application of geosynthetics.

Joaquim Macedo is a PhD in Civil Engineering. He is an Assistant Professor in the Department of Civil Engineering, University of Aveiro, Portugal. He teaches or taught several courses in Civil Engineering area including Soil Mechanics (undergraduate), Geotechnics for Roads and Pavements (graduate) and Foundations and Bearing Structures (graduate). He does research into transport infrastructures, particularly into traffic micro-simulation models.

Project-based learning in Geotechnics: cooperative versus collaborative teamwork

Abstract:

Since 2007/2008 project-based learning models have been used to deliver two fundamental courses on Geotechnics in University of Aveiro, Portugal. These models have evolved and have encompassed either cooperative or collaborative teamwork. Using data collected in five editions of each course (Soil Mechanics I and Soil Mechanics II), the different characteristics of the models using cooperative or collaborative teamwork are pointed out and analysed, namely in terms of the students' perceptions. The data collected includes informal feedback from students, monitoring of their marks and academic performance, and answers to two sets of questionnaires: developed for these courses, and institutional. The data indicate students have good opinion of the project-based learning model, though collaborative teamwork is the best rated. The overall efficacy of the models was analysed (sum of their effectiveness, efficiency and attractiveness). The collaborative model was found more adequate.

Keywords: project-based learning, Geotechnics, cooperative, collaborative, group work

1 Introduction

Traditionally engineering education uses deductive teaching (or direct instruction). Commonly such approaches promote a passive learning from students, as they are usually associated with teacher-centred models. In traditional deductive teaching in engineering, a subject is introduced in lectures on general principles, the principles are used to derive mathematical models, illustrative applications of the models are shown, students practice similar derivations and applications in their homework, the students' ability to reproduce them on exams is tested (Prince and Felder, 2006). The motivation for such approach and its link with reality may not be clear to students: "The only motivation that students get—if any—is that the material will be important later in the curriculum or in their careers" (Prince and Felder, 2006). Detractors of this model claim it promotes passive learning and compartmentalised curriculum; and it does not prepare students to engage in typical professional collaborative partnerships (Stump et al., 2011).

Inductive teaching uses an opposite approach, where observations, case studies or problems prompt topics, which later are generalised to the underpinning principles and theories. Some examples of inductive teaching and learning methods are inquiry learning, problem-based learning, project-based learning, case-based teaching, discovery learning, and just-in-time teaching (Prince and Felder 2006). According to these authors, all methods listed are also student-centred (as students take ownership of the knowledge and are more responsible for building it, than in the traditional deductive approached) and constructivist (as, instead of absorbing versions of reality presented by the teachers, students construct their own). Additionally these methods are forms of active learning, as most times students engage in in-class discussions and solving problems, and of collaborative or cooperative learning, whilst students work mostly in groups, in and out of class (Prince and Felder 2006). Westera and Sloep (1998) present and discuss the concept of a Virtual Company in education, where the students have the opportunity to put theory into practice in authentic situations. The intention is the students, in a collaborative way, develop their competences in a simulated company in which the functional structures of real life companies are represented.

According to Butler and Dee (2013), active learning refers to situations in which an instructor requires students to engage actively in some form of learning activity. Active learning strategies can help promoting effective learning, particularly when encompassing active learning by doing, cooperation and teamwork in learning and learning through problem solving - essential to foster creativity and innovative capacity, which is a critical skill for engineering students (Nordstrom and Korpelainen 2011). These active-learning strategies can promote reflection and discussion and, therefore, prompt concept building.

The main features of collaborative and cooperative learning include presenting new information to students, contextualised by their previous knowledge, and helping them to develop understanding and skills, through activity and reflection (Felder, 2012). This approach can only be successful if the instructors understand students' diversity, how to address it and value students as persons within that process (Blackie et al., 2010).

This paper focus on using both deductive and inductive teaching while encompassing active-learning strategies (project-based learning with collaborative or cooperative teamwork). Thus, to contribute to better prepare successful engineers, two complementary courses on fundamental Geotechnics - Soil Mechanics I and II - of the Civil Engineering program of University of Aveiro, Portugal, were redesigned. Since 2007/2008 project-based learning models have been used, with either cooperative or collaborative teamwork. The project-based learning was developed in teams and mostly out-of-class. The projects (open-ended assignments) were compulsory and aimed at promoting problem solving, critical thinking and engineering judgments by students. Realistic geotechnical cases were used (adapted to their level of knowledge).

Besides comparing cooperative or collaborative learning methods with traditional instructions, this paper also tries to compare the cooperative and collaborative models implemented.

The research questions addressed are:

- Are students' perceptions on the courses different when using student-centred learning models instead of teacher-centred models?
- Does using cooperative or collaborative teamwork affect students' perception of the courses?
- Does using cooperative or collaborative teamwork affect students' perception of the teamwork?

- Which model, cooperative or collaborative, do students better accept?
- Are these active learning models effective?
- With these models, do students develop competencies and skills other than those corresponding to the courses formal contents?
- After a second experience of the project-based learning model, are student’s perceptions of that model similar?

2 Project-based learning using cooperative and collaborative teamwork

2.1 Project-based learning in engineering programs

Project-based learning is a teaching method that organizes learning around projects (de Graff and Kolmos 2007; Thomas 2000) and in which students are faced with an assignment leading to obtaining a final product, which typically finishes with a final report summarising the process used and its result (Prince and Felder 2006). Usually, students previously had formal instruction and the focus of the project-based learning is on the final product (Yadav et al. 2011). Because the intent of this method is to be a form of active learning, the degree of teacher-centred planning and direction of the student's learning activities in relation to the desired objective varies along a sliding scale (de Graaff and Kolmos 2003). Thus, three fundamental types of project work can be distinguished: the task project, the discipline project, and the problem project (de Graaff and Kolmos 2003; Kolmos 1996).

Some benefits for students of project-based learning reported in the literature include experiencing (Palmer and Hall 2011): teamwork, ownership of the problem, its solution and corresponding learning, self-motivation, management skills (referring to time, people), problem solving, transversal dimension of engineering problems, realistic problems and professional practices, critical thinking and reflective skills, communication skills, coping with incomplete or inaccurate sets of information. Additionally, Puteh et al. (2010) point out that to tackle projects students are forced to link fundamental theories while developing engineering skills. Nevertheless, according to Gibson (2000), project-based learning is not effective with large classes.

The main features of project-based learning (Gibson 2005, quoting Savoie 1994) include a project, appropriately described in the students' context, where the final product reflects the learning of students. This enables encouraging collaboration in teams, while promoting responsibility and planning of both project activities and the necessary learning. These authors also point out that for a successful project-based learning both contents and facilities of the course should be organised around the project.

2.2 Cooperative and collaborative teamwork

To enable realistic engineering projects, usually project-based learning is associated with team (or group) work. In this paper, a team implies a group of students working together engaging in concerted activities. Collaborative and cooperative learning are sometimes identified as forms of active team learning. This paper includes several viewpoints found in the literature about these strategies.

Panitz (1999) presents a basic definition of collaborative and cooperative learning: collaboration is "a philosophy of interaction and personal lifestyle where individuals are responsible for their actions, including learning and respect the abilities and contributions of the peers"; while cooperation is "a structure of interaction designed to facilitate the accomplishment of a specific end product or goal through people working together in groups". Prince (2004) defines student interactions as the focus of collaborative learning, which include all group-learning methods in which students work in small groups for a common objective, including cooperative learning.

Group work is one of the core characteristics of these approaches. Both in collaborative and cooperative learning two or more students learn or attempt to learn something together. However, they use different paths to achieve that goal. In collaborative learning students interact and work together in order to complete their assignments (Razmerita and Brun 2011). In contrast, cooperative learning is a form of active learning in which students are grouped and each of them is assigned with different roles and task to accomplish (Keyser 2000). Similarly, Slavin (1996) defines cooperation as a classroom technique aiming at facilitating obtaining a final product, whereas collaboration is a broader concept (philosophy of interaction and personal lifestyle). In collaborative learning, group members share authority and responsibility within the group (Panitz 1999). Thus, cooperative learning is often defined as a structured group work (Johnson and Johnson 1989) encompassing positive interdependence, individual accountability, face-to-face interaction for at least part of the work, appropriate use of interpersonal skills and regular self-assessment of team functioning (Johnson and Johnson 2009).

Kyndt et al. (2013) summarise cooperative learning terminology by presenting the perspectives of various authors. Historically, different audiences were targeted by cooperative and collaborative learning models, with different age, experience and levels of interdependence (Bruffee 1995). Cooperative learning was introduced for children, while collaborative learning focused on higher levels of education. However such differences have faded with time, as instructors have been using both modes of group learning for different levels. As a reminiscence of that initial concept, cooperative learning usually is focused on foundational knowledge (spelling, grammar, mathematics, etc.), whereas collaborative learning is used for non-foundational knowledge, namely for new knowledge and high order thinking processes (Kyndt et al. 2013). The learners become therefore responsible by their own knowledge.

Matthews et al. (1995) identify some similarities and differences between collaborative and cooperative learning. These authors reported that these are similar as:

- both are active learning strategies;
- the teacher acts as facilitator;
- teaching and learning are experiences shared both by students and teachers;
- enhance higher order cognitive skills;
- the emphasis is placed on students' responsibility for taking charge of their learning;
- involve situations where students must articulate ideas in small groups;
- help students to develop social and teambuilding skills;
- increase student success and information retention;
- utilize student diversity and multiculturalism.

Relatively to the differences, Matthews et al. (1995) identified:

- the style, function and degree of involvement of the teacher;
- the issue of authority and power relationships between teacher and students;
- the students' training;
- the organization of the activities;
- how knowledge is assimilated or constructed;
- a variety of additional implementation concerns including, for example, group formation, task construction, and the degree of individual and/or group accountability necessary to ensure equitable distribution of work and accurate grading.

Schaf et al. (2009) also recognise the close relationship between collaboration and cooperation and point out some differences between them using the work by Carstensen and Schmidt (2002): cooperation implies dividing each task into independent subtasks, while collaboration forces handling interlinked problems and subtasks. Therefore, for cooperative work, to assemble the partial results into a final product, coordination is required. For collaboration all activities need to be coordinated and synchronous, in order to construct and maintain a common conception of a problem.

In this paper, the authors report using both collaborative and cooperative learning approaches. The cooperative group work includes using structured teamwork, where the teachers assign students from the same team with independent subtasks. For the collaborative group work the teams were free to organise themselves, forcing them to coordinate all subtasks. Detailed information of these two approaches are included in sections 3.3.1 and 3.3.2.

3 Case study

3.1 Civil Engineering program

The Civil Engineering program in University of Aveiro (UA) was redesigned to address the requirements of the Bologna Process. This created opportunities for faculty to adjust their courses to adopt student-centred learning models, as alternatives to the traditional teacher-centred model. Thus, in 2007/2008 the authors created and redesigned two undergraduate complementary courses on Geotechnics using non-traditional learning models. In the new courses of Soil Mechanics I and Soil Mechanics II active learning strategies were implemented, namely, project-based learning models with either cooperative or collaborative work. These models have been implemented since 2007/2008.

3.2 Soil Mechanics courses

Soil Mechanics I (SMI) and Soil Mechanics II (SMII) are two complementary courses of the Civil Engineering program in UA on fundamental Soil Mechanics and introduction to the design of Geotechnical structures. In SMI the aim is the introduction and promotion of the understanding of the basic concepts and fundamental quantities of Soil Mechanics to be applied in the design of civil engineering structures. The syllabus of SMI is grouped into: 1) Physical properties and soil identification; Sedimentary and residual soils; 2) Stress state in soils; Capillarity; 3) Water in soils; Seepage; 4) Compressibility and consolidation of clay soils.

At the end of the SMI course students should be able to:

- understand fundamental concepts of Soil Mechanics;
- define a laboratory test programme to characterise soil samples and interpreting its results;
- determine the stresses in a soil profile under different conditions;
- understand the water flow phenomena in soils and the risks associated;
- predict and accelerate settlements due to consolidation of clay soils;
- use computer programs to solve Soil Mechanics problems;
- work in teams;
- use communication skills (oral and written).

These subjects are complemented in the SMII course where the mechanical behaviour of soils is the focus, encompassing concepts, theories and methods normally used in the design of civil engineering structures in general, and geotechnical in particular. The principles of Eurocode 7 (EN 1997-1:2004) are introduced in this course. The contents also cover field tests generally used to characterize the mechanical behaviour of soils. In the SMII course, the emphasis is placed on works where the stability depends on the soils' strength and the analyses are carried out using both global safety factors and the partial safety factors approach from Eurocode 7. The contents are grouped into: 1) Introduction to shear strength of soils; Shear strength and stress-strain relationships in sands and in clays; 2) Lateral earth pressures; Earth retaining structures; 3) Stability of slopes and embankments; 4) Sampling and *in situ* tests.

At the end of the SMII course students should be able to:

- understand the fundamental concepts of shear strength of soils, sands and clays;
- calculate the shear strength using data from laboratory tests;
- determine the stress state of a ground profile for different conditions and analyse if there is failure;
- assess the lateral earth pressures for several types of structures;
- design retaining walls;
- analyse the stability of slopes and, when necessary, choose solutions to stabilise slopes;
- define a test program;
- use numerical tools to solve typical problems of Soil Mechanics;
- work in teams;
- use communication skills (oral and written).

The weekly contact hours of the courses are: for SMI, one theoretical-practical lesson (maximum of 45 students) and one practical lesson (maximum of 25 students), both with the duration of 2 hours; for SMII, two theoretical-practical lessons.

Each course represents 6 ECTS (European Credit Transfer System), which corresponds to a total of 162 hours work. Such workload includes the class time, individual study time, preparation of reports, bibliographical research, preparation of examinations, etc.

3.3 Project-based learning models

Project-based learning models, with either cooperative or collaborative group work, were implemented in both courses, to promote a more student-centred approach in the teaching and learning process. These models comprised the following features:

- Traditional lectures, where relevant concepts are introduced and some simple textbook exercises are solved, enhanced by in-class discussions and questioning;
- Practical lessons, in a tutorial format, providing opportunities for students to independently use hand calculations to solve problems (only for the Soil Mechanics I course, due to the format of the contact moments);
- Compulsory team projects;
- Oral presentations and discussion sessions;
- Individual marks on the team projects, obtained using peer-assessment.

The traditional designations for the different timetabled contact moments were kept in this paper (“traditional lectures” and “practical lessons”). However, both comprised both inductive and deductive strategies. The “traditional lectures” included different moments, such as:

- expositive (mini-presentations), with durations ranging between 5 to 20 minutes;
- large group discussions (for example, facilitating students trying to define a test program to obtain relevant design parameters for a specific case study, identifying their relevance and usefulness, facilitated by the teacher);
- inquiry and brainstorming moments (for example, students trying to identify causes for landslides after watching some provocative videos; these activities are often done in smaller groups that later report to the large group);
- questioning students when analysing realistic cases to infer equations or relationships representing the phenomena involved (for example, for the seepage bellow a concrete dam, questioning students which leads to identifying the impermeable boundaries, flow lines and equipotential lines and then trying to find relationships between them);

- using simple textbook exercises as an introduction to a topic, which students try to tackle, the relevant concepts are then introduced by the teacher.

In the “practical lessons” students independently tackled problems (using hand calculations), facilitated by the teacher. These contact moments tried to prepare students to the challenge of tackling the team projects, which included scenarios that are more complex.

The project-based learning model is done mostly outside the classroom and its main feature is an assessment for learning (alternatively to an assessment of learning), as suggested by Larkin and Richardson (2013). It includes test(s) and project(s) in a varied number, depending on the edition (Table 1). The team project - an open-ended assignment - is compulsory and aims at promoting problem solving, critical thinking and engineering judgment by students. Realistic geotechnical cases are used (adapted to their level of knowledge).

The team projects, though using the same base problem for all teams and due in the same date, encompassed specific choices, following “The Three S’s” structure (reported by Triten (2001) as a good structure for cooperative learning assignments): 1) same problem; 2) specific choice; 3) simultaneous report. All projects included creating spreadsheets to compute, compare and analyse results. Additionally, for most projects, using numerical tools was also required. To give more freedom to the teams while organising their work, a student license version of commercial software currently used by engineers when studying geotechnical problems was chosen (GeoStudio package). To validate the spreadsheets created and to check their answers to in-class problems, students were encouraged to use their spreadsheets and the available software. Critical analysis of the results and engineering judgement were promoted in the team projects by asking for comparisons of results obtained from different methods or from different base hypotheses. Such comparisons had to be adequately supported and the data analysed and discussed. To assist students in that process, students received some training at the beginning of the semester. A more detailed description of the projects, and how they promoted the use of computing and software, can be found in Pinho-Lopes (2012a).

For the SMI course in the academic year 2009/2010, a traditional teaching model was used. This included expositive lectures and solving of textbook exercises in the practical lessons; the assessment included two tests with the same relative weight on the final mark. This model did not include team projects.

3.3.1 Cooperative work

The project-based learning model used two alternative approaches, cooperative work and collaborative work. The main characteristics of the cooperative approach are:

- preparation of the projects in groups of four students with specific individual functions (jigsaw project system);
- mandatory rotation of functions in each project;
- groups formed by teachers;
- expert groups, gathering students with the same task and receiving adequate specialized training;
- share with peers of the knowledge and experience acquired by the students during the realization of a task;
- 4 team projects (to ensure all students perform each of the 4 functions).

The key point of the cooperative work is the preparation of the projects in a jigsaw system where each student performs a specific role in each project with mandatory rotations of roles. The teachers defined the roles and their allocation to students, creating a structured teamwork (as described in section 2.2). The four roles were: laboratory or informatics technician (depending on the project), analyst, reporter and coordinator. In the definition of the tasks, the teachers tried to ensure a parallel to functions normally fulfilled by engineering professionals. Table 2 summarizes the main tasks associated to each of these functions. The cooperative model was used mostly in the SMI course.

3.3.2 Collaborative work

The main feature of the collaborative teamwork, relatively to the cooperative one, was the fact the teachers did not impose functions and roles to the groups. The number of team projects was usually smaller (one or two) than that of the cooperative alternative. In this model the whole team was responsible for all the work, having to organise it and distribute tasks. The projects proposed under this model did not include preparing a state-of-the-art.

This model was used mostly in the SMII course or when only one teacher was delivering the SMI course. The collaborative model was defined initially as a reaction to the severe workload associated with the cooperative model, particular for the teachers.

Although students were freer to organise the work within the teams (when compared to the cooperative teamwork), the collaborative model forced them to better coordinate the activities and to carry them synchronously – typical for collaborative activities.

3.3.3 Group formation and assessment

The teachers grouped the students, simulating professional environments where, most times, an engineer does not choose with whom he or she works. The groups of students were heterogeneous and balanced, including students of different levels and with compatible schedules. For that, teachers used the students' answers to a questionnaire on the marks obtained in previous courses and on their time availability for group work.

Grouping students in such a non-traditional way of caused some negative feedback. To address it and, in some more extreme cases, to overcome conflicts between students of the same team (namely in the first experiences of implementation of these learning models) the teachers had to intervene. Such interventions enabled the teams in conflict to discuss; the teachers also provided the teams with suggestions on how to better organize their work, communicate more effectively and on how to establish professional rapports among team members. Such processes (supported by strategies suggested by Felder and Brent 2007) included: 1) brief discussion of typical problems during the contact time (large group), usually followed by in-class small group brainstorming and sharing of strategies; 2) organising meetings of teams in conflict in the presence of a teacher, to facilitate and moderate dialogue and to help defining problem solving strategies (Pinho-Lopes et al., 2011).

One of the most common issues students raised on the project-based learning models was the grouping. To address them in 2012/2013 two different approaches to group formation were used. In the first semester (for the SMI course), the students were free to choose their teams. While in the second semester (for the SMII course) the cohort was divided into four large groups using the answers to a questionnaire about their marks on previous relevant courses; the students were then free to form teams, providing each team had a representative of each of the four larger groups. The aim of using such approaches was to understand the differences in students' perceptions relatively to the influence of group formation on their performance.

There were two types of assessment elements, summarised in Table 1: team projects (P), throughout the semester, and tests (T). The team projects were compulsory to all students. For the students who failed there was a second chance of passing – final exam, for which the relative weight of the students' individual mark on the team projects was the same. Depending on the course and on its edition, the number of team projects and tests varied, as well as their relative weight on the final mark. The minimum mark (MM) in each assessment element for approval also varied (Table 1).

To ensure individual accountability of students (besides the tests, covering the complete syllabus), each student was given an individual mark on the team projects. Such marks were obtained by applying a weight to the team's mark, based on the students' self and peer assessment within the group. The weights used were the ones proposed by Felder and Brent (2007).

4 Assessment of the model used

4.1 Research methods

The research methods used to assess the impact of using the project-based learning model included informal feedback by students, monitoring of marks and academic performance and questionnaires.

The informal feedback was collected during the semester and after students concluded each course. The students' marks on projects and tests were analysed to assess their progress and retention, which included a statistical analysis on the attendance and on the success on the course by analysing the number of students enrolled, who attended, were assessed and obtained a passing mark. Two approaches were used for the questionnaires: 1) bespoke questionnaires addressing different research questions, 2) institutional questionnaires (for quality assessment, here identified as SGQ), providing an independent instrument to validate the answers collected from the first approach.

Although some initial results have been published previously (by Pinho-Lopes et al. (2011), Pinho-Lopes (2012b), Pinho-Lopes and Macedo (2013) and Pinho-Lopes and Macedo (2014), on an initial analysis of the project-based model), the current paper is informed by new and longer term data, corresponding to five editions of each course.

4.2 Main results from the assessment

4.2.1 Informal feedback by students

For collecting the informal feedback, a qualitative approach was used. Often this was done anonymously, or via the programme director; therefore, the number of students reporting specific questions is not available. The one common negative feedback across the different editions of both modules (except for 2012/2013) relates to the strategies used to group students. Additionally, for both cooperative and collaborative teamwork, students identified other issues:

- managing group conflicts;
- different levels of engagement of students within each team, associated with students with strategic approaches to the courses;
- workload, usually considered excessive, namely the time spent on the projects;
- using and understanding the software;
- the number of tests (in some editions).

Students also identified advantages of the project-based learning models used:

- the projects helped revising for the test(s);
- the learning was deeper;
- the models were found adequate and shouldn't be changed.

4.2.2 Marks monitoring and academic performance

The marks and the academic performance on both courses, SMI and SMII, are summarised in Table 3 and Table 4, respectively. The possible range of marks is from 0 to 20 (highest); passes correspond to marks of 10 or higher.

The results show the academic performance was always high. The minimum percentage of students passing was obtained for SMI, 75% in 2007/2008 with the cooperative teamwork, and for SMII, 69% in 2011/2012, with the collaborative work. These are particular editions. The project-based learning model was implemented firstly in 2007/2008 for the SMI course. The radical changes associated caused some reactions from students. Some of them expected the model to be abandoned the following year and thus decided to quit. It should be noted that the number of retakes students can have has a very high limit. A similar reaction may have happened for SMII in 2009/2010, for which 74% of the assessed students passed the course, as in the previous semester the same students had attended the SMI course with a traditional model. It is likely that the major reformulation of the team project structure has contributed to the differences relatively to the edition of SMII of 2011/2012 (passing rate of 69%). Such reformulation extended the project to most of the syllabus, which was not usual for the SMII course (using mostly the collaborative model). Therefore, students were lacking some reference from previous years. This explanation is corroborated by the lower marks obtained in the team project (Table 4). For the other editions of the courses using these project-based learning models, the academic success was always higher than 87% (SMII 2010/2011). For the traditional model (SMI 2009/2010), the academic success achieved was of 82%.

Tables 3 and 4 also include the marks obtained by students: data on the final marks and on the individual marks obtained on the team projects. Figures 1 and 2 include the distribution of the final marks in all the editions of SMI and SMII, respectively.

Most of the passing marks ranged between 10 and 13. The mean value of students' final marks for the SMI course (Table 3) was higher when project-based learning was used relatively to the one edition with the traditional model. This may be associated with having assessment elements other than tests, which usually result in higher marks. The distribution of marks is similar for all editions of SMI. For the SMII course, the mean final mark is higher than that of SMI in 2007/2008 only. However, for the individual marks on the team projects such trend was observed in 2007/2008, 2011/2012 and 2012/2013 (most editions where such analysis is possible). This may indicate that, after a first experience of a similar active learning model, students perform better on the projects on a second experience.

4.2.3 Questionnaires at the end of the semester

Two sets of questionnaires were used to collect students' perceptions: 1) developed by the authors, addressing specific topics for the courses, using a five-point Likert scale, 2) developed in University of Aveiro as part of the quality assessment system (SGQ), aiming at both monitoring and improving the quality of teaching, addressing general questions common to all courses in the university. Table 5 summarises the results from the first set of (bespoke) questionnaires and distributed to the students in 2007/2008 (SMI and SMII), 2008/2009 (SMI), 2011/2012 (SMI and SMII) and 2012/2013 (SMI and SMII).

From the data in Table 5 several conclusions can be drawn. Firstly, the students who answered the questionnaires considered that the degree of difficulty of the courses (Q1) was medium to high, regardless of the model used. The assessment methods were considered adequate to the objectives defined (Q3). However, higher results were obtained for editions with the collaborative model, relatively to those with cooperative teamwork. Thus, most students answering the questionnaires perceived the collaborative teamwork model as more adequate to the objectives of the course than the cooperative one. The same preference of collaborative to cooperative work was evident from the data for question Q6A, as students are more negative about the workload associated with the cooperative model comparatively to that of the collaborative one. The overall answers to questions Q6B and Q6C do not allow any firm conclusion regarding the model for which the proposed activities were more difficult/complex (Q6B) or interesting and relevant (Q6C). The results show that independently of the project-based learning model used (cooperative or collaborative) the activities proposed were perceived as difficult/complex but also interesting and relevant to the courses contents.

As obvious from the informal feedback, one of the most controversial issues when implementing these learning models was the group formation. Students identified the method used to distribute students within the groups as having a significant influence on their marks on the projects (Q15). In 2012/2013 students had the opportunity to choose their group colleagues with no restrictions (SMI) or with some restrictions (SMII), as described in section 3.3.3. The answers to Q15 collected in 2012/2013 reflect a similar perception of the influence of the group formation on the projects' marks, despite the drastically different process used for that. This may indicate that, although students report informally their lack of satisfaction with the group formation, this is not likely to be related to the allocation of students to groups by the teachers. However, such idea needs confirmation.

Across all the academic years students considered the groups functioned appropriately, regardless of the model used (cooperative or collaborative). Nevertheless, such appropriateness was perceived as higher for SMI in 2012/2013, where students distributed themselves in groups, without intervention from the teacher.

Finally, students perceived the non-traditional models as leading to the development of competencies and skills other than those associated with the formal contents of the courses (Q16 and Q17). Thus, they considered the models were relevant to develop such competencies and skills. The answers to questions Q10, Q15, Q16 and Q17 didn't allow concluding which of the two models (cooperative or collaborative teamwork) was perceived as the most appropriate for the group functioning or the development of competencies and skills. Therefore, apparently, they are not perceived as different, as far as the functioning of the group and the skills and competences acquired during the courses are concerned.

The institutional questionnaires (SGQ) were used to carry out an independent validation of results. They also tried to assess the working load of students by estimating the ECTS value of each course. According to the data summarised in Table 6, for the SMI course, the project-based learning models with cooperative teamwork resulted in an excessive workload (when compared with the 6ECTS assigned to the course). The collaborative model used in SMI (2012/2013) enabled a good match between the ECTS of the course and those estimated by students. The traditional model was associated with the lowest estimated working load (4.57 ECTS), followed by the only edition of SMI with collaborative teamwork (4.71 ECTS). For SMII only data for editions using collaborative teamwork is available. For most editions of this course, there is a good match with the expected working load of students (except for 2011/2012, when the estimated working load of students was 6.67ECTS). These results highlight that, despite the negative feedback on the excessive working load associated with these courses, in most cases students' perceptions underestimate the expected working load.

The results for the course characterisation obtained from the SGQ questionnaires are summarized in Table 7, for 2009/2010 onwards (inclusive). This is due to the evolution of the questionnaires used. In previous years either the questionnaires were different, which prevents relevant comparison of results between editions, or the minimum number of students answering them did not reach the threshold for the system to validate their answers. Later, the university found ways to increase the number of students answering the questionnaires.

The results from the SGQ questionnaires enabled comparing students perceptions on different approaches used for SMI: traditional approach (2009/2010), and project-based learning models with cooperative teamwork (2011/2012) and with collaborative teamwork (2010/2011 and 2012/2013). For SMII, as all results available refer to editions with collaborative teamwork, comparisons to other models were not possible.

For SMI, changing from a traditional model to the active learning models resulted in improving the perceptions of students on: the coordination of the different components of the course (P7); the adequacy of the recommended study elements and bibliography (P8); the articulation between the activities carried out in the course and the competences previously acquired (P15); the degree of difficulty of the course contents (P16); and the workload/time necessary for obtaining a pass mark (P17). Students' answers indicate that the traditional model was perceived as the most adequate (P13). A similar trend (collaborative model perceived as more adequate than the traditional one) was observed for the adequacy of the proposed activities to the course and its objectives (P9), the development of the comprehension skills on the themes covered (P14) and the global functioning of the course (P12). Nevertheless, students perceived the traditional model as more adequate than the cooperative one. In summary, the results from SGQ for SMI suggest that students prefer the collaborative model, followed by the traditional one; the least accepted model is the project-based learning with cooperative teamwork. One possible explanation for this may be related with the higher responsibility of students in the cooperative teamwork model. Although students consider the active learning models implemented are advantageous, in the particular case of the cooperative teamwork the need for a greater commitment and the higher degree of responsibility of each individual student is considered a disadvantage. Students feel that the collaborative teamwork allows other (more able) students to step in and cover for any limitation or lower engagement of other members of the group.

The data from SGQ for SMII does not enable comparisons between different models, or between cooperative or collaborative teamwork. However, they enable understanding the different perceptions of students after experiencing a project-based learning model for a second time, or when major changes are introduced on those models. Students' perceptions on SMII (Table 7) are more favourable for a second experience of an active learning model, independently of the active learning model used, if similar. When students didn’t have such previous experience (SMII 2009/2010) or when significant changes were introduced (SMII 2011/2012) students perceived the course on the second semester (SMII) as less adequate. This was particularly relevant for the global functioning of the course (P12), the assessment method (P13), the development of the comprehension skills on the themes covered (P14), and articulation between the activities carried out in the course and the competences previously acquired (P15). In 2011/2012 the team projects were significantly changed, resulting in a perceived higher degree of difficulty of the course contents (P16) and higher workload/time necessary for obtaining a pass mark (P17), relatively to previous years. Simultaneously, the lower values obtained for P7, P8, P9, P12, P14 and P15 using the 9 point scale, confirmed that students accepted badly the new challenges introduced in 2009/2010 and 2011/2012. Those changes limited strategic approaches students tend to use (basing their work in that from senior colleagues). In fact, students try to collect information from previous years, such as spreadsheets, to avoid creating their own.

Finally, it is important to point out that both sets of questionnaires led to the same main findings. This enables validating the instrument developed for this case study by using an independent one. The complementary strategies used allowed concluding that students perceived the non-traditional approaches implemented as very useful and successful in promoting competences and skills that they will need to use in future professional life.

4.3 Discussion

The data collected (from both the informal feedback and the questionnaires) and reported in the previous sections focus on perceptions of students. However, other dimensions of the project-based models implemented are discussed. The overall efficacy of the models is analysed, defined as the sum of their effectiveness, efficiency and attractiveness: a course is effective if what is learnt is relevant for the learning objectives; the efficiency is related to the effort used in the process; its attractiveness often relates to motivational dimensions.

When the two courses were redesigned to incorporate the project-based learning model, the corresponding competences to be developed by students and the more detailed learning objectives were updated, to accommodate those changes. The teachers created tables detailing specific learning objectives for each chapter of the syllabus. These were intended to guide students when preparing their projects and revising for the test(s). Later, the learning objectives were assessed in the team project outputs (reports and/or oral presentations) and/or in the test(s). To obtain a passing mark each student had to meet a threshold of 50% of the final mark, which included all learning objectives (although with different weights).

The passing rates presented in section 4.2.2 show that most students met the minimum learning objectives, therefore the courses were effective, regardless of the learning models used (traditional or project-based learning, either cooperative or collaborative). However, the learning objectives associated with the traditional learning model were different and, therefore, its effectiveness cannot be directly compared with that of the project-based learning models.

To meet the requirements of the accreditation bodies (for example, the European Network for Accreditation of Engineering Education, ENAEE), besides the traditional syllabus of Civil Engineering programs, many other competences and skills have to be promoted in a program. The quality label from ENAEE is EUR-ACE label (a certificate awarded by an authorised agency of ENAEE to a Higher Education Institution in respect of each engineering degree programme). There are six EUR-ACE programme outcomes of accredited engineering degree programmes: knowledge and understanding; engineering analysis; engineering design; investigations; engineering practice; transferable skills. Many of these competences, either technical or transversal and soft skills, were covered in these two courses (SMI and SMII), also contributing to the effectiveness of the courses and of the program. In 2012 the Civil Engineering program of UA has been awarded with the EUR-ACE label.

From the students' perspective, the courses seem to be efficient, as for most cases, the workload estimated from students answers matched the workload expected for the courses. From the teachers' perspective, several aspects need to be considered. On one hand, the workload associated with the project-based models implemented is higher than that of the traditional ones, as it is necessary to prepare the projects and organise all the activities around them. On the other hand, students are better prepared and more autonomous for the following courses on their programme, particularly at Master level, and for the M.Sc. dissertation. Consequently, the workload of the teachers when acting as supervisors will be reduced. Additionally, after the courses with project-based learning, students seem to be better prepared to tackle professional challenges, increasing their employability and the acceptance of the program by the industry stakeholders. On a medium- or long-term, this is likely to be reflected on the number of applicants to the programmes and the demand from the industry for its graduates. Such features do make the courses and, thus, the program more efficient from the university perspective.

The attractiveness of the courses was a significant concern of the teachers for several different reasons:

- Initially students were disruptive about the project-based learning models and found difficult to accept them.
- Due to the time and effort necessary to tackle the projects students often neglect other courses, which caused complaints from other members of the faculty.
- It was intended to increase the engagement and performance of students on optional courses on Geotechnical Engineering and on their dissertations.

The authors needed to make sure that, on the one hand, the courses were attractive for students and that they fully understood the motivations of the teaching team to use these models. On the other hand, it was necessary to make sure the working load of students was adequate and matched what was expected, to address any comments from faculty. The attractiveness to Geotechnical Engineering is not addressed significantly in this paper and will be object of a future paper.

The data collected and presented on the paper shows that, although there are some issues with the working load and the group formation, in general, students are happy with the courses, as well as with the learning models used and are motivated for the courses, as they are aware of their importance to their future professional life. The success of some of these students in national competitions for paid training internships with industry partners are additional attractiveness factors.

For some students these projects had a significant impact on how they faced Geotechnical Engineering and they chose to prepare their M.Sc. thesis on this area. By then, students attending SMI or SMII with project-based learning models exhibited a positive attitude towards the use of numerical tools and laboratory work, as well as fewer difficulties when using spreadsheets and text processors.

Additionally, six students who successfully attended these courses prepared their M.Sc. thesis in cooperation with a construction company. Such work was included in a national competition involving students from other universities and the prize was a paid 6 months' training period. The panel included technical staff from the company, the students' supervisors in the company, as well as external advisors. From the six students applying from UA (2010 and 2011) five were selected. In its 2011 edition, 3 (out of 4) winners were from the Civil Engineering programme at UA. The partners from the building company were positively surprised with both the quality of the students and their preparation to embrace professional work.

The attractiveness of the two models used (cooperative or collaborative) was found adequate, however students accepted the collaborative model better than the cooperative alternative. From the teachers' perspective, the cooperative model was found less effective than the collaborative one. Due to the clear division of roles used in the cooperative group work, some students tended to compartmentalize the contents, only attaining the learning outcomes associated with their task for each specific topic. Thus, students achieved different maturity levels according to their role in each project. In some cases, each team member was worried about fulfilling his/her own tasks, with no exchange of information within the team. Alternatively, with the collaborative model students had to organize their own work as a team and as team members. If, for some teams, that has addressed the issue of the compartmentalisation, for those teams where there was a clear division of the tasks the same limitation was identified. Simultaneously, if in a team there were students more comfortable with using computing and software they were assigned by the team to carry out the corresponding tasks. Although this has increased the quality of their final project report, in many cases, it did not allow other team members to acquire the corresponding competences (Pinho-Lopes and Macedo 2014). However, there were many groups working together to fulfil all the tasks like a real team.

The cooperative learning approach led to lower efficacy for the teachers (relatively to the collaborative one), as it was necessary to provide specialised training to the groups of students fulfilling the different roles in different moments. On the contrary, for the collaborative group work all students received specialised training simultaneously at the beginning of the semester. Due to the reduced number of projects used in the collaborative model compared to the cooperative one, the workload of the teachers was lower when this approach was used. However, this is not a direct consequence of the type of learning model used. The cooperative model forced using a larger number of projects (after establishing the number of students per team) to ensure all students performed the different functions, while for the collaborative model that is not necessary. Thus, with the cooperative model the workload of the teachers increased significantly, related to both supporting the teams' work and marking a larger number of reports. The support to the teams and a prompt feedback to their work are essential, because they allow students to correct and improve their work, change their approach in the following projects and feel the teachers continuously support them.

Finally, the success of these approaches depends mostly on the attitudes of students. Therefore, it is essential to convince them of their relevance for both their academic and professional success, making sure the models used are attractive for them.

5 Conclusions

The aim of this paper was to present a case study of the implementation of non-traditional engineering educational strategies, student-centred and capable of contributing to preparing future engineers. In this case study, project-based learning models were used, with either cooperative or collaborative work. Five years of implementation of those models have provided a large set of information, which can contribute to clarify the relevance of project-based learning models in engineering education. Another objective of the paper was to compare the cooperative and the collaborative work associated to the project-based learning models, as well as, when possible, comparing each one of them to a traditional model.

The different strategies used to assess the learning models implemented, together with institutional questionnaires (to enable independent validation of results), have provided a large and useful set of data. Considering all the results collected, the project-based learning models adopted since 2007/2008 have been well accepted by students. After a first reaction of rejection and suspicious, students ended up accepting them and recognising many associated advantages for their preparation to the future professional life as engineers.

Students’ academic performance indicated that using the project-based learning models, with either cooperative or collaborative teamwork, had a high success rate, though sometimes lower than that of a traditional approach. The increased workload and responsibility of students can explain it. Nevertheless, students’ perceptions indicated a good opinion of the project-based learning model, though collaborative teamwork was better rated than the cooperative alternative.

Students’ perceptions relatively to the use of either cooperative or collaborative learning model did not seem to significantly influence the opinions on the group functioning. Students considered the allocation of students in groups by the teachers more relevant than the type of the learning model used. It is worth noting that similar perceptions were associated with alternative processes for allocating students to groups (2012/2013).

The data collected allowed concluding that students better accepted the collaborative model than the cooperative alternative. One possible reason relates to the lower levels of individual responsibility associated with the collaborative teamwork (as there are no individual tasks attributed specifically to each team member). This feature can lead also to students functioning as a true team for the different tasks, working together to tackle them or distributing those tasks, while ensuring true collaboration. This can be perceived as a “safety net”, boosting students’ confidence. However, some students perceived the collaborative model as having a lower working load and enabling getting through the team projects with less effort, because there was not a mandatory task per student. The collaborative teamwork also has the advantage of minimize the compartmentalization of contents that students tend to show when these active learning strategies are used.

The results pointed out that a second experience of the project-based learning model (if no significant changes were made), was better accepted and perceived by students, while realising and recognising their benefits. This indicates that several exposures to active learning models can improve students' learning and their acceptance of those models.

In terms of the overall efficacy of the project-based models used, their effectiveness, efficiency and attractiveness were analysed. From the authors' perspective and based on the passing rates registered and on the students' answers to the tests, the courses are effective. Relatively to the efficiency, the conclusions are slightly different depending if the students or the teachers' perspectives are considered. From the students' perspective, the courses seem to be efficient. The workload estimated from their answers matched the workload expected for the courses. However, from the teachers' perspective several aspects need to be considered. The implementation of these models requires more time to prepare the projects and organise all the activities than the traditional approach, but the rewards are also higher. The students are better prepared, more autonomous for the following courses on their programme and they seem to be better prepared to tackle professional challenges. Additionally, students found the course attractive, despite the issues identified. In general, students are happy with these courses as well as with the models implemented, particularly once they recognize the importance such approaches can have on their future professional life. The success of some students in national competitions for paid internships with industry partners constitute additional attractiveness factors, which confirm the efficacy of the models used.

As for their efficacy, comparing the two approaches used and despite the differences associated with the number of tests and projects used in each of them, the collaborative model was found best, for both the intended learning objectives and the conditions available. On one hand, students were less likely to compartmentalise knowledge and, on the other hand, the workload of the teachers was lower.

Thus, the authors believe that the active learning strategies adopted were useful and successful in promoting and facilitating the construction of knowledge and in developing competencies by students (regardless of the type of model adopted, cooperative or collaborative). The implementation of those strategies combined with more traditional strategies, such as lectures and textbook problems, did not cause a radical rupture with the traditional models and allowed students to develop other skills necessary to the future work as engineers. However, the impact of the strategies adopted was not identical to all students. Their attitude and commitment are critical (as in any teaching and learning models).

Globally, five years of implementation of these project-based learning models and adjusting them to address questions rose by both students and teachers (using reflective processes) enabled concluding that such models are perceived as more relevant in preparing students for professional atmosphere and, likely, are associated with a deeper learning. Moreover, consecutive exposures to such models can possibly enhance the reported beneficial influence of these models.

Acknowledgments

The authors would like to express their thanks to all students that have participated in the SMI and SMII courses, for being part of it and, specifically for answering the questionnaires and helping to improve the courses.

References

Blackie, M.A.L., Case, J.M. and Jawitz, J. 2010. Student-centredness: the link between transforming students and transforming ourselves, Teaching in Higher Education, 2010, 15(6): 637-646.

Bruffee, K. A., 1995. Sharing our toys: Cooperative learning versus collaborative learning. Change: The Magazine of Higher Learning, 27(1): 12-18.

Butler, M. S. R. and Dee, K. C., 2013. Active learning requires learning–not just activity. In Annual Meeting of the American Society for Engineering Education, Atlanta, GA.

Carstensen, P. H. and Schmidt, K., 2002. Computer supported cooperative work: new challenges to systems design. In K. Itoh (Ed.), Handbook of human factors. Tokyo, Japan.

de Graaff, E. and Kolmos, A., 2003. Characteristics of Problem-Based Learning. International Journal of Engineering Education, 19 (5): 657-662.

de Graaff, E., and A. Kolmos. 2007. History of Problem-Based and Project-Based Learning. In Management of Change – Implementation of Problem-Based and Project-Based Learning in Engineering, edited by Eric de Graaff and Anette Kolmos, 1–8. Rotterdam: Sense Publishers.

Felder, R.M. 2012. Engineering Education: A Tale of Two Paradigms. In Shaking the Foundations of Geo-engineering Education, Bryan McCabe (Editor), Marina Pantazidou (Editor), Declan Phillips (Editor), 9-14.

Felder, R.M. and Brent, R., 2007. Cooperative Learning. Workshop support material, University of Aveiro.

Gibson, I. S., 2000. Group Project Work in Engineering Design-Learning Goals and Their Assessment. International Journal of Engineering Education, 17 (3): 261-266.

Gibson, I., 2005. Designing projects for learning. In Section 2: Designing Enquiry and Problem-based Learning of Handbook of Enquiry & Problem Based Learning. Barrett, T., Mac Labhrainn, I., Fallon, H. (Eds). Galway: CELT, 27-35.

Johnson, D.W. and Johnson, R., 1989. Cooperation and competition: Theory and research. Edina, Minnesota: Interaction Book Company.

Johnson, D. W. and Johnson, R. T., 2009. An educational psychology success story: Social interdependence theory and cooperative learning. Educational Researcher, 38: 365–379.

Keyser, M.W., 2000. Active learning and cooperative learning: understanding the difference and using both styles effectively. Research Strategies, 17: 35-44.

Kolmos, A., 1996. Reflections on project work and problem-based learning, European Journal of Engineering Education, 21(2): 141-148.

Kyndt, E., Raes, E., Lismont, B., Timmers, F., Cascallar, E. and Dochy, F., 2013. A meta-analysis of the effects of face-to-face cooperative learning. Do recent studies falsify or verify earlier findings?, Educational Research Review, 10: 133–149.

Larkin, H. and Richardson, B. 2013. Creating high challenge/high support academic environments through constructive alignment: student outcomes, Teaching in Higher Education, 18(2): 192-204.

Matthews, R. S., Cooper, J. L., Davidson, N., & Hawkes, P., 1995. Building bridges between cooperative and collaborative learning. Change: The magazine of higher learning, 27(4): 35-40.

Nordstrom, K., & Korpelainen. P., 2011. Creativity and inspiration for problem solving in engineering education. Teaching in Higher Education, 16(4): 439-450.

Palmer, S. and Hall, W., 2011. An evaluation of a project-based learning initiative in engineering education. European Journal of Engineering Education, 36 (4): 357-365.

Panitz, T., 1999. Collaborative versus cooperative learning: a comparison of the two concepts which will help us understand the underlying nature of interactive learning.

Pinho-Lopes, M., 2012a. Implementation of the use of computing and software in undergraduate Soil Mechanics courses. In Shaking the Foundations of Geo-engineering Education, Bryan McCabe, Marina Pantazidou and Declan Phillips (Editors), CRC press, 193-200.

Pinho-Lopes, M., 2012b. Some reflections on the use of a cooperative learning model in Soil Mechanics courses, In Shaking the Foundations of Geo-engineering Education, Bryan McCabe (Editor), Marina Pantazidou (Editor), Declan Phillips (Editor), 301-308.

Pinho-Lopes, M. and Macedo, J., 2013. Promoting problem solving and high order thinking skills in Geotechnical courses, 1st International Conference of the Portuguese Society for Engineering Education (CISPEE), 2013, Porto, Portugal, 10p.

Pinho-Lopes, M. and Macedo, J., 2014. Project-based learning to promote high order thinking and problem solving skills in Geotechnical courses, International Journal of Engineering Pedagogy, 4(5): 20–27.

Pinho-Lopes, M., Macedo, J. and Bonito, F., 2011. Cooperative learning in a soil mechanics course at undergraduate level, European Journal of Engineering Education, 36(2): 119–135.

Prince, M.J., 2004. Does Active Learning Work? A Review of the Research, Journal of Engineering Education, 93 (3): 223-231.

Prince, M.J. and Felder, R.M, 2006. Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases, Journal of Engineering Education, 95(2): 123-138.

Puteh, M., Ismail, k.M. and Mohammad, S., 2010. Project-based Engineering Design Education: A Malaysian Case. European Journal of Social Sciences, 16 (3): 411-419.

Razmerita, L., and Brun, A., 2011. Collaborative Learning in Heterogeneous Classes: Towards a Group Formation Methodology. In The 3rd International Conference on Computer Supported Education (CSEDU 2011). 189-194.

Schaf, F.M., Mueller, D., Bruns, F.W., Pereira, C.E. and Erbe, H.-H., 2009. Collaborative learning and engineering workspaces. Annual Reviews in Control, 33: 246–252.

Slavin, R. E., 1996. Education for all. Lisse: Swets & Zeitlinger.

Stump, G.S., Hilperta, J.C., Husman, J., Chung, W-T and Kim, W., 2011. Collaborative Learning in Engineering Students: Gender and Achievement, Journal of Engineering Education, July 2011, 100(3): 475–497.

Thomas, J.W. 2000. A review of research on project-based learning. San Rafael, CA: Autodesk Foundation.

Triten, D.A., 2001. Progressing from Small Group Work to Cooperative Learning: A Case Study from Computer Science, Journal of Engineering Education, 2001, 90(1): 85-91.

Westera, W., and Sloep, P. B., 1998. The virtual company: towards a self-directed, competence-based learning environment. Educational Technology, 38(1): 32-38

Yadav, A., Subedi, D., Lundeberg, M.A. and Bunting, C.F., 2011. Problem-based Learning: Influence on Students' Learning in an Electrical Engineering Course, Journal of Engineering Education, 100 (2): 253–280.

Tables

TABLE 1. SUMMARY OF THE LEARNING MODELS AND ASSESSMENT ELEMENTS USED (INCLUDES DATA PREVIOUSLY PRESENTED IN PINHO-LOPES AND MACEDO (2013) AND PINHO-LOPES AND MACEDO (2014)).

Course	Edition	Model	No. of P[a]	No. of T[b]	Weight on the final mark (%)		MM[c]
					P[a]	T[b]	
SMI	2007/2008	Cooperative	4	1	25	75	7
	2008/2009	Cooperative	4	1	40	60	8
	2009/2010	Traditional[d]	-	2	-	100	7
	2010/2011	Collaborative	2	2	25	75	7
	2011/2012	Cooperative	4	1	40	60	8
	2012/2013	Collaborative	4[e]	1	40	60	8
SMII	2007/2008	Cooperative	4	1	40	60	8
	2009/2010	Collaborative	1	2	20	80	7
	2010/2011	Collaborative	2	1	25	75	7
	2011/2012	Collaborative	1	2	30	70	8
	2012/2013	Collaborative	1	1	30	70	8

a. P - Team projects;

b. T - Tests;

c. MM - Minimum mark in each assessment element, for approval;

d. Traditional model: expositive lectures (theoretical-practical lessons), and solving textbook problems (practical lessons);

e. The work was divided into four parts, but the students only submitted one report at the end of the semester.

TABLE 2. MAIN TASKS ASSOCIATED TO EACH FUNCTION.

Function	**Tasks**
Laboratory or informatics technician	Carry out laboratory tests to identify and characterize a soil sample (Laboratory technichian)
	Use numerical tools to perform the numerical analysis of the problems using commercial software with student licenses (Informatics technichian)
	Compile results for analysis and interpretation by the analyst
Analyst	Create spreadsheets
	Analyse, interpret and discuss the results obtained by the laboratory or informatics technician
	Compare the results obtained using the spreasheets and the numerical tools (when relevant)
Reporter	Write the report
	Carry out bibliographic research on the topic of the project
	Write a short state-of-the-art and describe the work of the other colleagues
Coordinator	Organize and articulate the team
	Ensure all members comply with the deadlines and exchange of information
	Read a scientific paper on the subject and prepare a summary (in some academic years)

TABLE 3. ACADEMIC PERFORMANCE IN SMI COURSE (INCLUDES SOME DATA PREVIOUSLY PRESENTED IN PINHO-LOPES AND MACEDO (2014)).

Edition	Model	NES	NSA	Pass	Fail	Quit	Final Mark			Team Projects		
							Average	*Standard Deviation*	*CV (%)*	*Average*	*Standard Deviation*	*CV (%)*
2007/2008	Cooperative	91	77	58	16	3	10.84	2.36	21.77	12.03	2.05	17.04
2008/2009	Cooperative	63	56	52	4	0	11.16	2.03	18.19	12.45	0.63	5.06
2009/2010	Traditional	65	57	47	10	0	10.58	3.10	29.30	-	-	-
2010/2011	Collaborative	82	69	61	8	0	11.45	2.84	24.80	14.41	2.32	16.10
2011/2012	Cooperative	70	61	57	2	2	11.76	1.62	13.78	13.01	0.76	5.84
2012/2013	Collaborative	59	49	44	5	0	11.49	2.11	18.36	12.81	1.57	12.26

NES – Number of enrolled students;
NSA – Number of assessed students;
CV – Coefficient of variation.

TABLE 4. ACADEMIC PERFORMANCE IN SMII COURSE.

Edition	Model	NES	NSA	Pass	Fail	Quit	Final Mark			Team Projects		
							Average	*Standard Deviation*	*CV (%)*	*Average*	*Standard Deviation*	*CV (%)*
2007/2008	Cooperative	75	71	65	4	2	11.39	1.45	12.73	14.24	1.21	8.50
2009/2010	Collaborative	69	57	42	15	0	10.33	2.14	20.72	12.22	1.73	14.16
2010/2011	Collaborative	87	68	59	9	0	11.38	2.64	23.20	13.76	2.16	15.70
2011/2012	Collaborative	58	42	29	13	0	10.38	1.70	16.38	13.20	0.94	7.12
2012/2013	Collaborative	58	53	49	4	0	11.38	1.72	15.11	13.60	0.93	6.84

NES – Number of enrolled students;
NSA – Number of assessed students;
CV – Coefficient of variation;
Note – The authors weren't delivering this course in SMII 2008/2009.

TABLE 5. SUMMARY OF RESULTS FROM THE BESPOKE QUESTIONNAIRES (INCLUDES DATA PREVIOUSLY PRESENTED IN PINHO-LOPES ET AL. (2011) AND PINHO-LOPES (2012B)).

Course (Model)		Q1	Q3	Q6A	Q6B	Q6C	Q10	Q15	Q16	Q17
SMI (Cooperative) 2007/2008	NVA	31	30	31	31	31	30	31	31	31
	Average	3.52	3.13	2.45	3.39	3.71	3.40	3.84	3.52	3.77
	SD	0.57	1.01	1.36	0.72	0.82	1.13	1.42	1.24	0.99
	CV (%)	16.2	32.3	55.5	21.2	22.1	33.2	37.0	35.2	26.3
SMII (Cooperative) 2007/2008	NVA	67	63	67	65	66	59	64	65	65
	Average	3.65	3.38	2.52	3.58	3.74	3.78	3.91	3.55	3.55
	SD	0.54	0.68	1.12	0.83	0.69	0.81	1.14	0.83	0.81
	CV (%)	14.8	20.1	44.4	23.2	18.4	21.4	29.2	23.4	22.8
SMI (Cooperative) 2008/2009	NVA	55	51	55	55	54	47	51	52	52
	Average	3.75	3.45	2.58	3.55	3.54	3.85	3.84	3.67	3.62
	SD	0.62	0.83	1.49	0.81	0.95	0.98	1.26	1.04	0.91
	CV (%)	16.5	24.1	57.8	22.8	26.8	25.5	32.8	28.3	25.1
SMI (Cooperative) 2011/2012	NVA	53	51	52	53	53	52	52	52	53
	Average	3.66	3.45	2.94	3.64	3.94	3.69	3.77	3.35	3.28
	SD	0.48	0.73	1.16	0.65	0.69	0.96	1.29	1.20	0.99
	CV (%)	13.1	21.1	39.5	17.9	17.5	26.0	34.3	35.9	30.1
SMII (Collaborative) 2011/2012	NVA	41	40	41	40	40	40	39	40	38
	Average	3.88	3.68	3.12	3.50	3.88	3.53	3.77	3.00	3.76
	SD	0.46	0.83	1.12	0.68	0.85	0.91	1.18	1.15	0.82
	CV (%)	11.8	22.5	36.0	19.4	22.0	25.7	31.3	38.5	21.8
SMI (Collaborative) 2012/2013	NVA	46	43	47	47	47	47	45	46	46
	Average	3.61	3.63	3.47	3.53	3.79	4.00	3.91	3.59	3.54
	SD	0.58	0.72	0.88	0.58	0.69	0.93	1.29	1.07	0.81
	CV (%)	16.0	20.0	25.4	16.5	18.2	23.3	33.1	29.7	22.8
SMII (Collaborative) 2012/2013	NVA	30	30	30	30	30	30	30	30	29
	Average	3.87	3.77	3.27	3.73	4.00	3.73	3.53	3.30	3.52
	SD	0.43	0.73	0.69	0.64	0.59	1.14	1.28	0.84	0.63
	CV (%)	11.2	19.3	21.2	17.1	14.7	30.6	36.2	25.4	18.0

NVA - Number of valid answers;
SD -Standard deviation;
CV (%) - Coefficient of variation;
Q1 - Degree of difficulty of the course (1 – Very easy; 5 – Very hard);
Q3 - Adequacy of the assessment methods to the defined objectives (1 – Lower; 5 – Higher);
Q6A - Adequacy of the proposed activities to the course contents – work volume appropriate to the available time (1 – Lower; 5 – Higher);
Q6B - Adequacy of the proposed activities to the course contents – degree of difficult/complexity (1 – Lower; 5 – Higher);
Q6C - Adequacy of the proposed activities to the course contents – interest and relevance (1 – Lower; 5 – Higher);
Q10 - Proper group functioning (1 – Lower; 5 – Higher);

Q15 - Does the groups' formation by the teachers have influence on the team projects final marks (1 – Little; 5 – Much). Note: In 2012/2013 the groups was formed by students without any restrictions (SMI) or with restrictions (SMII) as explained before;
Q16 - Personally, did you admire, learn or absorb some competence (people, organization, motivation, written communication, presentation in group) from another group colleague? (1 – Little; 5 – Much);
Q17 - With the implemented teaching and learning model in the course, did you learn something else beyond the corresponding formal contents? (1 – Nothing; 5 – Much more).

TABLE 6. SGQ RESULTS – ECTS ESTIMATED BY STUDENTS (INCLUDES SOME DATA PREVIOUSLY PRESENTED IN PINHO-LOPES AND MACEDO (2013) AND PINHO-LOPES AND MACEDO (2014)).

Course	Edition	Model	NES	NVA	Estimated ECTS		
					Average	SD	CV (%)
SMI	2007/2008	Cooperative	91	39	6.3	3.4	53.9
	2008/2009	Cooperative	Data not available				
	2009/2010	Traditional	64	38	4.57	1.24	27.1
	2010/2011	Collaborative	68	51	4.71	1.73	36.7
	2011/2012	Cooperative	67	43	6.77	2.93	43.3
	2012/2013	Collaborative	58	36	6.05	2.29	37.9
SMII	2009/2010	Collaborative	67	37	5.26	2.33	44.3
	2010/2011	Collaborative	84	51	5.24	1.91	36.5
	2011/2012	Collaborative	58	26	6.67	3.74	56.1
	2012/2013	Collaborative	59	25	5.69	2.02	35.5

NES - Number of enrolled students (eligible to SGQ);
NVA - Number of valid answers;
SD - Standard deviation;
CV (%) - Coefficient of variation.

TABLE 7. SGQ RESULTS – COURSE CARACTERIZATION (ANSWERS' SCALE FROM 1, LOWEST, TO 9, HIGHEST); (INCLUDES SOME DATA PREVIOUSLY PRESENTED IN PINHO-LOPES AND MACEDO (2013) AND PINHO-LOPES AND MACEDO (2014))

Course (Model)		NVA	P7	P8	P9	P12	P13	P14	P15	P16	P17
SMI (Traditional)	**Average**		6.16	6.57	6.12	6.72	6.58	6.36	5.86	5.65	6.50
2009/2010	**SD**	38	1.32	1.67	1.36	1.19	1.34	1.22	1.33	1.40	1.50
	CV (%)		21.4	25.4	22.2	17.7	20.4	19.2	22.7	24.8	23.1
SMI (Collaborative)	**Average**		6.80	6.76	6.75	7.24	6.33	6.54	5.86	6.53	7.51
2010/2011	**SD**	51	1.34	1.59	1.78	1.37	1.89	1.43	1.49	1.42	1.07
	CV (%)		19.7	23.5	26.4	18.9	29.9	21.9	25.4	21.7	14.2
SMI (Cooperative)	**Average**		6.37	6.67	6.02	6.14	5.26	6.20	5.95	6.05	7.76
2011/2012	**SD**	43	1.80	1.44	1.91	1.60	1.83	1.17	1.31	1.11	1.23
	Cv (%)		28.3	21.6	31.7	26.1	34.8	18.9	22.0	18.3	15.9
SMI (Collaborative)	**Average**		7.25	6.92	7.06	7.25	6.42	6.81	6.31	6.75	6.92
2012/2013	**SD**	36	1.34	1.38	1.43	1.30	1.65	1.26	1.39	1.00	1.27
	CV (%)		18.5	19.9	20.3	17.9	25.7	18.5	22.0	14.8	18.4
SMII (Collaborative)	**Average**		6.39	6.91	6.38	6.62	5.92	6.08	6.28	6.30	6.92
2009/2010	**SD**	37	1.32	1.27	1.59	1.55	1.72	1.52	1.47	1.35	1.66
	CV (%)		20.7	18.4	24.9	23.4	29.1	25.0	23.4	21.4	24.0
SMII (Collaborative)	**Average**		6.56	6.84	6.90	7.16	6.24	6.66	6.88	6.59	7.20
2010/2011	**SD**	51	1.54	1.25	1.57	1.30	1.58	1.27	1.30	1.24	1.30
	CV (%)		23.5	18.3	22.8	18.2	25.3	19.1	18.9	18.8	18.1
SMII (Collaborative)	**Average**		5.85	6.12	5.77	6.27	6.15	5.96	6.23	6.92	7.35
2011/2012	**SD**	26	1.83	1.70	1.95	1.51	2.13	1.80	1.18	1.47	1.38
	CV (%)		31.3	27.8	33.8	24.1	34.6	30.2	18.9	21.2	18.8
SMII (Collaborative)	**Average**		6.04	6.92	6.38	7.20	6.28	6.32	6.60	6.76	7.24
2012/2013	**SD**	25	1.63	1.22	1.28	1.15	1.40	1.14	1.04	1.48	1.42
	CV (%)		27.0	17.6	20.1	16.0	22.3	18.0	15.8	21.9	19.6

NVA - Number of valid answers;
SD - Standard deviation;
CV (%) - Coefficient of variation;
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 course and its objectives;
P12 - Global functioning of the course;
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 course and the competences previously acquired;
P16 - Degree of difficulty of the course contents;
P17 - Workload /time necessary for obtaining pass mark.

Figures

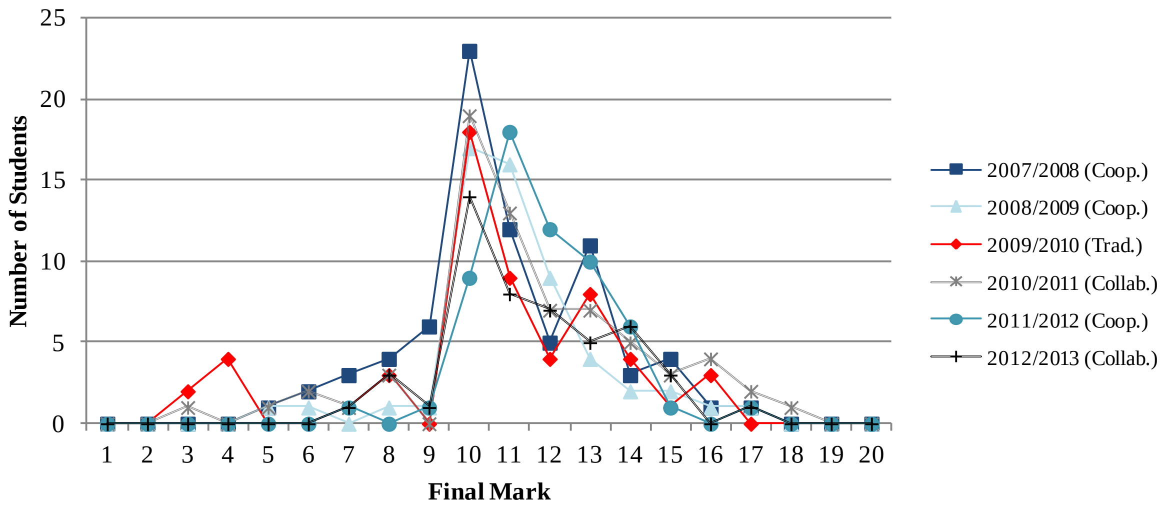

Figure 1. Distribution of the final marks in the different editions of the SMI course (includes some data previously presented in Pinho-Lopes et al. (2011) – 2007/2008 and 2008/2009)

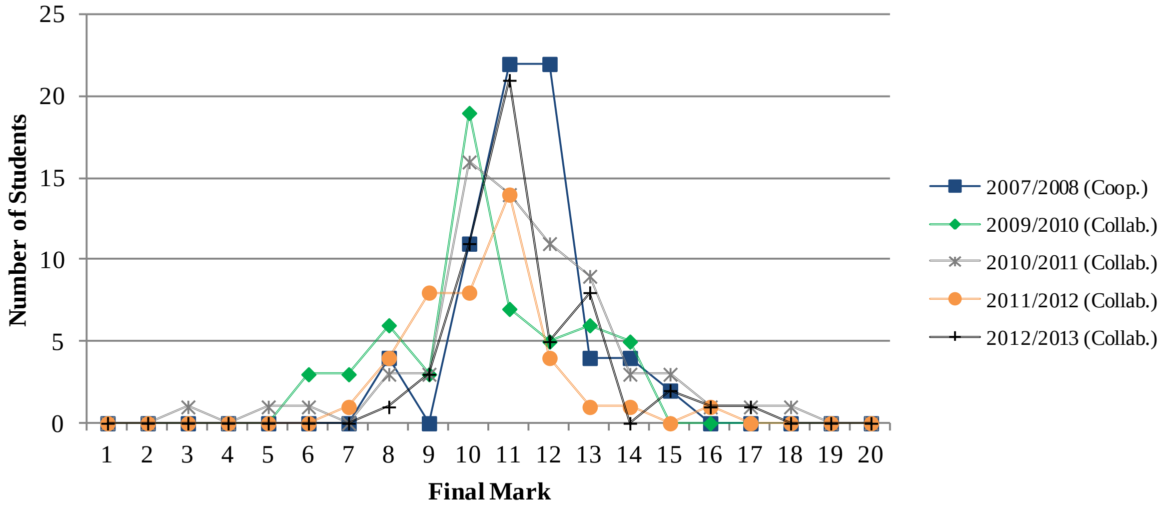

Figure 2. Distribution of the final marks in the different editions of the SMII course