Implementation of the use of computing and software in undergraduate Soil Mechanics courses

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ABSTRACT: To respond to the industry’s increasing demands, it is generally accepted that Civil Engineering graduates and postgraduates should have broad technical knowledge, together with significant soft skills. In two courses on Soil Mechanics as part of the degree in Civil Engineering of University of Aveiro, Portugal, students undertake projects using general computing and specific geotechnical software that both enhance their technical learning and develop soft skills. Critical thinking is required for the validation of ‘blackbox’ numerical results by making comparisons with theoretical solutions, in reflection on the limitations of numerical tools, as well as for estimation of values for input parameters for analyses.

1 INTRODUCTION

1.1 Scope

To respond to the increasing demands of the industry, it is generally accepted that Civil Engineering graduates and postgraduates should be equipped with broad technical knowledge, together with significant generic competences and soft skills. Some examples are: efficient communication, orally and in writing; development of human relations, particularly the ability of working in team; ability to work with a computer, namely with text processors and spreadsheets. The ability of using computing and specific software can be included in both technical knowledge and soft skills.

To increase the employability of the Civil Engineering graduates and postgraduates at University of Aveiro (UA), Portugal, and to improve the quality of the program, the author implemented some non-traditional teaching and learning strategies in most of the courses under her coordination. Parallel, to assess the effect of such strategies on enhancing students learning, the author analysed its impact.

In two sequential courses on Soil Mechanics in the five year degree in Civil Engineering at UA, the students were confronted with the need to use computing and specific geotechnical software. The main goal was to help students develop soft skills and to become familiar with typical numerical tools currently used in Geotechnics. Such learning strategies were adopted using a cooperative learning system. More details on such system can be found in Pinho-Lopes et al. (2011) and in a companion paper Pinho-Lopes (2012).

1.2 Use of computing and software in geoengineering

Several authors have pointed out the importance of using computing and software in engineering practice and different perspectives of such use can be found in literature.

For example, Toll (2001) states that the information technology was becoming increasingly important in geotechnical engineering and computers were being used much more for non-computational purposes. This author points out several major areas of usage: geotechnical database systems, the use of artificial intelligence techniques, such as knowledge-based (expert) systems, and neural networks.

Rose (1978) said that it should be the duty of the university to teach how to use engineering computer packages intelligently, stating that engineering design using computer packages was a new technique to be learned, being a mixture of experimental planning, engineering logic and economics. The author points out that a computer package is also an excellent educational aid, allowing the student to get an engineering feel for a piece of equipment or system much quicker than by laboratory work or a series of hand calculations.

The use of software and computing has thus been increasing in engineering education as preparation for the professional atmosphere.

Jaksa et al. (2000) present computer aided learning (CAL) resources available in geotechnical engineering and engineering and environmental geology in undergraduate courses, which at that time were becoming more widespread and an accepted form of teaching.

According with Rothberg et al. (2006) engineering students in the UK like the use of CAL
materials, but they still want notes to take away; they want to be supported in their use of software, especially when engineers' tools are used to demonstrate principles; timetabled support can work well as a catalyst to encourage self-study using the software.

Budge (2006) states that providing students with the chance to use a few of the tools they will use once they begin their careers as practicing engineers (e.g. finite element method commercial software) is a significant benefit to both the students and their employers.

Zoghi (1996) presents a case study where personal computers were integrated in the teaching of geotechnical engineering courses. The author refers to the use of spreadsheets as an alternative to a 'blackbox' approach, stating that for the design of foundations, such strategy leads to students gaining an insight into the material characteristics and the design implications by considering numerous 'what if' conditions. Zoghi (1996) also states that, during the several soil mechanics courses, a series of spreadsheet templates are generated by the students to incorporate the weight-volume relationships, compaction density curves, and soil classification characteristics. However, the majority of effort is expended on formulating spreadsheet routines for the permeability, compressibility, and shear strength characteristics. The same author states that, for instance, “a template is initially generated to compute and plot the vertical stress distributions due to overburden pressure as well as induced foundation loading. The concepts of effective stress, neutral stress and total stress are incorporated in this program. Once, the stress distribution is configured in a soil mass, the compressibility (or settlement) characteristics of soil are readily determined in a subsequent spread sheet template.”

Carter et al. (2000) state the importance of validating computer simulations and geotechnical software, and suggest some methodologies for achieving this. Furthermore, they state that there is a strong need to define procedures and guidelines to arrive at reliable numerical methods and, more importantly, input parameters which represent accurately the strength and stiffness properties of the ground in situ.

Zoghi (1996) concludes that the use of microcomputer spreadsheets appears to be amenable to the solution of myriad of geotechnical problems. Due to the versatility that these tools offer and the fact that they furnish an interactive environment, the prospect of 'blackbox' approach may be eliminated. Thus, the students can enhance their knowledge of the material by primarily varying the input parameter values and instantly observe the outcome (Zoghi, 1996).

Therefore, introducing future engineers to this type of approach and encouraging a critical attitude towards the use and the results from computing and software is essential for achieving adequate preparation for the professional life.

2 CASE STUDY

2.1 Civil Engineering programmes in Portugal

Presently the Civil Engineering degree in UA is organised in two integrated cycles, corresponding to a program which lasts for five years. To clarify the meaning of such cycles it is important to mention that this organisation resulted from the Bologna process.

The most visible transformation from the Bologna Process in Portugal was the degree's reorganisation in three cycles:

- 1st cycle, three years (degree of 'licenciatura');
- 2nd cycle, two years (degree of 'mestrado');
- 3rd cycle, three to four years (degree of Ph.D.).

The engineers’ professional organization in Portugal demands a minimum of 5 years scholarship for civil engineers to be responsible for all types of engineering projects. Thus, most civil engineering programs are organized in two integrated cycles (1st and 2nd cycle) leading directly to a M.Sc. degree.

Currently, at the University of Aveiro (UA) such a cycle has a duration of 10 semesters (300 ECTS), where ECTS stands for European Credit Transfer System. The concept of ECTS is based on a mutually agreed assumption that the annual workload of a student represents 60 credits. Student workload is estimated at being a value between 1500 and 1680 hours work per year. The value is based on a presumption that the average student works for 40 weeks per year with an average weekly workload of 40 hours. Thus, each ECTS credit unit represents 25 to 28 hours work. The workload includes, apart from class time, individual study time, preparation of reports, bibliographical research, preparation of examinations, etc. (UA, 2010).

2.2 Soil Mechanics courses

There are two Soil Mechanics courses in the Civil Engineering program at UA, Soil Mechanics I and II included in the 3rd year, 1st and 2nd semester, respectively. Therefore, they are included in the 1st cycle (undergraduate).

The aim of the Soil Mechanics I (SMI) course is the understanding of basic concepts and fundamental quantities of Soil Mechanics, so that later, they can be applied in the design of civil engineering structures. The course syllabus is grouped into four main chapters:

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.

The Soil Mechanics II (SMII) course is focused mainly on the mechanical behaviour of soils (in particular its strength). Concepts, theories and methods generally used for the design of civil engineering structures are presented. Emphasis is placed on situations
where the soils’ strength conditions the stability. The field tests generally used to characterise the mechanical behaviour of soils are also presented. The course syllabus is grouped into four main chapters:

1. Introduction to shear strength of soils. Shear strength and stress-strain relationships in sands and clays;
2. Lateral earth pressures; Earth retaining structures;
3. Stability of slopes and embankments;
4. Sampling and in situ tests.

In these courses, the stability analyses are carried out using both global safety factors and the partial safety factors approach from Eurocode 7 (EN 1997-1:2004).

The Soil Mechanics courses correspond to 6 ECTS each and typically have 60-90 students per school year. The weekly timetable of SMI consists in one Theoretical-Practical (TP) lesson with a limited number of students (up to 45), duration of two hours and includes a practical component, and one Practical (P) lesson with the duration of 2 hours and limited to 25 students. In the P lessons, the students use hand calculations to solve problems linked to the each aspect of the syllabus. The weekly timetable of SMII consists of two TP classes. Some type of hand calculations are done in the TP lessons, however, with this format it is more difficult to ensure individual support.

The Soil Mechanics I course is taught in the 1st cycle degree (‘Licenciatura’) in Civil Engineering Sciences. This course is also offered to the students of the 1st cycle degree ‘Licenciatura’ in Geological Engineering, in the same semester and year (20 to 25 students). This results in a variety of backgrounds, which conditions the teaching. The Soil Mechanics II course is also mandatory for the Civil Engineering students and optional for part of the Geological Engineering students. Typically there is one student per school year from such a programme.

Before the Soil Mechanics courses, the Civil Engineering students have contact with Geotechnics by attending two courses on geology: General Geology and Engineering Geology.

The cooperative teaching and learning model has been used in a more elaborated form in the SMII course. For the SMII course a ‘lighter’ version of such model has been adopted as the author has been teaching the course on her own.

2.3 Cooperative learning model used

This paper focuses on the use of computing and software in undergraduate Soil Mechanics courses as part of a cooperative learning model. In this section, such a model is briefly described. More details can be found in Pinho-Lopes et al. (2011) and Pinho-Lopes (2012).

The assessment system implemented was defined using suggestions by Felder & Brent (2007) and included two assessment elements: four team projects, developed during the semester, and one test. For the students who failed there was a second chance of passing – final exam, where the team projects’ mark was still considered.

The team projects were compulsory for all students. During the semester, students prepared four projects (one for each chapter of the SMI course syllabus) and presented some of them orally to teachers and colleagues. The projects to be orally presented were chosen by the teachers, based on the necessity of clarifying possible confusing aspects revealed during their correction.

The projects were prepared in groups of four students with specific individual functions in each work and mandatory rotations. The four roles performed by each one were: laboratory/informatics technician, analyst, reporter and coordinator. This way, all students performed the four established functions (a different one in each project), representing the corresponding role-jigsaw project system.

The laboratory technician had to carry out laboratory tests to identify and characterise a soil sample (for the first and the fourth projects). The informatics technician had the responsibility to use numerical tools, such as finite element programmes (in the second and third projects). Such numerical tools are freeware versions, with student licenses, of commercial software currently used by engineers when studying geotechnical problems. The elaboration of spreadsheets and the analysis, interpretation and discussion of the results obtained were done by the analyst. The reporter assumed the preparation of the written part of the project, which included a short state of the art and a description of the work of his/her colleagues. Lastly, the coordinator had to organise the group, guaranteeing that all members followed the deadlines and exchanged information. In some school years, this role also included reading a scientific paper in English on the subject and preparing a summary of such information.

These roles had, as much as possible, a parallel to functions normally fulfilled by engineering professionals. Thus, the jigsaw project system was implemented, promoting positive interdependence between students. Areas of expertise were defined, corresponding to the several roles (literature review, theory, experiment, data analysis, etc.). At the beginning of the semester, the students assigned with a particular task were put together in expert groups and each group received specialised training, resources and checklists. Each team member had to make sure that his/her area of expertise was covered in the team project.

To get individual accountability, the test covered all subjects of the course syllabus and the individual mark on the project was obtained by applying a weight to the team project mark to consider the individual performance of the students. This weight was based on the students’ self and peer assessment within the group (according to Felder & Brent, 2007).

All the information was available for the students via the e-learning system at the UA, where group areas were created, allowing each group to save and exchange files, e-mails and short messages.
For the SMII course there are usually only two or three team projects and, therefore, the roles are not imposed. The whole team is responsible for all of the work. Individual accountability is also done.

3 USE OF COMPUTING AND SOFTWARE

3.1 Team projects and functions

As mentioned before, the team projects were prepared in groups of four students, with specific individual functions in each work and mandatory rotations. The four roles performed by each team member were: laboratory/informatics technician, analyst, reporter and coordinator. Most of the team members had to use computing or software when preparing a specific project.

The reporter prepared a file using a text processor, gathering the information provided by the other team members and with a short state of the art on the subject of the project. The analyst had to prepare a spreadsheet from scratch to obtain results using theoretical numerical solutions. The analysis, interpretation and discussion of the results obtained were also a responsibility of the analyst. The role of the fourth group member was either laboratory or informatics technician, depending on the project. When the team project involved carrying out laboratory tests, this team member also had to work the test results, using a spreadsheet. In the case where numerical analysis were to be done, this team member had to use commercial numerical software to carry out such analysis and to help the analyst to compare the results from such tool with the ones obtained using the theoretical numerical solutions.

3.2 Projects – Soil Mechanics I

According to Triten (2001), a good structure for cooperative learning assignments has been developed by Michaelsen, as he recommends that all cooperative learning assignments be characterised by “The Three S’s”:

1) Same problem;
2) Specific choice;
3) Simultaneous report.

This was the approach adopted in the case study described.

Allowing students to analyse different aspects of the same problem, each project includes different perspectives of the corresponding part of the syllabus. Thus, on each project it is necessary to prepare a short state of the art on the subject, to carry out laboratory tests or to perform numerical simulations, to do calculations using theoretical solutions and to compare and criticise the results obtained.

When possible, the same geotechnical problem is used throughout the semester, allowing students to analyse different perspectives of the same problem. In Figure 1, the problem used in the school year 2011/2012 is shown. Particular aspects of this problem were analysed in each project, with the necessary adaptations.

For SMI, Project 1 includes carrying out identification and characterisation laboratory tests on soil samples and deriving the main physical properties of, for example, Soils 1 and 2 (Figure 1). The calculations are done using spreadsheets and include relationships between soil properties, in order to students to become more familiarised with them. Those results are also used to classify the soil samples using three different systems (Unified Classification system, AASHTO and LCPC-SETRA). Students have to prepare spreadsheets which, besides the calculation of the main physical properties, include, for example, the implementation of the plasticity chart of the Unified Classification system for soils.

Project 2 includes the determination of the stress state of a soil profile in different stages of construction (for example, in situ and after the construction of a given structure) and the representation of the variation of such stress states with depth and using Mohr circles and stress paths, for specified points within the profile. Different vertical sections are imposed for such calculations. The teams use spreadsheets to implement the theoretical equations for the determination of the stress states, which also involve the application of the equations valid for homogeneous, isotropic and semi-infinite half-space. The elastic settlements of the soil mass are estimated. Simultaneously a finite element program is used to carry out the same calculations (Figure 2). During the preparation of the assignment the team has to make some engineering judgement, for example in the estimation of the Young modulus and Poisson coefficient of the soils involved. The team options have to be justified and, when necessary the quantities determined in the previous assignment can be adjusted or corrected. A critical analysis of the results and their relative values is expected.
determining the consolidation settlement, the time necessary to attain a certain average degree of consolidation, the pore pressure distribution with depth in different moments, among others. These calculations are, once again, done using spreadsheets, where maximum automation is desired.

3.3 Projects – Soil Mechanics II

As mentioned before, in the Soil Mechanics II course in most school years a ‘lighter’ version of this system has been used.

Project 1 usually covers the syllabus chapter on the soil shear strength of both sands and clays. Usually the students are confronted with results from triaxial and/or direct shear tests and have to use spreadsheets to derive parameters from them (for example, cohesion and friction angle, peak and critical state values, Skempton parameter $A_f$, undrained shear strength, etc., depending on the type of soil and on the type of test). For a realistic field problem, the students have to determine the new stress state resulting from the construction works (sometimes including phasing) and to assess whether the stress states in the soil at given locations are permissible. Mohr circles, as well as stress paths, are also used to represent the stress state during the defined construction phases, for specified points within the soil profile. These calculations are done using both spreadsheets (for particular vertical sections) and numerical programs with the finite element method. A critical analysis and comparison of the results has to be done. A sense of the limitations of such tools, as well as their dependence on the quality of the input of the materials’ properties is targeted.

Project 2 refers to the calculation of lateral earth pressures and the external stability of a retaining wall. Moreover, the students use spreadsheets to calculate the earth pressures and to make external design of such walls. Such spreadsheets allow students to carry out simple parametric analysis to assess the influence of chosen parameters on the wall stability. Furthermore, the students are asked to carry out some scenario analysis where, for example, the width of a retaining wall is determined using the prepared spreadsheets in order to simultaneously satisfy all the external stability requirements while at the same time minimising the wall width.

Project 3 refers to slope stability and includes analysis of infinite slopes and of more general slopes. For infinite slopes, the stability is analysed for different scenarios (usually varying the seepage regime established) using both spreadsheets and numerical tools (Figure 4). Results are compared (an example is illustrated in Table 1) and discussed. Engineering judgement is stimulated, for example on the choice of the distance to the boundaries to be used in the numerical analysis. For the more general slopes, a similar stability analysis is carried out, using software and, for some specific failure surfaces, the same analysis is done using spreadsheets. The use of computer-aided design (CAD) is encouraged. This project includes

Project 3 involves seepage in soils. The structure of the project is similar to Project 2, for example, in this case simulating the excavation necessary to build the structure (Figure 3) and the seepage resulting from the pumping inside the excavation. For this project a finite element programme is used to determine the flownet in the soil and the water pressure distribution. The same flownet is also hand-drawn. The students have to use the flownets to determine the pore water pressures in the soil. The safety against hydraulic failure is analysed using the two types of results (from spreadsheets, using the hand-drawn flownet and from the numerical analysis). These results refer to particular imposed sections of the soil mass. A critical comparison and analysis of all the results has to be done. The soil permeability is estimated: for the granular soil, using semi-empirical equations (for example, Hazen equation); for the fine-grained soil the students use tables with indicative values and are invited to choose values, to justify their choice and to carry out a parametric analysis, using ranges of values and comparing results.

In Project 4, the consolidation of fine soils is studied. As the oedometer tests are long and the number of test rigs available is limited, typically students use results from previously performed tests, without carrying them on their own. With those results a series of parameters has to be determined (compression index, swelling index, consolidation coefficient, overconsolidation ratio, etc.). The preparation of the spreadsheets includes the analytical and graphical determination, within the spreadsheet, of the mentioned quantities. Later, this information is used to study the consolidation process in a realistic (field) problem, by
using circular arc analysis. In the software the normal method of slices and methods of Bishop, Janbu and Morgenstern-Price are used and the results obtained are compared.

In some cases, Projects 2 and 3 are merged, where the stability of a slope which includes the analysed retaining wall is done as part of verifying its external stability.

3.4 **Progressive implementation**

This system has been implemented progressively. In fact, when the author started teaching these courses, limited material was available and the classes were quite small. When teaching the basic soil mechanics courses, besides presenting simple examples the author felt the need to confront students with realistic problems. The use of computing and software was the next natural step in order to allow working on field problems, to develop critical thinking and to increase the awareness of software limitations.

Thus, on first approach the use of spreadsheets was implemented. The students reaction was quite good, many of them stating that they finally had to learn how to use them.

Later, the use of typical numerical tools currently used in Geotechnics was implemented. To stimulate students and to allow them to work on their own, it was decided to use freeware versions, with student licenses, of commercial software currently used by engineers when studying geotechnical problems. Usually such software is in English which, for Portuguese students, can be an additional obstacle. Nevertheless it obliges the students to learn English technical language, which is a good and useful professional skill.

The students’ reaction is distinct. While some of them are quite frightened by the need of using such software (particularly in English), others are quite enthusiastic about it. In some cases the fear is rapidly overcome by implementing classes where the students receive specialised training, resources and checklists. Video tutorials available at the software companies can also be quite useful.

The students are encouraged to use the spreadsheets they prepared and the software to derive solutions for the problems proposed in classes. In fact, when comparing the results obtained in the numerical analysis with the ones from textbooks or even with the problems solved in classes, students become more interested and involved in using computing and software and aware of its advantages, even during the time they spend at university.

The last addition to the teaching method was the laboratory testing, which in many institutions is the starting point. The Civil Engineering department in UA is quite a recent development (15 years old) and only after the laboratory had been adequately established and when Ph.D. students or laboratory technicians were available could this be implemented. The ideal situation would be that all the students would go to the laboratory and use all of the different software, however this could be difficult given existing conditions.

3.5 **Further details of project work**

It is important to note that, for both SMI and SMII, the projects were broadly the same for each team but with some significant differences.

Firstly, the soil samples tested were different. These samples were gathered, and sometimes manipulated in the laboratory, to ensure that all teams would analyse samples of a granular and of a fine-grained soil. Therefore, the amount of work and degree of difficulty of each team’s problem was the same.

The use of different soil samples led to different geological profiles for each team and different decisions to be taken. In later projects, though the base problem was the same, different values for distances, soil properties and loads were also used, creating individualised situations.

Up to this point of their curricula the students have not encountered the finite element method. Sometimes this is a real obstacle for the use of software with such method. A simplistic explanation of such method was done, for example in order to allow the students to understand the need of manipulating the mesh, refining certain areas.

Comparing the results obtained from spreadsheets and from ‘blackbox’ software was quite useful in order to call students’ attention some problems arising from the use of computing and software.

4 **STUDENTS’ REACTIONS**

4.1 **Assessment of the system**

During the first application of the cooperative learning system in 2007/2008 and in the Soil Mechanics I
course, the teachers felt the need to evaluate its success and impact on students’ learning. In later years where the cooperative learning system has been used, a similar evaluation has been made.

Therefore, different and complementary strategies were used, namely: students’ feedback during the semester; marks monitoring; and questionnaires at the end of the semester. These results are presented and discussed by Pinho-Lopes et al. (2011) and Pinho-Lopes (2012). The impact of computing and software has not been assessed separately. Nevertheless some of the students’ opinions can be included here.

During the semester, the students were asked to give an informal opinion on the implemented evaluation system (orally and written, anonymously).

To better understand the efficacy of the implemented model, a statistical analysis of the number of students enrolled, which attended, evaluated and obtaining passing mark was done. The marks of the four team projects were analysed and some possible explanations for the results were put forward (Pinho-Lopes et al., 2011).

Questionnaires were prepared and were divided into two large blocks of questions: (1) course organisation and implementation; (2) functioning of the teams during the projects. For most of the questions, a five-point Likert scale was used.

4.2 Results from the assessment

From the students’ feedback, the major difficulty associated with the use of computing and software was using and understanding the software. In fact, as mentioned before, for some of the students the language was a real problem. For others, with less aptitude for the use of computing, the necessity of using both computing and software was quite a challenge. In some cases, these difficulties were not completely overcome.

The specialised training on such issues helped. Students with the same role in a specific project got together to work out how to use the numerical tools and how to overcome the difficulties felt. A true specialists’ team was formed.

The impact of the use of computing and software on the marks is not clear. In fact, the marks’ monitoring revealed a very significant drop of the marks from the first project to the second one (for SMI). Another important difference was the marks obtained in Project 4. Some reasons can be pointed out to explain these differences, namely (Pinho-Lopes et al., 2011):

- The experimental nature of Project 1;
- More time available for preparing Projects 1 and 2 (due to less workload from other courses);
- Difficulties in using software packages for Projects 2 to 4;
- Need for more theoretical knowledge for the last projects;
- Fewer resistance from the students to the cooperative learning model in 2nd year of application (2008/2009);
- Increase of students’ conflicts within some groups, hindering their performance. It should be noted that in some groups the opposite occurred – as the semester advanced the relational difficulties decreased.

The students that answered the questionnaire considered, almost unanimously, that the implemented learning model also led to the development of skills and knowledge other than the formal course content. There were questions meant to find out the students’ difficulties during the elaboration of the projects and in fulfilling the different roles. Some questions were also introduced about the projects added value to the students’ preparation for future engineering work. It was somehow consensual among students that this model has advantages in their preparation for ‘real life’ and for their future role as civil engineers.

4.3 Impact of the teaching experience

The impact of this teaching experience on the learning outcomes of the students can be quite varied. The author’s experience and views are summarised.

The group projects improve the overall learning outcomes of fundamentals for most students. However, their magnitude depends on the students and on their attitude towards their degree. They practice concepts using different approaches and perspectives and some also use their own spreadsheets to check the solutions of the given problems. In some extreme cases, students tend to compartmentalise knowledge. Weaker students, who just want to do the minimum to pass, limit themselves to carrying out their own task in the project. In those cases, it is clear from the examinations in which project they coordinated the team.

Some students try to pass around spreadsheets. They ask for information particularly from colleagues from previous years. This cannot be avoided and students that do that are the most affected by such procedure. Their learning is compromised and they will not be as prepared as their colleagues. In some cases, the students confided in the author that they tried that as a first approach. However, to understand their colleagues work, to adapt the spreadsheet to the problem under study and to correct the mistakes they find is more difficult and time consuming than creating their own spreadsheet, thus most of them have abandoned such approach.

This teaching experience is also very demanding on the teacher. In fact, it caused a significant extra workload for the lecturers, which is difficult to quantify, as an accurate assessment of the impact of the method implemented on the workload of the lecturers was not done.

5 CONCLUSIONS

In this paper, a case study of the use of computing and software in two Soil Mechanics courses was described, which included a generalised use of spreadsheets, text
processor and numerical programs, for example with the finite element method.

The use of such learning strategies was found to be adequate and led to enhancing students’ learning, as well as acquisition of soft skills, necessary for any civil engineer professional.

The validation of numerical results through the application of theoretical solutions for the problems as well as the estimation of values for certain quantities was achieved. The development of critical thinking was targeted.

The author observed that some students tend to compartmentalise knowledge. In fact, for some students it is easily identifiable by the lecturer in which project these students coordinated the team. Thus, it is essential that all students participate in the practical lessons, where they use hand calculations to solve problems linked to the each aspect of the syllabus, so that they work on all aspects of the course. In the case study presented, for SMI this is relatively simple as it can be done in P lessons. For SMII, all the course lessons are TP, which creates an additional difficulty. Nevertheless, the lighter version of the learning model implemented enables partially overcoming such problem. As there are no established functions and the group has to organize its own work, some groups tend to solve all parts of the projects together, as a team, without dividing the work in several tasks.

REFERENCES


