Teaching methodologies in civil engineering: a multidisciplinary approach

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Abstract

Nowadays universities are rethinking their teaching methodologies not only in order to adapt to the use of new technologies, such as the ICT (information and communication technologies) or the GIS (Geographic Information Systems) but also in order to advance the international students towards a multidisciplinary approach. Thus, this article is the result of a multidisciplinary approach gathering scholars from Portugal and Romania, presenting a set of several teaching methodologies used on the domains of civil engineering. It is based on the experience of the University of Beira Interior (UBI) in Portugal and the Faculty of Constructions, Cadastre and Architecture of the University of Oradea (UO) in Romania. Among other descriptions, the conclusions show that there are several different and common aspects in between the Portuguese and the Romanian experiences. Regarding the common aspects there is the need of finding new teaching methodologies in order to consider the different backgrounds of the international students coming from several countries and continents, having diverse high educational systems. Thus, the international students are encouraged to work together and to actively participate in the development, presentation and discussion of their scientific findings.

Keywords: Teaching methods, multidisciplinary approach, international students, civil engineering.

1 Introduction

The good weather conditions and the seashore, the cultural and historical legacies, the good performance of the higher education system or the easy settings of mobility among the European citizens, are aspects that are contributing to attract to Portugal students from abroad. During the most recent years the number of international students is increasing. In the past, international students were mainly originated from Portuguese speaking countries, such as Brazil, Cape Verde Islands, Angola or Mozambique, nowadays they are coming from all continents, including countries such as Algeria, Iran or Syria. In this sense, this multidisciplinary research, gathering the experiences of a university in Romania and one in Portugal, both focused on civil engineering, aims to present some viewpoints about teaching methodologies that scholars from these institutions are using to guide their practices, in order to promote de integration of international students.

2 Teaching methodologies in civil engineering studies

2.1 One case in Portugal

2.1.1 The master degree at University of Beira Interior

The master degree in civil engineering has a multidisciplinary approach and several scientific domains. Among them there are the spatial planning, the mathematics, the transportation engineering or the GIS issues. UBI is located in a medium size city, Covilhã, in the Interior region of the country near to the border with Spain, having approximately eight thousand students as a whole, coming from all regions of Portugal including Madeira and Azores islands. Such as all the other Portuguese universities, the number of international students has been growing at UBI. The different backgrounds, where these students are mainly coming from are the old Portuguese colonies, being Portuguese language speakers, such as Brazil (in south America), Angola, Cape Verde Islands, St Tomé and Prince (in Africa) or East Timor (in Asia); and the non-Portuguese speakers such as the ERASMUS students coming from the European countries, Turkey or more recently from places such as

Algeria, Iran or Syria [1]. Therefore, there was the need of rethinking the teaching methodologies in order to advance these students. In this sense the scholars responsible for the master degree in civil engineering are carrying out several strategies in order to improve the adaptation and the performance of these students, regarding the high educational Portuguese system. The Master Degree in Civil Engineering (MIEC) at UBI is organized according to Bologna process. It was boosted on the behalf of the Department of Civil Engineering and Architecture, in order to promote a high specialized graduation in the domain of the civil engineer's professional activity. It comprises a set of ten academic semesters along five years of graduation course, allowing the students to tailor their course of study on their own interests and to highlight the theoretical and practical aspects of civil engineering. This is made possible through the selection of optional units in the 1st semester of year 5, as well as through the choice of dissertation topic in the 2nd semester of the same year.

2.1.2 Mathematics issues

Within the framework of the mater degree in civil engineering, the teaching methods used in the mathematic issues are changing over the time, undergoing through consecutive transformations, which are believed to be useful for the improving of the results among the students. Considering the continuous development of the educational reforms, the main idea among the scholars from the Department of Mathematics is to prepare strategies together focused on the teaching methodologies, which are coming from their own experiences, from years and years as teacher at the educational university level. In common sense, the teaching method refers to dynamic details of the teaching manner, such as scientific explanation, elaboration or presentation. In this sense, there are authors [2] suggesting that the teaching method is the application of various manners of dealing with the *praxis* of teaching and learning. Thus, a question that can be asked to the students is the following: "*What kind of Mathematics class do you prefer?*" [3]. One possible answer to the previous question is to have lessons where the teacher is the only responsible to guide the discussion, explaining the topics to the students. In fact, the majority of students like their teachers to guide them during the discussions. However, they also agree that they should discuss the research questions previously to the teachers' explanations. According to the same author, when students are asked about if they "*often discuss with their classmates in class?*", the majority of them say that sometimes there is a discussion in the mathematics class. Consequently, the experience at UBI shows that they will become increasingly interested in mathematics issues, once they are required to search for the ways of learning, by themselves, independently.

Another sensitive aspect for the scholars is the need of identifying the topics where the students are having difficulties in terms of understanding [4]. Therefore, they have to identify, whether the students most difficulties with the concepts or procedures involved in each topic, and the resources they should use to overcome these difficulties. The mathematical concepts and procedures where students found most difficulties were not uniform across all topics. The students' rate for conceptual understanding is higher than their abilities to research questions. Among scholars there is a general agreement that students used to have problems at the transitioning process from the mathematics achievements required at secondary level of education to the higher education system. So, there is a significant number of students that don't have the required mathematical skills in the first year of their studies at the university. This happens at the MIEC. Guedet [5] has identified the differences in teaching methods between secondary level and higher education system as being partly responsible for students' difficulties. This author suggests that the use of appropriate online resources may be helpful in order to develop students' autonomy during this transition. As a result of the widening access to the higher education level [6, 7, 8], the range of mathematical abilities demonstrated by incoming students at the first-year has increased. This fact, added with the difficulties associated with the transition to mathematics requirements at the higher education system, has resulted in many students being inadequately prepared, having a lack of understanding regarding some basic mathematical concepts. In fact, in many cases students are very confident about their mathematical skills and preparation, despite teachers check their poor skills. Consequently, the strategies to adapt and to adjust the teaching methodologies to the students' skills in maths are pivotal priorities [9]. Nevertheless, they both agree that the maths skills coming from the secondary school are not always enough regarding the university requirements. Tariq [10] argues that students are better prepared at mathematical calculations than at word problems, suggesting their lack in terms of conceptual understanding of mathematics. There are a number of common areas which were identified as problematic across the courses including basic knowledges of algebra, arithmetic, logs, statistics, calculus and functions. The students' conceptual understanding and procedural skills were assessed because many engineering students are often attempted to solve conceptual problems using procedural techniques. They were able to solve problems by following presented methods but *they often didn't understand the underlying mathematics*. Engelbrecht [11] says that the students with an adequate conceptual knowledge in maths can also perform the procedures. For example, Mahir [12] found that most students did not possess a conceptual understanding of integration and were using routine manipulations and procedures rather than a conceptual approach in order to solving integration problems. One aim of the previously referred author study was to determine if students perceived that they had a different ability to 'Understand' (concept) or 'Do' (procedure) a particular mathematical question type. There are also

studies which have shown that students' self-rating of their abilities can be an effective measure of the learning outcomes that they have achieved [13, 14].

Regarding MIEC at UBI, the scholars have observed that students reveal difficulties to take the first step in facing a maths problem and that they will get the correct result more often when they receive a model of how to work out with the solution. There is also the fact that the students have a lack of ability in terms of visualization. The idea that students' understanding is enhanced by the visualization has been discussed in Engelbrecht [11] arguing that conceptual approaches to solve tasks require translation between verbal and visual representations. Mathematical confidence and prior mathematical attainment have been shown as aspects that have influence at the students' ability in first-year of mathematics at the university [8, 15, 16]. Students do better in maths when they have already encountered the mathematical contents before [17]. Thus, they need to overcome the "*fear of new*" when transitioning to the higher level of education [18].

The literature reveals a set of several initiatives, implemented to address the gap in between students' mathematical abilities, at the entering point to the high education system and the skills that they are required to have in order to succeed in the first year of the master degree in civil engineering. In order to improve the maths skills of the first-year students, there is at the Department of Maths of UBI, the called "Year Zero", a unit that includes topics coming from the last year of the secondary school. It comprises as well a project based on the development of technology-enhanced formative assessment resources, to support teaching and learning methodologies [19]. In addition to these strategies, scholars have introduced a diagnosis test in order to identify students' particular gaps in maths [20], from the very first moment of their academic paths. Finally, scholars are incorporating particular materials in their units' syllabi, precisely planned to help students to develop a proper understanding, such as interactive mathematical tasks designed to improve mathematical knowledge. In this process, students are being informed about their insufficiencies of understanding through a set of formative assessments that give them an immediate feedback, such as the use of audience response systems [19]. The previously referred strategies are ongoing, throughout a framework that offers three introductory courses of studies for students attending to management, economics, life sciences and engineering (including civil engineering), or computer science courses. Each one of these courses are taught in one academic semester time, with two classes of 110 minutes each per week, along to 15 weeks. It shows that there are slight differences among the referred courses, however they all share some features such as the use of ICT, to improve teaching and learning achievements.

Authors [21] have been spilled a lot of ink studying the performance of students at the maths issues. Given that in some courses of UBI there is a high number of students attending to these subjects, there is the *praxis* of informing and warning them about their potential difficulties, providing them in the first day of class, a review sheet or note book of maths requirements. In doing this, scholars are allowing students to know from the first day, how to have a better performance. In addition, teachers schedule extra hours per week to answer to students' questions and to provide individual help. In parallel, students are encouraged to participate in the classroom by asking and answering questions, in order to keep their engagement and interest, being focused. Math's units are currently using both types of materials, online and standard paper assignments. The online assignments offer an excellent assessment and tutorial tool, used to help students to achieving a better management of their study time. In this strategy, the maths questions are created considering that students know similar examples, which were discussed during the classes, being part of the note books or textbooks. These online assignments are used not only as assessment, but also as tutorial tools. They are created, posted, submitted, graded, and recorded at the web platform of UBI, being available to students. The maths problems are parametrically generated, i.e. each student randomly gets one question from a pool of a few hundred different variations of the same problem. This methodology considers a large number of attempts in terms of resolution, to allow students to use the maths questions as a learning tool rather than as a quiz with an immediate feedback. Most of the questions have been built-in hints that would pop up in case of wrong answer, giving to students the chance to learn from their own mistakes. In the end, students' answers are graded on every question in these online assignments. The results show that because of the parametrically generated problems, students are starting to work together to achieve a proper understanding, rather than simply copying the solutions from the textbook.

2.1.3 Transportation engineering and GIS

The MIEC at UBI comprises two transportation engineering units and one GIS unit: Roads (for all students), Complements of Roads and Geographic Information System (for students in Geotechnical and Environment specialization and not for the branch of Structures and Construction). Each one of these units, lasts one academic semester, involving 60 hours of contact with the teacher (30 theoretical hours and 30 theoretical-practical hours), 98 hours of autonomous work and 10 hours for evaluation (comprising 168 hours as a whole). The approval on these units gives the students 6 ECTS (European credit transfer system) credits each.

The students are introduced to aspects related to transportation engineering in the 2nd semester of year 3, within Roads course unit. In this course, they are provided with theoretical and practical knowledges and skills, required to perform a proper analysis and selection of road location, analysis of road traffic conditions and road

project design (horizontal, vertical and cross-section profile). This unit has continuity in the 1st semester of the 5th year for students attending the unit of Complements of Roads, which is optional.

The second referred unit aims to prepare students for the design and processing aspects of the construction and maintenance of roads (earthworks, pavement mechanics, paving technology and principles of management of road and airport pavement maintenance). Key concepts of roads safety are also introduced. Additionally, the GIS unit provides theoretical and practical skills about spatial representation and geo-referenced information analysis. This knowledge allows a technical decision-making, promoting and optimizing territorial management, as well as different infrastructure systems (such as transport), and assessing possible evolution scenarios to improve citizen's quality of life. The pedagogical contents of these units are linked and consecutive, meaning that in the end of the master´s programme, students should be able to analyse traffic conditions, to design new road infrastructures and to define the main structure of GIS based on pavement management systems. In parallel, there are other MIEC units, which are also contributing to the success of the learning process at the transportation engineering domain. Among these, there are pivotal units such as the following: topography, technical drawing, soil mechanics, urban and regional planning, and transport and sustainable urban mobility.

The previously mentioned three units adopt a methodology based on the student-centred approach of teaching ([22] apud [23]), which refers to a teacher oriented method, with an autonomous, independent and critical thinking learning. In this sense, a Project Based Learning (PBL) is structured and planned by the transportation engineering scholars, where the students are expected to raise, implement and evaluate road projects with applications in the real world. This method uses problems as a starting point for the acquisition and integration of new knowledges [24]. In addition to this, considering the more advanced units (in the 5th year), part of the theoretical contents, is addressed through a diverse set of bibliographic references analysis, performed by student (individually and in groups) under the teacher supervision. The research main findings are presented by students at the classroom and discussed with the teachers. One of the strongest results of this experience that can be observed is the increasing of students' autonomy and their critical scientific thinking. In addition, this methodology facilitates the understanding about transversal skills, such writing technical reports, searching information, teamwork or results presentation.

Table nr. 1. Evolution of the number of international students attending to Roads (R) and Complements of Roads (CR) units, in Civil Engineering at UBI (2013-2018)

Academic Year		2017-2018	2016-2017	2015-2016	2014-2015	2013-2014
Nr. of International Students	**R**	4	1	0	4	2
	CR	5	2	2	3	4
Mobility framework		Erasmus Other programs	Erasmus	Erasmus Other programs	Erasmus Other programs	Erasmus Other programs
Origins		Spain, Brazil, Syria	 Spain, Poland	Poland, Syria	Spain, Cape Verde Islands, Turkey	Brazil, Czech Republic, Spain

With regard to international students, they are integrated at the same classes as the Portuguese students. The number and origins of international students have varied over the years, such as can be seen (Table nr. 1) for Roads and Complements of Roads units. ICT tools are available online, used in the learning process to consult, research and communicate information (such as UBI moodle web platform, B-on - Online knowledge library, scientific data bases, web sites, or university library web site), and students are encouraged to search bibliographic references and to present their findings at the class in English. Other activities as student site visits and participation in competitions, awards for students, national and international congress are also encouraged. A special attention is put to the following aspects: the low English proficiency, the lack of educational skills in terms of dealing with scientific documents, and the different approaches about citations that can lead to unintentional plagiarism [25]. The latter is addressed at MIEC from an educational perspective (rather than punitive) thought an extracurricular lecture and workshop. The lecture is dedicated to how to cite, paraphrase and reference, while the workshop instructs in the use of free bibliographic references management tools, available online. As final remark, it can be said from this experience that the integration in small classes (10 to 15 students), providing support materials and visual teaching tools, classes taught in English, and using ICT have shown favourable results for both host and international students in a friendly learning environment.

2.2 One case in Romania

At the Faculty of Constructions, Cadastre and Architecture of the UO in Romania, the Infographics issues (as a specialty) represent a set of abilities that enable an individual to effectively find, interpret, evaluate, use, and create images or visual media. Frequently, Infographics is associated with creating "visual literacy" or common visual language. The notions taught at the Infographics classroom for civil engineers, include conventional symbols/signs that students should assimilate, in order to correctly depict buildings. The process by which the students prepare the drawings is called "technical drawing" and is defined as a graphical language with the help of which objects and structures are represented [26]. Technical drawings for civil engineering can include graphical representations of many types of buildings structures. For example, civil structures, industrial structures, bridges, tunnels, hydro technical constructions among many others. When teaching Infographics at UO, the scholars are required to respect a common core of SR EN standards (European Standards) as well as international standards (ISO). The same applies for its partner related to the UBI in Portugal. Both countries are members of the European Union and, consequently, their high education institutions are required to respect the same sets of norms and regulations. Finally, the methods by which students of civil engineering assimilate the conventional signs and symbols (for technical drawing) in both institutions are the same. They are starting with classical methods (paper, pencil and square tool) and continuing with AutoCAD learning. When teaching AutoCAD drawing, scholars are encouraged to use the program's commands in English. Because the program uses English icons and abbreviations, it can be understood even by non-English speakers.

3 Conclusions

As this research aimed to show, there are similar aspects in between the experiences of UBI and UO, such as the fact that the computer-assisted learning, using ICT has penetrated equally at both universities as a crucial feature of the teaching methodologies. In terms of maths issues at UBI, the students are very keen on using ICT, because they belong to the called technological generation. However, the experience has shown that it should happen at the same time of the use of traditional teaching methodologies. The most important change to do is to bring students to think about maths resolution strategies and discuss them during the classes. The ICT should be used after the explanation/understanding of the maths contents. The student's main goal is to achieve resolution routines, given that the software generates the same kind of exercise, in a random way. In both universities, the scholars are stimulating students to use their visual memory and to ask questions. The Civil Engineering Department at the UO hosts mostly Romanian students but also few Erasmus students (especially from Turkey). Stimulating the auditory and visual memory of students enables them to more easily acquire the necessary know how for the graphical representation of structures. At UBI the situation is similar, however there is a wider range of backgrounds and students' origins. As final remark, it can be said from the Civil Engineering Department experience at UBI that the strategy includes a student-driven and teacher-facilitated approach to learning (Project Based Learning), small classes, support material and classes taught in English-language, visual teaching tools and ICT use. This results for both host and international students in a friendly learning environment. At UBI, in transportation engineering and GIS subjects, an oriented but autonomous, independent and critical thinking learning approach is applied as teaching methodology. Finally, in terms of language skills, Romanian students have generally a good grasp of English. The situation is similar at UBI, but some students, particularly the Portuguese-speakers coming from African countries or Brazil, are needing to improve their skills in English as a special requirement not only regarding particular units but also for a better performance along their academic experiences in general.

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