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In memoriam  
**Prof. Iacint MANOLIU**  
Technical University of Civil Engineering, Bucharest, Romania  
Secretary General of the EUCEET Association (2008-2018)

Prof. Iacint Manoliu was Emeritus Professor of Geotechnical Engineering at the Technical University of Civil Engineering [TUCEB] in Bucharest.

At the first General Assembly of the EUCEET Association (Warsaw, 24 October 2008), he was designated as General Secretary.

He died on June 12th, 2018.

The EUCEET Association and the Civil Engineering Educational Community will be always indebted to him.
PREFACE

World economy is changing rapidly. On the one hand, issues like health and safety, quality, resilience, sustainability, social justice and environment are increasing their weight for decision makers compared with traditional pecuniary considerations.

On the other hand, the advent of cheap powerful computers, smart phones and robots is changing society drastically and also the economic interactions.

The general agreed on professional requirements for future generations are the ability to interact with computers and robots, and the ability to do what these are not able to do (the so called soft skills as ethics or creativity).

Civil Engineer practice is also impacted by this change.

In the frame of Bologna Treaty, most universities are striving to adapt their educational contents as well as their training methods. Is Civil Engineering Education able to keep pace?

In this book, this question is answered addressing the following topics:

1. **New contents and capabilities**: Resilience, sustainability, BIM (Building Information Modelling), soft skills, automation, artificial intelligence, smart cities, UAV (Unmanned Aerial Vehicles).

2. **Methodology**: Student centered teaching methods, online learning, flip learning, active learning, PBL (Project Based Learning)

3. **The impact of educational policies**: quality management, quality control and accreditation agencies, links between teaching, research and practice

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LECTURES
Introduction

University training is a transformative life experience that can lead to personal, intellectual, cultural, professional and civic excellence, and moral education is an essential part of this process.

Higher education is at the apex of the educational system and therefore focuses on providing students with the highest level of qualification in various areas of knowledge. However, education at this level should also allow students to reach the highest levels of human development in its broadest and deepest sense.

The university (derived from the Latin universitas) is a community of teachers and students who seek truth, goodness and beauty (Gardner 2012). Thus, moral education reflects and puts into practice the same virtues that orient the task entrusted to this community.

1. Universities today

Society expects universities to play a central role in scientific and technical progress as well as being the main driver of critical analysis and social, cultural and political progress. This conception of the dual role of universities shows that the institution is still marked by the defining tension that has always sustained it: the delicate balance between training professionals and producing graduates with intellectual spirit and curiosity.

Society, political authorities and the civil society of which universities and their students form part have the opportunity to create universities that deliver quality results in these two key dimensions. However, when universities focus on developing professional skills they often neglect their role as a key intellectual, social, cultural and political actor in the complex, uncertain society of the present day.

Universities need to commit to building an enlightened society that is able to progress because it is composed of individuals trained in the practice of the capabilities that will contribute to improving it — a ‘wise and virtuous’ society as Pérez Díaz (2010) puts it. But this reference to the idea of a good society must be more than just a statement of intent: we need to be able to translate it into a plan of action within universities.
To help create a good society, universities must cultivate intelligence, create a climate of active trust among members of the university community (students, faculty and other staff), and promote a series of virtues, including the ability to cooperate, compete fairly, persevere in tackling tasks over the medium and long term, analyse issues from an open perspective and with an eye to the future, and act with equanimity. These are skills that will allow universities to move forward as democratic communities, whatever system of representative democracy they adopt, and educate citizens who are interested in the truth, in knowing more, in people, and in tackling problems; and who are prepared to act and pursue solutions that are just and equitable.

Universities should be designed for students to experience, spaces where they can explore and ask questions in an atmosphere of freedom, cooperate and share a sense of belonging (key aspects of the education of all good professionals and citizens), and where they can learn and develop an interest in transforming our world into a better one.

Universities and teachers must therefore maintain a close link between research and teaching and ensure that they address socially controversial issues. By taking such an approach, teachers can genuinely act as mentors in the learning process of students. The dual activity of faculty (i.e., research and teaching) allows students to properly integrate, in the context of their learning activity, the practice of the virtue of enquiry and a concern with knowing more and asking better questions with the knowledge and competences specific to each discipline (Martinez & Viader, 2008). The close link between teaching and faculty interest in socially controversial issues helps orient student learning according to principles relevant to science, technology and innovation that take account of society and its development in a way that reflects social and ethical considerations in addition to economic and technological ones.

The development of intellectual capabilities, an essential aspect of every university educational process, must be accompanied by the practice of ethical competences that allow university students to strengthen their self-confidence, take risks and make decisions, engage in reasonable discussions and formulate questions, and help improve the world in which they live, both locally and globally.

However, when universities focus on quality, understood in a narrow sense that equates it exclusively with the excellence they strive for, these objectives become more difficult to achieve. Academic and social discussion on universities and their role, particularly concerning the scope and meaning of university education today, takes place in the context of an information- and technology-driven society that needs to achieve adequate levels of sustainability. This pursuit of
In order to improve quality and pursue a quality-oriented process of renewal in universities, it is essential to integrate objectives related to excellence in teaching, student learning, institutional management, research and knowledge transfer with goals that focus on the social responsibility of universities. And the way the latter are pursued must be concrete rather than abstract. This means, for example, focusing on the institution itself and contexts and territories close to its sphere of activity. The development of students’ ethical competencies and sense of social responsibility must also be an integral part of this process.

2. Ethical competences at university

To promote Ethical Competences seeks to add a new dimension to the learning process at universities, to make the time students spend in higher education a real-life experience for them, one that fundamentally transforms them — a cultural, scientific and personal event that impacts the development of their character.

As a result of professional, social and cultural factors, universities are under increasing pressure to tackle the task of developing what one might call personal excellence in students rather than focusing exclusively on professional skills.

Following the implementation of the Bologna process, and in the context of declarations on the European Higher Education Area, our universities are addressing this issue in various ways, most notably by focusing on 1) training for social commitment and responsibility, 2) moral education, 3) ethics training in different areas of knowledge and professional practice, and 4) development of ethical and transversal competences.

In recent years we have witnessed the emergence of a new paradigm of university education, both at the European level and within Spain. Higher education is no longer aimed simply at imparting theoretical knowledge and developing technical and professional skills: students are now expected to demonstrate competence (European Council 1996, 2007; European Commission, 2005, 2006). Moreover, as some studies of international significance have shown, there are many types of competence: cognitive, functional and technical; ethical, moral and civic; as well as so-called personal competences (DeSeCo 2002; González & Wagenaar, 2003). The latter have become a matter of academic, as well as social, professional, political and cultural concern (European Commission, 1995).
Broadly speaking, the reasons for this new emphasis fall into two categories. First, European universities have set themselves the goal of carrying out a reform of considerable magnitude, driven mainly by the expectation that they should be one of the key players in the process of creating a new economic, professional, social and cultural order. A range of factors, including the social circumstances in which we now live (Giddens, 1991; Bauman, 2005; Duke, 2008), the rise of social individualism, the weakened state of Western democracies, and postmodern nihilism provide grounds for concluding that universities — acting in conjunction with other political and socio-cultural institutions — should be actively involved in the personal education of students. Second, by their very nature universities have a role to play in this process. This is evident in various ways from the history of the university as an institution (Rüegg, 1992, 1996). It is a role assigned to universities in classic reference texts on the idea and mission of the university (Mercier, 1914; Ortega & Gasset, 1930; Newman, 1986; Wyatt, 1990) and in more recent works (Pelikan, 1992; Kerr, 2001; Scott, 2006; Laredo, 2007).

The model of Personality Construction (Buxarrais, Martínez, Puig & Trilla, 1997) is thus a comprehensive and diverse approach in terms of the objectives it seeks to achieve, which include ethical and moral goals as well as aims related to the practice of democratic citizenship, leadership, virtuous conduct and social responsibility. Within the framework of this approach, education of the person can be seen as integral to university education insofar as the latter is a transformative life experience that can lead to personal, intellectual, cultural, professional and civic excellence.

Educating the person at university is an essential and integral part of university education; there is no way to isolate the personal dimension from the broader process. Yet often the education of the person and technical or professional training are treated as separate issues and in a disconnected way. This has a detrimental effect on university education and has drawn criticism from academics and intellectuals, some of whom we cite in this article.

The years students spend at university are important for their professional training, but also, both developmentally and socially, for the shaping of their character. Students should undergo a process that allows them to round off the personality they developed before entering university and emerge with a character that enables them to build an autonomous, individual life project as professionals and citizens. This means developing a character and a set of virtues that make students and graduates people who recognise a series of values — veracity and rigor, freedom, justice and equity — and who are equipped to take a critical view of the world in which they live and contribute to improving it based on the values of a participative, active, collaborative form of democracy.
As citizens, individuals are subject to rights, duties and feelings. Universities should train and equip them to demand their rights, not to accept the silence of those who have a duty to respond, to assume their own duties, to have moral feelings, to actively participate in the community to which they belong, to recognise the other as a valid interlocutor in the search for just solutions, and to build their lives by pursuing happiness in their community. The aim of education for citizenship is to help students develop a sense that they are part of their community and give them the tools they need to prioritise their actions based on principles of justice.

Universities should therefore provide students with opportunities to recognise the value of democratic lifestyles (in family, social, employment and community contexts) and adopt a model that focuses on citizenship building and education. This model should be underpinned by principles of justice, recognition of the other and the value of caring, recognition of memory as a good and valid source to draw on in building our identity, and the defence and further pursuit of inclusive approaches to intercultural coexistence and the construction of citizenship.

To achieve these objectives, university declarations on social responsibility should include the aim of developing graduates who are able to collectively build a sense of belonging and of active, inclusive citizenship. To this end, we advocate an approach that integrates the construction of models of life based on freedom, justice and dignity with learning and coexistence practices that allow students to recognise the value of memory, of empathy and compassion (sharing the feelings of others and assuming a duty of care towards them), and of ethical responsibility as the building blocks for coexistence and factors that facilitate social transformation and citizenship building. This means a model oriented towards active citizenship and a democratic society based on collaboration, mutual support, compassion and participation.

The training that students receive at university should incorporate a set of values and be firmly rooted in the tradition that characterizes the university. However, this objective cannot be achieved if it is not accompanied by another complementary goal: that of the critical appraisal of this tradition with the rigor that the university tradition itself demands. For this reason, our perspective integrates psychological and pedagogical developments and research that are not only drawn from the perspective of character formation, but which also provide knowledge about how to promote the development of moral reasoning, critical understanding, self-knowledge, skills of dialogue, self-regulation of behavior and argumentative and communicative competence.

Training in true autonomy should not be confused with the cultivation of individualism, as occurs in some approaches within radical
liberalism. Autonomy is built on dependence, within a tradition – though within a tradition that is not limited to simply recreating it but within one that opens it up to constant revision and consolidation. This is the goal of university tradition in societies founded on diversity today. For this reason, in the methodological proposals on how to address the teaching of social responsibility to students, we integrate strategies drawn from different perspectives, but which form part of a paradigm aimed at shaping the character of future graduates in terms of their social responsibility. And this character integrates the recognition of the values of the university tradition as well as those of discussion, intellectual rigor and openness to criticism.

3. Pathways for Ethical Competence Formation

University education should offer an integrated, comprehensive educational experience that provides students with scientific, technological, humanistic and artistic training (in the various disciplines in which they are trained) that consciously, systematically and institutionally incorporates sufficient spaces for formal and informal ethical learning. Such spaces will ensure that students are effectively trained to practise an active form of citizenship aimed at deeper engagement with democratic values.

We believe it is possible to make more progress towards simultaneously achieving the two key objectives of university education if the learning and teaching contexts related to each goal are not separated. It is more effective and efficient to integrate professional training and citizenship education in the same activities than to pursue these two aims in isolation from one another. In other words, it is not necessarily a matter of adding subjects that focus on ethical issues and citizenship to the curricula of degree programmes, but rather of integrating the ethical and citizenship dimension in the approach faculty take to teaching and learning processes in practice, and in the forms of coexistence and participation encouraged by the university community.

For some time now, most universities have recognised the importance of ensuring that students receive ethics training, but they often equate this with training in the professional ethics of each professional discipline. In our view, in addition to covering professional ethics — certainly an essential part of the training of all professionals — it is important to focus on the social conditions and practices associated with the spaces for learning, coexistence and participation promoted by universities; in other words, on what happens in classrooms, in community life, and in spaces for discussion and participation. Universities need to ensure that such spaces and practices reflect the values so easily proclaimed in official documents and strategic plans.
The very nature of the university (a group of learners and teachers who share a common project, a particular identity) should lead to a change in those involved, to their transformation, because university life is full of moments and experiences that transform those who undergo them, that shape their character. These are moments when ethical learning takes place, moments that allow for the transmission and assimilation of ethical values, values which when practised help make life more human (Cortina, 1996) – worthy values for life.

University students are likely to understand the significance of values like justice, solidarity, respect and engagement, but it is less certain that they will have made them an integral part of their behaviour and the way they relate to others. It is therefore necessary to ensure that the educational process includes moments and spaces that provide them with opportunities to build their moral character and develop the capabilities that will enable them to act responsibly and autonomously in all contexts. One of the roles of higher education is to help students develop into thoughtful citizens who are capable of critical thinking and able to think for themselves (Naval, 2008).

After completing their studies, university students will be prepared to take decisions in occupational contexts. They will therefore need to have developed a series of personal skills that allow them to make their professional work an ethical endeavour. In other words, they will need to have developed a moral character that allows them to make sound ethical decisions. In the following sections, we will set out the main approaches that we propose universities should pursue with respect to character education and chart the path we believe university students should follow to receive both excellent technical and professional training and a civic-ethics education that will allow them to become socially engaged citizens.

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APPLICATION OF BUILDING INFORMATION MODELLING METHODOLOGY IN A PROJECT BASED LEARNING SUBJECT

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Key words: Building Information Modelling, Civil Engineering, Project Based Learning, Teaching Innovation, Wastewater Treatment.

Abstract. Building Information Modelling (BIM) could be understood as a collaborative work methodology that documents a building, plant or infrastructure, making use of computer tools in order to generate a unique repository (digital model) that contains all the information useful for all participating stakeholders (owners, promoters, constructors, designers, suppliers, manufacturers, administration, etc.) throughout its entire life cycle. Therefore it consists in the collaborative transmission of information for the development and execution of a constructive project through the elaboration of a unique 3D digital model.

The use of BIM produces multiple advantages in the quality of the projects, in terms of communication, efficiency, savings of cost and time, reduction of risks and environmental impacts, etc. For these reasons, BIM is called to become the standard for the development of infrastructure projects in public administrations and in the private sector. Nonetheless, in the architecture, engineering and construction (AEC) industries there is still room for its wider implementation. The industrialization in the AEC industry is one of its main challenges to improve the construction processes, since the traditional systems still have a great weight. In Spain, the compulsory use of BIM in the design and construction phases of public projects of buildings and infrastructures is due to 2018 and 2019, respectively, while it is expected to be also mandatory for the maintenance or rehabilitation works in 2020. However, the use of BIM is not very widespread in the Spanish AEC industry, and it is considered essential the teaching of the BIM methodology in Schools and Faculties for its implementation in the industry in the short and medium term.

With the above background, the School of Civil Engineers of Ciudad Real (Universidad de Castilla-La Mancha, Spain), a pioneer in the Project Based Learning teaching methodology, has recently embarked in a Teaching Innovation Project whose main objective is the implementation of the BIM methodology in the Project Work subjects. In this work we present the BIM-aided design of a Wastewater Treatment Plant developed by the students of the subject “Project Work: River and Water Management” (4th year, Degree in Civil and Territorial Engineering).
1 INTRODUCTION

Building Information Modelling (BIM) methodology still has no single, widely-accepted definition. It has been defined as “the use of a shared digital representation of a built object (including buildings, bridges, roads, process plants, etc.) to facilitate design, construction and operation processes to form a reliable basis for decisions” [1]. Another possible definition of BIM would be “a modeling technology and associated set of processes to produce, communicate, and analyze building models” [2]. Therefore, BIM could be understood as a collaborative work methodology that documents a building, plant or infrastructure, making use of computer tools in order to generate a unique repository (digital model) that contains all the information useful for all participating stakeholders (owners, promoters, constructors, designers, suppliers, manufacturers, administration, etc.) throughout its entire life cycle.

The digital representation of both the physical and functional characteristics of a project allows users to transfer design data and specifications between different software applications and between members of a multidisciplinary work team. Since information is stored in a BIM database, whatever is necessary throughout the project life cycle - planning, design, construction, use, maintenance and deconstruction - can be properly planned and managed [3].

The origin of BIM can be found in the computer-aided design research from decades ago, and it has been used increasingly in several industries. Nonetheless, in the architecture, engineering and construction (AEC) industries there is still room for its wider implementation. The industrialization in the AEC industry is one of its main challenges to improve the construction processes, since the traditional systems still have a great weight. However, the large initial investment that it requires (e.g., training, software and resources) hinders its adoption in most construction companies.

BIM is one of the most promising developments in these industries, as it could facilitate a more integrated design and construction process that would result in better quality buildings or infrastructures at lower cost and reduced project duration [2]. This would in turn lead to a decrease in work accidents and a lower environmental impact. The concept of BIM was first introduced in the AEC industry in terms of increasing efficiency, reducing costs and serving as support for the different stages of execution of the work, although its extension to all levels of civil engineering is currently in process.

Some advantages of using BIM would be: i) it improves the quality of the projects, reducing the risks and saving costs and time in its elaboration; ii) it improves the final result of the work, as well as the estimation and fulfillment of construction deadlines and costs; iii) it facilitates real-time interoperability among all participating stakeholders throughout the construction life cycle; and iv) it can be applied to all types of projects, regardless of their size or complexity.

BIM is called to become the standard for the development of infrastructure projects in public administrations and in the private sector. The European Union has created in 2016 the EUBIM Task Group to promote the use of BIM in the public sector, because of its advantages for the public sector: “from a public stakeholder perspective, BIM can provide significant efficiency benefits to public works, to public value for money and be a driver for growth and competitiveness” [4].

In Spain, the compulsory use of BIM in the design and construction phases of public projects of buildings and infrastructures is due to 2018 and 2019, respectively, while it is expected to be also mandatory for the maintenance or rehabilitation works in 2020. However, the use of BIM
in Spanish construction companies is still limited: it is estimated that while 55% of the construction companies have implemented a BIM project, only 15% have implemented it in all their works [5]. Although the use of BIM is not very widespread in the Spanish AEC industry, since 2015 there is a commission whose main mission is the implementation of BIM in Spain, bringing together all the stakeholders involved in the industry [6]. One of its objectives is to promote the teaching of the BIM methodology in Schools and Faculties, which is considered essential for the implementation of this methodology in the industry.

Some Spanish Architecture and Building Engineering Schools are beginning to include the BIM methodology in their plans, but the implementation is much smaller in Schools of Civil Engineering. The main exception is the Universidad Europea de Madrid, which incorporates this methodology in various undergraduate subjects and has a postgraduate specialization in BIM [7]. Worldwide, the BIM methodology is being progressively incorporated in university teaching, allowing teachers to efficiently develop more realistic educational examples [8].

The implementation of the BIM methodology in university teaching will not only facilitate the incorporation of competent professionals that allow a greater development to the entire AEC industry, but will also provide new skills for students to face new challenges with greater efficiency [9]. Some studies [10] advocate the integration of the BIM methodology among the traditional disciplines, cooperating among them without isolating themselves, and collaborating with companies in real projects in the last years of the university studies.

The purpose of this work is to present the implementation of the BIM methodology in the teaching of a Project Work subject, related with Water Management, in the School of Civil Engineers of Ciudad Real (Universidad de Castilla-La Mancha, UCLM). Following the Project Based Learning (PBL) methodology, the students themselves had to carry out the BIM-aided design of a Wastewater Treatment Plant, as part of their group work of the subject (fourth year, Degree in Civil and Territorial Engineering).

2 MATERIALS AND METHODS

2.1 The UCLM’s School of Civil Engineering and the PBL

The UCLM’s School of Civil Engineering, which is located in Ciudad Real (Spain), was created in 1998, when only seven universities in Spain offered the 5-years degree (“Ingeniero de Caminos, Canales y Puertos”). From their beginnings, this School tried to implement a modern and high-quality training model with different teaching methodologies and specialization approaches than the existing schools [11], based on the following aspects: i) Adoption of PBL teaching method as a key differentiator element of the educational process; ii) Learning in small groups (about 50 students admitted per year), with emphasis on the development of communication and innovation skills; iii) Deepening in the territorial and environmental aspects of civil engineering; iv) Actions of internationalization and use of new technologies; and v) Promotion of study trips and visits to work sites as fundamental elements in the learning of civil engineering.

Nowadays, this School offers two degrees: a Bachelor’s Degree in Civil and Territorial Engineering (recognized in 2016 with the EUR-ACE® quality label) and a Master’s Degree in Civil Engineering, being the PBL methodology the key difference of this School. This methodology, where students solve real (civil engineering) problems, was firstly implemented at McMaster University Medical School in the early 1970s. Since students have to deal with
real projects, they are involved in the design, problem solving, decision-making or researching activities during the whole duration of the subject. Additionally, students also get transversal skills such as management, communication, critical thinking, teamwork, leadership, innovative and entrepreneurial ability [12-16].

2.2 The Teaching Innovation Project on BIM

In 2017, the UCLM’s School of Civil Engineering was granted by the Vice Chancellor of Teaching of the UCLM in the 10th Call for Teaching Innovation Projects (TIP) to develop the project “Application of the BIM Methodology to the subjects of Degree in Civil and Territorial Engineering”. The main objective of this TIP was the introduction of BIM as a transversal tool in the training of the students, mainly through the Project Work subjects, optimizing the results of the Projects carried out by the students and increasing their professional skills. In addition, it is intended to lay the foundations for a future specialization in BIM of the School.

The first step in the project was to train the teachers of the School in BIM methodology. After that, the methodology would be applied in two pilot subjects: one Project Work in the specialization track in Transport and Territory, and another in the specialization track in Hydrology. Finally, the methodology would be extended to the rest of the subjects of the degree where it is pertinent and beneficial.

2.3 The Project Work: River and Water Management

The Degree in Civil and Territorial Engineering of the UCLM’s School of Civil Engineering is developed over a span of 4 years; the first two are common and, from the third year, a specialization in Transport and Territory or in Hydrology must be chosen. All the students have to take 6 Project Works subjects (42 ECTS credits) during their studies: 3 common subjects during the second and third years (18 ECTS credits) and 3 specialization subjects during the third and fourth years (24 ECTS credits). This work presents the implementation of the BIM methodology in the Project Work subject “River and Water Management” (12 ECTS credits), which is in the fourth year of the Degree, in the specialization in Hydrology.

The main objective of this Project Work is the analysis, diagnosis and proposal of solutions for a real river basin. For this, teams of between 4 and 10 students are formed, which, in turn, are divided into groups of 2-4 members, which have a coordinator. The composition and coordinator of all the groups change in each of the 3 blocks in which the subject is structured. These 3 blocks, with a duration of 5 weeks each, are the following:
- Block 1: Analysis of the quality of water bodies and the risk of flooding.
- Block 2: Modelling of hydrological-hydraulic processes and pollutant flow.
- Block 3: Proposal and definition of structural and non-structural solutions to mitigate the problems detected.

The training activities include: i) Field work (Fig. 1); ii) Seminars and supervised work; iii) Resolution of practical cases; iv) Preparation of partial and final reports; and v) Exhibition and defence of their work.
3 RESULTS

The implementation of the BIM methodology in the Project Work “River and Water Management” has been carried out for the first time in the 2017/18 academic year, as a pilot experience. The river basin studied has been that of the Guadalhorce River, in Andalucía, South Spain (Fig. 2).

Figure 1: Students measuring flows and dimensions in a river channel during the fieldwork

Figure 2: Location of the Guadalhorce River Basin, study area in the Project Work “River and Water Management” during the 2017/18 academic year
The implementation of the BIM methodology has consisted in the development of a 3D model of a Wastewater Treatment Plant (WWTP) proposed by the students for the town of Cártama (Málaga, 25317 inhabitants) and its implementation in the study area. For this, the following steps have been followed:

- Development of the digital model of the study area using Autodesk Infraworks as BIM software.
- Collection and import of raster and vector layers from several public websites: Digital Terrain Model, orthophotos, hydrography, transport network, land uses, etc.
- Simulation of floods for different return periods ($T = 5, 100, 500$ years) to obtain the flood inundation area.
- Design of the 3D model of the WWTP based on the drawings prepared in 2D by the students and using 3D modeling software (e.g., Civil 3D, ScratchUp, Revit) (Fig. 3).
- Import of the 3D model of the WWTP to Infraworks.
- Creation and incorporation of auxiliary elements in Infraworks (urban furniture, vegetation, urbanization, etc.)

![Figure 3: Designed Wastewater Treatment Plant in 2D with AutoCad (left) and in 3D in Infraworks (right)](image)

4 CONCLUSIONS

The introduction of the BIM methodology in Spain, and in the Civil Engineering industry in particular, is slow, although it seems that it is unstoppable and that it will bring multiple advantages to the industry. Therefore, higher education in civil engineering should be an example and leader in the integration of disciplines. An immediate action would involve the incorporation of technicians in the medium term who have assimilated this methodology of work with the consequent improvement of the design process of the works.

Furthermore, the BIM methodology would be a very useful tool in teaching the subjects of Civil Engineering since it would allow or facilitate:

- The collaborative work of different groups of students in the design of the same project.
- The interaction between the working groups and with the professor/s of the subject.
- The optimization of the work of each student and each group.
- The achievement of a greater degree of definition of the Project, with better quality and more realism than in the current ones.
- A differentiating competence of the students in view of their subsequent job placement.
The present work has shown a way of introducing this methodology in a School of Civil Engineering, without reducing the contents to be taught but complementing them with new training tools. Although it has not been possible to deepen in the BIM tools, the result has been positive and hopeful for future courses.

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INTRODUCTION OF BIM IN A CIVIL ENGINEERING SCHOOL: CURRICULAR PROGRAM

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Abstract. The attention of Civil Engineering is currently oriented to the methodology Building Information Modelling (BIM), a new concept that is based on recent scientific advances concerning the ability of computer systems to store, manage and manipulate large amounts of information, and established as the big breakthrough in the construction industry. Being the school the main actor in the formation of new engineers, it has the mission to offer disciplines or training workshops to prepare students for the professional activity, giving the knowledge concerning the current most advanced computer technology. In the context of implementing BIM, the future engineer should acquire the ability to apply basic BIM tools in different specialties and recognize the advantages in developing collaborative projects provided by BIM platforms. The incorporation of different disciplines in a single model BIM, through a collaborative effort, requires, on the part of each expert, the knowledge of the benefits and mode of operating of the tools necessary for an effective development and monitoring of a BIM project. This process requires study, practice, research and dissemination. In Portugal, the involvement in terms of design offices and construction companies, have been growing and as so this interest of the Construction industry is an incentive that justifies the inclusion of BIM in the curriculum of the Master course of Civil Engineering. In order to add the topic BIM to the course offered by the DECivil students Civil Engineering, it was proposed the introduction of the "BIM Methodology" discipline. A correct insertion of this curricular unit, involving the different specialties was at the level of last year of formation, taking the form of a discipline.

1 INTRODUCTION

The Building Information Modelling (BIM) concept focuses on the development of engineering projects, on the basis of collaborative work involving a single digital model that archives in a organized way, the information coming from the different linked specialties [1]. The information, required in each design phase, is transposed from the central BIM model and handled in such a way, supporting the development of follow design stages. The processes of transfer, manipulation and generation of data, are carried out using basic BIM tools resources,
and require an effective team work coordination and information management [2].

The amount and variety of information produced during the life cycle of a project, makes its management, without the proper tools, a complex process [3]. In this sense, the recent technological developments, the increase in information processing by computers, the creation of networked information sharing and the development of parametric modeling, are the catalysts for the BIM. The incorporation of different syllabus in a single BIM model, through a collaborative effort, requires, on the part of each expert, the knowledge of the benefits of how to use and operate with the necessary tools to achieve an effective development and monitoring of a BIM project. This process requires study, practice, research and dissemination.

BIM implementation covers various sectors of the construction industry. The engineer should know what basic tools BIM are available in the market that can be used to support the development of his specialty. BIM methodology interferes with all aspects involved in the project in engineering: at the initial stage when generating the geometric form of the building (architecture); at different phases of structural analysis (structural solution design and detailed reinforced drawings production); at the budget estimation (material take-off of materials); at the construction planning stage (linking the Gantt map with milestone components of the model); or, later, controlling the building occupation (supporting the management and maintenance activity and the establishment of repair or rehabilitation projects).

In order to add the BIM new topic to the course offered to students, at the University of Lisbon, it was proposed the introduction of the "BIM Methodology" discipline. A correct insertion of this curricular unit, taking the form of a discipline and involving the different specialties, was at the level of last year of the Civil Engineering course.

2 CONTEXTUALIZATION

The proposed curricular program was established to encompass: the introduction to the topic and to the parametric modeling process, pointing out the benefits and limitations; the reference to the sectors in which the BIM has had greater visibility and success; the use of BIM, which base their potential and specificities; the development of each expertise in a BIM environment; overlapping components and conflicts analysis between disciplines; the verification of the correctness of data transferred between components of the project; the analysis of the consequences and benefits introduced in project planning; the establishment of methodologies of collaborative work required in the process of implementation.

The course aims to address the various areas involved in the development of a project. The BIM education at school is now a necessity towards society. It is up to the school to introduce the subject as a complement to the studies of the future civil engineer. It is also the mission of the school to be kept up to date in relation to the advanced technology resources that have immersed in the construction industry.

The interest shown by finalists’ students of the Master course has been growing in recent years. The proposed themes for master’s theses were sought by students of construction and structures fields. The most recently theses focus on several aspects: conflict analysis based in overlapping BIM model components (building); Maintenance of buildings supported in the BIM methodology (construction); Analysis of the BIM model in the structural perspective (structures); Application of BIM technology in structural design (structures). It turns out that
the student, in the final stage of his formation, is more aware of the subject involved and recognizes that this competence will be useful for them in the job market.

These aspects justify and reinforce the incorporation of the courses in the last school year. The academic discipline is elective and is offered to all branches of the Master curriculum. Besides the fields of building and structures, the sectors of architecture, management, and hydraulic systems may also be involved. The training of collaborative working teams, involving this diversity of domains is, naturally, enrichment for students, for the Department of Civil Engineering and for the school.

3 TEACHING METHODOLOGY

The BIM issue requires the enlightenment of concepts and its applicability and level of internalization to students. However, the practical component is that makes the student able to act in different contexts and phases of the project. So, the practical use of teaching basic BIM tools is essential in the course. The training provided should enable the student to: carry out modelling of different specialties, namely data transfer between phases, reuse and create new information; be critical in every step regarding the correction of data transferred and know how to perform in accordance; carry out the addition of components on the centralized BIM model, meet its organization and learn how to establish effective management of information; be able to extract the model documentation inherent to a project in the way usually required in the construction sector.

As an approach of training, and learn how the BIM involves various aspects of the project, namely, the initial architectural component, it was proposed the implementation of a complete project over a real case study. The student is prompted to initiate the contact with the BIM methodology with the generation of the architectural model, using the first parametric objects. This model serves as the basis for the development of the following components:

- Generation of structural models (analysis, design and detailed drawings);
- Definition of MEP models (service networks of water, sewerage, electrical and air conditioning installations) and the corresponding analysis of conflicts between specialties;
- Construction process planning (associating several model components to the steps of the Gantt map of, creating a 4D model);
- Extraction information from the model in order to obtain tables of quantities of components and material.

The student must, sequentially, perform the listed steps. In the last years, different stages of the model process were performed concerning architecture, structures, MEP and construction (Figure. 1). The practical component is carried out on the basis of the compilation of distinct phase of a BIM model including creating all the disciplines and the use of data that is transferred between stages. The building, serving as a work base, should presents a low volume case study, to enable its use to be completed explored in an educational context. The teacher, through the use of BIM tools, develops the project which will be followed by the student, noting the process displayed in data show projection.
Figure 1. Examples of didactic exercises [4] [5] [6] [7].

The student carries out, at the same time, the same exercises and after he is invited to develop its real case. The workshops and the individual exercise have been held in the computer lab, equipped with the updated software required in the course. As pedagogical methodology, each new item (architecture, structure, MEP) have been taught at two levels:

- The theme which will be trained in practical sessions is initially addressed by the teacher or by invited experts, on theoretical sessions. About each topic, given by the teacher, the new step must be contextualized, referring to procedures and how to use the BIM based software on the modelling work. The theoretical sessions presented by experts intends to demonstrate the methodology and level of implementation of each specific topic in real projects;
- In practical sessions it is taught the procedure of using BIM based tools showing modeling capabilities and information extraction process, within the context of the previous issue exposed on the theory lesson. In this process the student follows the teacher, in the model generation or in the execution of the procedure performed over the didactic model and visualized in the projection display. The first exercise is exposed by the teacher and the second case is distinct for each student to be developed in an individual way, in order to train and consolidate the new subject.

### 3.1 Programmatic content

The curricular program of the syllabus consists of different modules trying to address all topics that will be useful to the engineer in his future profession. The sequence of items stars from the generic concepts reaching a comprehensive use of all the information added to the centralizer BIM model (Figure 2), throughout the all course. The BIM model is composed of all disciplines and must contains all the information that later is needed to define drawings and maps of quantities or to support construction planning and building maintenance. Below are listed the considered items:

- **Introduction to BIM concept:** State-of-the-art, application, benefits and limitations; Parametric modeling process; Model detail levels and project phases; BIM implementation strategies in enterprises.
- **Interoperability capacity and standardization:** Information transfer formats; Collaborative platforms and systems managers of BIM projects; Limitations of BIM interoperability in design management.
- **Model of architecture:** BIM base tools frequently used; General aspects of BIM base software (interface, parametric objects and unit definition); Initial settings of the modelling process (orthogonal grids and levels of floors), Selection and edition of parametric objects (walls, windows, doors, floors, and roofs); Display views of the
model (drawing plants, elevations, horizontal and vertical sections, axonometric perspective); Getting information query (type of objects or materials proprieties).

- **Model of structures**: Re-use of information of the architectural model; Selection and edition of structural parametric objects (columns, slabs, foundations); Association of material and physical properties to objects; Transposition of geometric model to analytical structural model.

- **Structural analyses**: Transposition of structural model to a structural analysis software; Verification of the correctness of the transferred information; Structural analyses; definition of reinforcement details; Transfer of structural results information to the initial BIM model; Elaboration of reinforcement details drawings.

- **MEP model**: Networks and services equipment; MEP software—mechanical, electrical, and plumbing engineering; Modelling of water and sewerage networks; Air conditioning model generation; Analysis of conflicts between components.

- **Construction planning**: Establishing milestones in Gantt map; Generation of the 4D/BIM model; Use of BIM viewers;

- **Extraction of information from the model**: Maps of quantities of materials; Definition of technical drawings; Budgets estimation;

- **Coordination and management of information**: collaborative project (team and BIM work methodology); Analysis of advantages and limitations in BIM processes.

![Figure 2](image.png)

**Figure 2.** A real case developed in several modelling steps (architecture, structure, and MEP) [6].

### 3.2 Evaluation and expected result

The knowledge assessment is carried out on a final draft. This work should include:

- **Elaboration of BIM models** of architectural, structural and MEP;
- **Overlapping components** and corresponding analysis of conflict;
- **Structural analyses** including representation of detailed reinforcement drawings;
- **Planning the construction** process by defining the correspondent 4D model;
- **Getting maps of quantities take-off** and elaboration of budgets concerning several design stages.

For the preparation of individual BIM design real cases, a set of initial information is provided, concerning drawings and characteristics of the building components for a posterior comparison, between traditional way and BIM environment. The work can be developed in an individual way or in group:

- **In individual work** the volume of work under review should be reduced, as it is more complex than the didactic example, so the student can develop a complete project of
an autonomous mode, and thus he became able to be assessed for all taught valances;

- **Group work**, with a team of 3 to 4 students, must be developed over a case study of greater volume and in which each member can develop more depth, one of the components. The team should collaborate in order to present a complete BIM model.

The last procedure is the ideal teaching methodology BIM, because it makes students more likely to work later in the context of collaborative project, the genesis of BIM. The biggest drawback in this process is that each element does not develop in a balanced way their capabilities in relation to different specialties. However the collaboration is needed and, bearing, transmission of knowledge is somehow made between the members of the working team. Performing a complex job and obtaining success is of course challenging and a cause for satisfaction for the student, making him more confident in his ability with BIM projects in his future activity.

The final design should be complemented with a descriptive report of the main stages of its development, in order to carry out a comparative analysis with regard to traditional project design based on the usual interpretation from two-dimensional stroke created using drawing software.

As a result the student adds to his skills in Civil Engineering the subject BIM. Along the course he acquires knowledge of the applicability of BIM and its benefits in various areas of the project, as well as the working methodology inherent to BIM concept. The students are able to set important guidelines in the process of implementation of BIM in an engineering office; he is able to indicate which are the changes and the adjustments that must be made on the team and on usual the work methodology, in order to establish collaborative platforms. The knowledge and training gained enables him to perform with success the projects as may be requested by means of an innovative methodology, for which only a few engineers are currently trained. In Portugal and in the current early stage of the BIM implementation, the student, as a future professional, constitutes an important difference in a world of scarcity of job opportunities, motivated by the current reduced activity of the construction.

### 4 PREVIOUS EXPERIENCE IN INTRODUCTION BIM AT SCHOOL

The Computer-Aided Design syllabus offered to 1st year Civil Engineering students was recently improved including this advanced technology, in order to adjust its issue to the current social and scientific requirements. From 2014-2015 curricular year, the program of the discipline incorporates the BIM component, for a trial period of 1 week (4,5h), and it was extend for two weeks the following year. It is intended to incorporate the subject incrementing in each new academic year a greater volume of BIM topics.

However, BIM cannot eliminate completely the practice in computer graphic systems, like AutoCAD, because this is still a frequent tool used in design offices and as so the students’ training must continue to contain this strand. As this discipline is taught at the level of the first academic year of the Master course, just the modeling BIM perspective, of the architectural [8] and structural components [9], is taught in tutorial lessons and only this part can well be understood by the young students (Figure 3). As mentioned, the complexity of BIM methodology and its whole understanding is only perceptible when developing a more comprehensive project.
4.1 MSc thesis

In the last years, the search for the BIM theme, as a Master thesis topic, has been great. The thesis’ supervision has been one of the teachers’ activity most involved in the BIM subject. All the completed thesis reports were inserted in the digital platform of IST allowing its consult [10]. Below are listed some of the most recent research works (Figure 4):

- J. D. Oliveira, “BIM model management within the structural design”, 2016 [5].
- C. Mota, “4D/BIM model construction planning based on BIM technology”, 2016 [12].
- D. S. Silva, “Construction management supported in BIM: central energy”, 2015 [7].
- D. G. Simões, “Maintenance of buildings supported on a model BIM”, 2013 [4].
- P. M. Neves “BIM technology applied in architectural design”, 2012.
4.2 Short courses

Additionally, in the school some workshops, short courses and seminars have been organized within the FUNDEC DECivil activity. The contribution of invited experts reporting real experiences of the BIM implementation in their respective sectors of activity are an asset in these courses. The main topic of the most recent short course December 2017, “BIM model generation and its use in construction”, was the generation of nD/BIM models. The dissemination of how information of the 3D model can be manipulated in such a way allowing the generation of: 4D model (with the addition of the parameter time); 5D model (including the extraction of quantities of material and estimated costs); 6D model (considered in the post-occupation maintenance and management). A set of multi models was created and analyzed in order to identify the main benefits and limitations concerning the BIM implementation. The course was offered at various levels and sectors of the AEC industry. The main course items are listed below:
- Concept of BIM model multiuse and adding information to parametric objects;
- 3D/BIM model used in conflict detection in MEP and construction projects;
- 7D/BIM model applied in the maintenance of buildings;
- Management of 3D/BIM model in structural design;
- 4D/BIM model supporting construction planning;
- Generation and updating parametric objects in nD/BIM models;
- Interoperability in BIM: present situation and future trends.

The FUNDEC course presented several uses of BIM supporting distinct activities that are usually operated over a project (Figure 5).

4.3 Workshops and seminars

Other activity, concerning the dissemination of BIM within the Department of Civil Engineering, behind the coordination of the author, is the realization of workshops. Two events were already made in March and November 2017. The forum Civil, a student
association, has been asking the author to offer a BIM workshop to Civil Engineering finalist students. The session “BIM: Concept and practice” of one day initializes with a breve introduction followed by an applied lesson:

- Building Information Modelling (BIM): Concept of BIM methodology, collaboration, implementation and application; Parametric modeling and interoperability (parametric objects and standard exchange format - IFC); nD/BIM models.
- Practice of basic BIM tool handling: Initial settings (project units, display scale and geographic location; floor levels and grid alignment); Generation of 3D/BIM model (creating parametric object); Applications of 3D/BIM model (2D drawings, 3D perspectives and sections, tables of quantities).

The course had a great acceptance from the students, a clear sign that the issue is attractive and that it is important to them to acquire BIM skills as it will be useful on their future activity in the labor market.

5 CONCLUSIONS

The school of Civil Engineering follows the newest advances in technology that can be applied in the Construction activity. The BIM methodology, its concept and based tools are important issues to be taught to students. The present report describes the curricular program approach of an academic discipline proposed in order to introduce this emergent topic in the scholar activity. The motivation and contextualization are referred in detail as well as the teaching methodology. Some examples that were worked out in classes by students follow the detailed programmatic content; some images presented along the text illustrate the positive result achieved with the course. Other activities supporting the course are also described, namely, workshops and FUNDEC short courses. As referred initially BIM implementation is a new process that requires study, practice, research and dissemination. The described teaching work is a positive contribution that goes in the right way.

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EDUCATION IN ENGINEERING: BIM AND VR TECHNOLOGIES
IMPROVING COLLABORATIVE PROJECTS

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Abstract. Building Information Modelling (BIM) is defined as the process of generating, storing, managing, exchanging, and sharing building information. The potential of BIM methodology to support a transformation of the processes of design and construction has been evident in the construction industry. A current topic that requires attention is the integration of BIM with Virtual Reality (VR) where the user visualizes a virtual world through interactive devices or a total immersion. VR combines several devices for interaction, creating virtual environment, and this must followed by studies concerning how to use devices or how to establish links for the presentation of information contained in a BIM model. By adding VR, the BIM solution can address retrieving and presenting information and increasing efficiency on communication and problem solving in an interactive and collaborative project. BIM + VR allow two main capacities: walkthrough and consulting data, and currently BIM tools allow links to VR plugins in order to achieve both capacities. As such, it is expected to be further explored in the near future. The text presents a review of actual perspective of the VR use applied over 3D/BIM models to supports multi-dimensional BIM applications, namely, 4D/BIM and 7D/BIM models. The objective of the study is to report the improvement of BIM uses with the addition of interactive capacities allowed by VR technology. Being the school the main actor in the formation of new engineers, it has the mission prepare students for the professional activity, giving the most advanced technology knowhow allowing them to make a difference in the job market.

1 INTRODUCTION

Building Information Modelling (BIM) methodology enables project stakeholders to create information-rich virtual models that help better visualize building projects. BIM is defined as the process of creating building information, stored in a centralized virtual model, that can be managed allowing exchanging, and sharing building data in an interoperable and reusable way [1] (Azhar et al., 2008). BIM provides an opportunity to analyze a model namely for:
constructability conflicts; ways to reduce energy usage; validating energy reducing design ideas; or improving life safety. BIM represents the procedure of development and use of a computer generated model to simulate the planning, design, construction and operation of a facility [2] (Eadie, et al., 2013). The resulting product, a centralized BIM model, is a data-rich, intelligent and parametric digital representation of the building project. So, BIM can first be considered as a digital representation of a building, an object-oriented three-dimensional (3D) model, but also a repository of project information to facilitate interoperability and exchange of information with related software applications. Therefore, BIM data-rich model allows views and data, appropriate to various users’ needs. BIM data can be extracted and analysed to generate information that can be used to make decisions and to improve the process of delivering the project or the facility.

BIM can generate and maintain information produced during the whole lifecycle of a building project, from design to maintenance, and can be applied to various fields [3] (Chen and Luo, 2014). Due to the consistency of design data, with quality data and construction process with quality control process, the potential of BIM implementation in quality management lies in its ability to present multi-dimensional data including design data and time sequence. BIM and its applications in project management are considered nD/BIM models, namely [4] (Sampaio, 2017):

- 3D/BIM model refers to all 3D building components (architectural, structural, mechanical, electrical, etc.) and it incorporates all the building aspects, including geometry, spatial relationships, properties and quantities;
- 4D/BIM model concerns the construction process that can be visualized by building the 3D product model through time according to the critical path network (the model supports dynamic construction site safety management, preparation of schedules and estimates, tracking and managing changes, and managing site logistics) [5] (Sampaio and Mota, 2016);
- 5D/BIM model is related with costs (take-off material quantities, cost planning and estimating, safety checking integration for dynamic safety analysis);
- 6D/BIM model is associated to support management facilities and maintenance along the post occupation lifecycle of the building;
- 7D/BIM model is created to support management facilities and maintenance along the post occupation lifecycle of the building [6] (Sampaio and Simoes, 2017).

The nD directions of BIM use must be based in an adequate relationship between the team members improving an adequate collaborative project, supported in an efficient interoperability of specific software. As per the reports, companies began seeing faster project approvals, increased positive team interactions and higher product quality. Unlimited extension of the use of BIM information combines BIM-based software with other advanced technologies. These advanced technologies link the digital to the physical entities and research has already been conducted to investigate the combination of BIM and other technologies such as Virtual Reality (VR) for quality defect management.

The objective of this text is to report the improvement of BIM uses with the addition of interactive capacities allowed by VR technology. The text analyses the degree of achievement allowed by the actual software to perform each aspect combining BIM and VR, mainly in two important applications: 4D model supporting construction activity; 7D model concerning maintenance. A bibliographic and software research was made to support the study.
2 VR AND BIM CAPACITIES

Virtual Reality (VR) technology has been improving BIM allowing interaction with 3D/BIM models in two essential ways:

- The **walkthrough** is the most popular as the user can view the 3D model in a virtual environment in real time from multiple perspectives, from inside or outside of the building;
- The **consulting data** focus concerns the possibility to consult the information centralized in a BIM model.

The VR context is interrelated with other fields that can make use of the visualization allowed by the BIM model, such as facilities management related with the visualization of data included in a BIM model, in real time following the interaction made possible by VR technology.

2.1 Walkthrough

Currently there are various applications of virtual reality tour applied in the field of construction. Revit files as *fbx* format can be imported into 3ds Max, and render with appropriate materials and settings for virtual space can be applied. An experience VR content can be non-immersive, by using just a desktop or tablet PC, or immersive, by using a head-mounted display like Gear VR [7] (Rho, 2015) (Figure 1) or Oculus Rift [8] (Rift, 2017).

![Figure 1: Improving BIM with Gear VR glasses in a desktop and in a work place.](image)

- **Oculus** can be used to replicate an entire building and give a better perspective of the actual scale of the project, which is impossible using traditional monitor oriented systems and offers a wide viewing angle of up to 110° [7] (Rho, 2015). VR glasses are handling to visualize and experience 3D model, 360-degree panorama picture, and virtual mock-up over a BIM model. Currently architects, engineers and other construction specialists are already exploring the length and breadth of this joint technology (Figure 2);
- **CAVE-like platforms** have been developed for immersive VR experience as they track user’s head and control wand usually with 6 degrees of freedom, to navigate inside the virtual environment and interact with the contents. Due to its immersive experience and intuitive manipulation capability, it quickly gained popularity in both research and industry community [9] (Du *et al*, 2016). VR can evoke a quit realist response in exactly the same way that physical architecture can play an important
role at all stages of the design-to-construction process, from evaluating design options and showcasing proposals, to designing out errors and ironing out construction and serviceability issues before breaking ground on site.

![Image of a BIM model in a VR environment](image)

*Figure 2: Virtual reality tour inside and outside a BIM model and supporting a collaborative meeting.*

In construction activity the use of VR capacities brings great potentials. Presenting BIM models of projects in VR environment redefines communication and collaboration in the field and in the office. BIM technology and VR have the ability to innovate the building industry. At a first glance, many feel the benefits of using a BIM model with VR are purely for marketing leveraging the 3D model for visual aids, but taking a deeper look at a BIM model it will reveal many practical reasons to adopt BIM with VR. Collaboration in VR can be the future of BIM.

### 2.2 Consulting Data

The basic concept of BIM is a consistent 3D model of buildings containing all main data as base for collaboration for all disciplines. Compared to dedicated AEC design review software like Navisworks or Tekla BIMsight, equivalent tools inside a VR environment are still very much in their beginning. This is particularly true of game engine VR experiences, where the onus tends to be on presenting a polished vision of a proposed building, rather than delivering practical tools for solving real world design and construction problems. When moving from Revit to Autodesk Stingray [10] (Stingray, 2017), data is not only retained, but users can click on objects and view the underlying attribute information. In VR mode, users can click on an object to view information, including metadata.

Fully interactive VR software also has extremely high performance demands, so some form of model optimisation is required when bringing BIM data into a VR environment. This is one area where specialist VR consultancies earn their keep with finely tuned processes for tasks like simplifying geometry, adding lighting, fixing gaps in the model and culling objects that will not be visible in the scene. Once the model is inside the VR environment, things like materials, lighting, furniture and other small details that make the VR experience feel real are added:

- An accessible high end visualisation and virtual reality of a BIM model is obtained using the VR plugin of Revit, the Enscape [11] (Enscape, 2017). Enscape is a VR and real-time rendering plugin for Revit. Inside Revit is possible to access the plugin Enscape and start to walk through the fully rendered project, without uploading to cloud or exporting to other programs. The user can observe both models in Revit and
in Enscape (Figure 4). So, all changes in Revit are immediately available to evaluate in Enscape. With Enscape, the user is able to quickly explore different design options supporting a collaborative project team. As the Revit allows the user can work over the model applying all the capacities of modelling, consulting the information linked to the parametric objects used in the model process, and obtain cuts over perspectives allowing the analyses of the composition of all elements of the BIM model. So the aspect of linking the consulting capacity and the VR ability of walking around is a very important improvement in the use of BIM methodology. To improve VR experience Enscape can also be used together with Oculus Rift;

![Figure 3: Enscape plugin of Revit.](image)

- Some progress has been made on VR techniques such as registration on tracking and display hardware, but only recently the link to BIM methodology have been made. However, a VR system should be more convenient and combined with in-use applications to support multi-disciplinary users throughout construction lifecycle. Jiao et al. [12] (2013) presents a pilot cloud framework regarding an environment utilizing web3D, BIM and BSNS (Business Social Networking Services). Technical solutions to key issues such as authoring, publishing, and composition are designed. The proposed environment is seamlessly integrated into in-use information systems and therefore enjoys greater usability.

3 4D/VR/BIM MODEL – CONSTRUCTION PLANNING

4D CAD models, that integrate physical 3D elements with time, have been used to visualize construction processes in several projects worldwide [13] (Mahalingam et al., 2010). 4D models have been used during the construction phase and have been shown to have benefits over processes that span the entire lifecycle of a project such as collaboration with stakeholders, making design decisions, assessing project constructability, identifying spatial conflicts in construction. Concerning the creation of 4D applications, as a support to follow construction planning, several studies can be found, linking VR technology to 3D geometric models and reports related with the generation of 4D/BIM models (Figure 5):

- Sampaio et al. [14] (Sampaio et al., 2012) implemented a prototype based on VR technology applied on construction planning. The geometrical AutoCAD 3D model of distinct steps of the construction activity is linked to the construction planning schedule, defining a 4D model. VR technology allows the visualization of different
stages of the construction, and the interaction with the construction activity, resulting in a valuable asset in monitoring the development of the construction activity. The prototype makes use of MS Project, AutoCAD and EON Studio a VR software. The 4D/VR application clearly shows the constructive process, avoiding inaccuracies and building errors, and so improving the communication between partners in the construction process;

![Figure 4: Screen shots of 4D/VR/BIM simulation processes.](image)

- Sampaio and Mota [5] (Sampaio and Mota, 2016) created a 4D/BIM model using Autodesk software (Revit and Navisworks) and MS Project. The 4D model allows the addition of time associations to the 3D elements, grouped in sets related with each task, allowing the visualizations and analysis of the activity sequence for the construction. The Navisworks software allowed the interconnections amongst the 3D models created in the planning where this solution built the interconnection of 3D models with planning in MS Project. The ability to navigate through the model allows analyzing each corner and each location of the model. Navisworks also has the potential to provide support in the analysis and detection of conflicts amongst the specialty projects.

Recent developments in VR have encouraged the utilization of interactive architectural visualization in the design, construction and facility management of building BIM projects. Du (2016) [9] find that the interpersonal interaction in the VR environment is more critical to the effective communication in a building project, as it creates a shared immersive experience, and developed a BIM-enabled VR environment to realize multiplayer walkthrough in virtual buildings. The multiplayer virtual walk allows real time interactions of remotely located project stakeholders in the same environment, with a shared immersive walkthrough experience [15] (Gu and London, 2010).
VR combines a device for interaction creating virtual environment and the current aim is study how to use device or establish links for the presentation of information contained in a BIM models. Following that perspective, commercial software houses have been developing advanced BIM/VR products. The use of BIM technology on construction projects has the potential to improve the process by allowing all team members to collaborate in an accurate and efficient way. Some of the VR software adapted to BIM and the main capacities are listed below:

- **Enscape** is Revit plugin that creates a VR walkthrough with one click, based on BIM data and can be also used in a 4D context [11] (Enscape, 2017). There is no need to download or learn how to operate additional software. All materials, geometry and entourage come from the Revit construction project and can be changed during the VR simulation. This flexibility allows spontaneous presentations with a real-time rendering quality within the construction design workflow;

- Combined with the **Oculus Rift**, customers can virtually walk through the Enscape project and experience it as if it were already built. In the construction process the engineered visualise the correspondent building 4D/BIM step and consult all the information the user need to compare the progress building stage, the delay or the advance realized in the construction place. Enscape has become a standard application in projects worldwide namely as a construction planning support;

- **Augment** is software that can be used in smartphone or tablet allowing the user to view the 3D model in the real environment in real time from multiple perspectives. BIM with VR enables project stakeholders to create information-rich virtual models that help better visualize building projects. Data-rich virtual information is available on site through connected devices in real time. Site managers can overlay the BIM model on the project site. Construction issues can be addressed in real time, saving time and resources [16] (Augment, 2017) (Figure 6);

- **Samsung Gear VR** is a virtual reality device that allows exploring virtual worlds at the construction site or during meetings. To use Gear VR during construction phases and facility management purposes two paths are needed: BIM model and construction site picture based, and users must be familiarized with Revit software and 3ds Max software for visualizing and rendering, or to navigate inside game engines like Unity3D with Android Studio are need [7] (Rho, 2015).

![Figure 5: Screen shots of Augment software.](image)
Combining BIM with VR is expected to envision efficient collaboration, improved data integrity, intelligent documentation, distributed access and retrieval of building data and high quality project outcome through enhanced performance analysis, as well as multidisciplinary planning and coordination. VR research considers not only the technological development; a very important part of the research also concerns the application of the technologies and their adoption by the practices. In BIM, while the potential benefits of the technologies may seem evident, the industry adoption rate of BIM varies and now the importance of adding VR benefits must be a research point [17] (Advenser, 2016).

The BIM includes semantics into the construction process (e.g., structure, air conditioning/ventilation, mechanical, electrical, plumbing, etc.) and data for simulation (materials/structure resistance, energy consumption, thermal calculations, lighting, acoustic simulations, etc.). These issues must be addressed throughout the construction project but mainly, at the beginning during the design phase to fulfil the customer’s requirements, during the construction work to anticipate technical constraints on site, and during the maintenance phase to control the building;

The acceptance and expansion of VR has been growing exponentially in the construction field. A VR tour can be applied, from a facility management perspective, in the maintenance control (7D/BIM model), or from a project team view, to review constructability (4D/BIM model) and to support decision making (Figure 7):

- A virtual tour together with Enscape allows the facility manager to look around the facility and check the conditions of equipment and obtain relevant information from the BIM model. For instances, visualizing the BIM model of a MEP system, in a virtual tour and using on a tablet PC, helps the facility manager to understand what is installed behind the ceiling tile. Augment tool can also be used to view and consult the 3D model data, in the real environment and in real time, to facilitate installation and layout;
- The traditional EON software has been used in 4D/VR models to support the construction activity. Currently the EON Icube is a multi-walled system where the user is completely surrounded by images and sound. The EON Icube uses light-enhancing rigid wall material, provides users with an impressive speed of immersive content creation and deployment, and has built-in collaborative capabilities. EON Icube is compatible with most Virtual Reality peripherals, such as data-gloves, Xbox controllers, joysticks, or motion tracking systems. EON maintains a virtual reality library that already has many sample AEC environments built [18] (Eon, 2017);
- The **Autodesk LIVE** allows users to transform Revit models and step inside their own designs to share and present. AEC professionals can upload BIM models to the cloud with just one click and interactive visualizations that can be published to mobile. This gives collaborators a better sense of the design early on so changes can be made with minimal disruption or delay. It allows the consult of BIM data and so it support management and maintenance within a collaborative team.

5 CONCLUSIONS

For architects and designers, VR+BIM enable them to better communicate design intent. A challenge for architects is that of communicating concepts and visions for buildings. The advantage in using VR is in the communication of ideas, concepts and the vision for the building. This enables all the parties to more quickly reach a full appreciation of the building plan. When everyone shares a common understanding of the design, the project is executed more efficiently from the outset. This current BIM with VR topic require dissemination; application in real cases and pointed out, in reports, achievements and limitation; following the technologic advances that supports the BIM use and the visualization of data, in real time while the interacting with the model made possible by VR technology. BIM + VR provide an opportunity to analyse and explore BIM models within virtual environments.

Introducing VR interactive capabilities into 3D/BIM models in the construction process is a main way to test virtually and correct a construction project before the realization, as the walkthrough is available as well the visualization of data linked to each parametric object, improving the necessity collaboration within the design team. So, BIM/VR applications can contribute to reduce costs due to the construction of a real mock-up, and to avoid mistakes on site that generates material wastes.

Software houses have been demanding the integration of BIM with VR plugins in order to support the development of nD/BIM tasks. The fundamental base of BIM+VR concerns the collaboration as a first step, but the possibility of consult data while walking through the building, improves significantly the use of BIM in design, construction, maintenance and management.

REFERENCES


INTRODUCING BIM INTO EDUCATION: OPPORTUNITIES AND CHALLENGES

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Abstract.
Digital transformation is altering the way architecture, engineering and construction (AEC) professionals worked traditionally. BIM (Building Information Modelling) technology is at the centre of this transformation, connecting design, construction, management and operation of buildings. Its advantages versus previous practice are many and benefits owners, designers and contractors. Demand of BIM projects is growing significantly and is expected to increase faster in the next years while the industry improves the standards and available tools are developed further. Education in Civil Engineering must acknowledge these changes and include BIM in the core of its contents to prepare future practitioners.

The introduction of BIM philosophy in education presents advantages not only for future professional practice, but also for current students. This article covers the opportunities of BIM introduction into education: (1) It would help students to improve both hard and soft skills, highly valued by employers. (2) It would attract more students to Civil Engineering studies by changing its image of being an old-fashioned sector. Existing barriers for this introduction related with the current teaching methodology and software use will also be mentioned. Despite the efforts to adapt university courses to introduce BIM, these changes must be encouraged as this investment will pay off in the medium term with better trained professionals which in turn will increase productivity in the AEC sector.

1 INTRODUCTION
Digital transformation is altering the whole economy and changing the way professionals used to work. With certain delay compared to others industries [1], the architecture, engineering and construction (AEC) sector is also embracing these changes. Building Information Modeling (BIM) technology is at the centre of digitization of the AEC sector [2]. The demand of BIM projects is growing significantly and is expected to accelerate in the next years while the industry improves the standards, software tools are developed further and more clients make it mandatory. Education in Civil Engineering must acknowledge these changes to properly prepare future practitioners and include BIM in the core of the academic contents.
Compared to other industries the AEC sector has traditionally been more conservative and changes have been introduced slowly; this has led to relatively low productivity and efficiency levels. The introduction of the BIM technology aims to revolutionize the industry in design, construction and operation. The use of computer-aided tools and data in a comprehensive manner as proposed by BIM presents many advantages compared to the traditional use of software tools, but also requires changes in the way practitioners used to work.

University degrees are sometimes criticized for focusing too much on theory and not much on practice. The introduction of BIM into Civil Engineering studies presents an opportunity to provide a more practice-oriented training, improving both hard and soft skills. Moreover, it can change the perception among young students that the AEC industry is old-fashioned, which frequently stops them considering it as a career path [3]. Although the introduction of BIM into education presents some barriers, most of them are salvageable as addressed in this paper. Governmental and academic institutions should promote and facilitate the introduction of the necessary changes given the benefits of the BIM technology. Efforts to adapt university courses to introduce BIM will pay off in the medium term with better trained professionals which in turn will increase productivity in the AEC sector.

2 BIM TECHNOLOGY

2.1 The use of software tools in the AEC industry

The use of software tools in the AEC industry has been growing exponentially during the last decades and today they are an essential part in professional practice. Software tools increase greatly the productivity of practitioners taking advantage of modern computers to undertake automatically repetitive, time-consuming tasks and solve complex problems. The supply of software tools is widespread and covers from drawings production to generation of bills of quantities, from structural analysis to water supply networks design.

The development and application of computer-aided tools is usually limited to solve a certain problem of the project (definition of the physical model, estimation of the cost, design of structural elements, definition of the geometry of supply and sewer pipes…). This is so because projects are usually undertaken by several professionals (the architects, the project managers, the structural engineers, the utility engineers…) which are in charge of specific parts on which they are specialized.

It is obvious that the different parts in which a project can be subdivided are interrelated because, after all, the project is unique (the physical model defined by the architect affects the structural model of the structural engineer; the location of beams and columns restricts placement of supply and sewer pipes…). Traditional software tools do not take advantage of this interrelationship, which not only leads to an increment of the workload (for instance, the architect, the structural engineer and the utility engineer need to define each one a model from scratch), but also makes it more difficult to identify clashes between the different disciplines in the design phase (for instance, intersections between the pipe network and structural elements such as columns and beams).
2.2 What is BIM?

BIM is a process for creating and managing data related with construction projects which covers from design to operation through construction. A BIM model is a digital representation of a construction project. It does not only include the 3D geometry, but also the properties of the different elements forming the project (structural elements, pipes, insulation elements), geographical information, time and cost data, maintenance… To have all this information in the same model presents several advantages versus working with different, independent models. Some of them are mentioned next:

(1) It reduces the workload and, hence, costs associated with the project development. Data shared in the BIM model does not need to be defined twice. For instance, if the architect has created the physical model, the structural engineer does not need to define it again before defining the structural model; this also guarantees that they work with the same geometry.

(2) It reduces the occurrence of conflicts between parts undertaken by different people. Having all relevant data from different disciplines in the same model permits to identify clashes between elements and modify them accordingly in an early stage. This results in substantial cost savings in the construction phase, when modifications of the project are much more expensive.

(3) It promotes collaboration between the different agents working on the project. It is for the best interest of all participants to create a realistic, complete model.

(4) It permits to visualize the project in a comprehensive manner. This feature has clear benefits to better understand the implications of construction and operation of buildings. These advantages will be even greater with further development and refinement of augmented and virtual reality tools.

2.3 Open BIM

Some BIM software tools present constraints related to the compatibility and interoperability with other applications. This can represent a real limitation to practitioners if they are forced to use certain software for compatibility reasons rather than for technical/preference reasons. Open BIM is a complementary proposal to traditional BIM which puts information on the centre of the workflow rather than on the software application. It is an initiative of buildingSMART [4] supported by several leading software vendors, including CYPE.

Open BIM is based on the use of standard, open, public files which permits sharing information regardless of the application used. The most popular file inside this philosophy is the IFC file (Industry Foundation Classes). This technology permits a transparent and open workflow and facilitates the participation of all professionals without imposing constraints on the use of certain software. Moreover, the use of standard formats facilitates subsequent data analysis which will be of great interest in an economy where big data is meant to be revolutionary (if it is not already).

An IFC file with the 3D geometrical model is necessary to start a project in the Open BIM workflow (BIM Project Starter) (Figure 1) [5]. This file can be generated with any modeling software for architecture; free applications are available in the market (e.g. IFC Builder by
The IFC file is then placed into a directory which is shared with the rest of project participants and where all the information generated by them will be shared. As the workflow is based on a standard, open file (IFC), any software application importing and exporting this format may be used by the participants, giving great flexibility to choose software based on professional/personal preferences. The original IFC file is then completed with additional IFC files generated by the specialized tools and the BIM model is updated consequently.

The Open BIM workflow permits the development of specialized tools without having to tackle the whole problem. This opens unlimited possibilities to developers to work on smaller applications which solve a specific problem in different project fields: structures, HVAC, plumbing, electricity, telecommunication, lighting or other disciplines, and which can then be integrated into the workflow with other tools. The BIM server center managed by CYPE offers an excellent platform for developers to offer their BIM software products to the general public.

3 OPPORTUNITIES

Introducing BIM into education presents many opportunities, not only because it will prepare students better for professional practice, but also because it will result into more
attractive education programs in the digital age.

3.1 Professional development of future practitioners

Education must prepare students for the job market by providing them with those capabilities needed and valued in professional practice. Two different skill categories are usually distinguished when evaluating a job candidate: (1) hard skills and (2) soft skills. Hard skills include knowledge and abilities which are acquired through education and training, in general related to a specific field and which are usually quantifiable. Soft skills, also known as “people” skills, are related to the ability of individuals to interact with others and involve emotional intelligence. Traditionally employers used to focus mainly on hard skills (university degrees, courses, certifications, languages, software use…), but in the current workplace soft skills have gained much importance; indeed, it could be stated that today they are as equally important as hard skills. Introduction of BIM into education results in improvements of both hard and soft skills as detailed next.

Regarding hard skills, two important capabilities can be enhanced with the introduction of BIM into education: (1) handling different computer-based tools for the resolution of engineering problems and (2) engineering knowledge by itself. The use of computer-aided software in engineering offices is widespread, highly valued by employers and usually a requirement. Nowadays the number of engineering software applications is so large that it is impossible to be familiar with all of them. However, having learnt some of them facilitates the learning process of other tools. Therefore, those students who arrive to the job market with a good degree of expertise in the use of some engineering software tools, even when these are not specifically the ones required by the employer, have a great advantage versus those who have not learned any tool during their education. Related to the second hard skill, computer-aided tools facilitate teaching engineering concepts thanks to examples of applications and trial-and-error tests that can be undertaken easily. For instance, identification of the influence of different factors in design becomes clearer with computer applications (e.g. study the effect of reinforcement quantity on the column strength).

As mentioned above, Open BIM promotes the development of tools for the solution of specific problems which can then be integrated into the workflow via the IFC standard. This can represent an incentive to students to develop their own tools either individually or in group projects as part of a course. This would not only provide them with a computer-aided tool for the resolution of the problems they need to face, but also will encourage them to understand better the theoretical concepts embedded in the application before programming it. As mentioned earlier, the BIM server center managed by CYPE then provides an excellent platform to offer the developed products to other users, which is always very motivating for engineering students which can see how their work can have an impact in real practice. This was not possible until now as applications needed to be very complete and, hence, clearly out of the scope even for the most advanced students.

Regarding soft skills, BIM process promotes (1) leadership, (2) communication and (3) collaboration: one of the participants must play a manager role and coordinate the work of the rest; working everyone on the same projects requires a good communication between team members to know at which stage each member is and work together on potential clashes identified in the BIM model; and collaboration is critical in order to develop a comprehensive
model including all relevant, matching information.

3.2 Motivation of current trainees

The AEC industry is frequently identified as an industry with a low degree of digitization, where no major changes have appeared in the recent decades. For this reasons the AEC industry is frequently seen as an unattractive sector by young students who were born in the digital era. Introduction of BIM into education can change this image.

The idea of creating virtual buildings through the development of BIM models is engaging and more appealing than producing drawings or analysis models whose connection with reality is frequently difficult to establish. In addition, the use of software may make more attractive the learning process in engineering, which is characterized in many cases by complex concepts whose usefulness at first sight is not easy to identify for a student. Therefore, introduction of BIM into academic plans could results in an increment of the interest showed by high students on construction-related careers.

4 CHALLENGES AND BARRIERS

The introduction of BIM into education is not free of difficulties and barriers considering the traditional teaching methodology and the use of software in academic centers. However, these barriers are salvable as addressed in this section.

4.1 Teaching methodology

Introduction of BIM into education requires bringing in some changes in the current teaching methodology. This affects especially to coordination between different faculties and courses. The scope of university courses is usually limited to a specific field inside the construction industry (courses on reinforced concrete design, water networks design, urban planning…). Currently most courses operate independently; the only relationship may be in many cases that more advanced courses require background knowledge from previous courses. Therefore, with the current system a student needs to wait almost till her final year to have a clear picture of what a construction project entails.

The introduction of BIM into education requires enhancing coordination and collaboration between different courses because it would not be reasonable to work on a BIM project if the student cannot see how the different parts of project fit with each other. The development of BIM group projects by students from different courses and even from different degrees would be of great interest. This would not only permit students to fully grasp the essentials of construction projects and BIM, but also to foster collaboration with other students outside the classroom, promoting the development of soft skills.

Introduction of BIM into university courses would be at the expense of other areas. Currently, much importance is given to theory in engineering studies and little space is given to practice. Importance of engineering theory is doubtless to educate future professionals, but this sometimes results in disregarding the importance of practice. In this sense, introduction of BIM into Civil Engineering studies would help to even out theory and practice.

It should also be noticed that sometimes there is some mismatch between academia and professional practice. In some cases university changes occur with a certain delay compared to industry trends. This is a consequence of conservative practice, but also of the difficulties
of introducing modifications into the university system, especially when these involve structural changes. The establishment of testing groups or programs could be a good initial approach to check the suitability of the new modifications and also to attract more students looking for the latest trends.

4.2 Software use

The introduction of software tools into education is not always as straightforward as one may think. First, the software to be used needs to be decided. Decisive factors include appropriateness for students, applicability in professional practice and cost of license fees. In addition, for BIM applications compatibility with other tools should be considered. In this sense applications inside the Open BIM workflow are very appealing as data interchange through IFC files guarantees the interoperability with other applications. Regarding the cost associated with licenses fees, some software vendors offer free versions for students and universities. CYPE not only offers free student versions, but also many of its professional versions to both students and practitioners.

Second, and related with the interoperability between different programs, it is of importance to guarantee that students will be able to work as realistically as possible when compared with professional practice. This is of special interest for projects involving different disciplines (especially for courses in collaboration with other degrees or faculties as proposed in section 4.1…). Sharing models and information between students is critical in these cases. For this purpose the online platform BIM server center managed by CYPE offers many opportunities: file interchange takes place in real time; students can work on the same project at the same time; interaction and clashes are identified automatically.

Third, software tools are sometimes denoted as black boxes, which can be a disadvantage for teaching purposes as it is of importance that students grasp all the implications of the models used. Despite this, some software tools as those developed by CYPE generate not only final results, but also provide intermediate results and lists of checking which facilitate to follow all the process without hiding relevant information. Moreover, and as mentioned in section 2, the Open BIM workflow facilitates the development of own tools which are not black boxes anymore.

5 CONCLUSIONS

BIM is transforming and gaining much importance in the AEC industry. Attracted by its benefits, more clients are requiring the development of BIM models for their projects. Indeed, BIM is mandatory by many public sector organizations and, hence, affecting directly to the civil engineering industry. Professionals who are trained or have experience in this new technology have a tremendous competitive advantage versus those who do not.

Civil Engineering studies must recognize BIM importance and adapt courses to introduce this technology. Opportunities and challenges have been addressed in this document. Benefits for the AEC and the society will pay off the investment needed in introducing these changes.
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VR-BASED TEACHING AND LEARNING TOOL FOR BUILDING DESIGN AND CONSTRUCTION

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Abstract. A Virtual Reality (VR) based teaching and learning tool is proposed in the present paper. A virtual 3D environment is built for students to conceive their design ideas, plan the layout, design the structure, construct the products (buildings, communities, infrastructures, etc.), and to directly interact with the products they designed. The aim of the research is to strengthen the learning-by-doing approach. The objectives are: (1) to build a VR design environment for students to experience corresponding impact from different scenarios, which will help the student understand and investigate different design theories and schemes; (2) to build a VR construction environment for students to investigate how the building is built and what are the safety issues should be noted when visiting a construction site; and (3) to provide a collaborative environment for students in the Built Environment domain for better communication through a complete building project featuring active and experiential learning. Students with different majors in the cluster can work together in a design project using the VR platform so as to enable collaboration work, which is a common working situation in reality. A game was developed to guide the students to explore a virtual construction site by answering technical questions and carrying on tasks resolving safety hazards on site. Unity is used as the game engine to develop the package. VR software package, VIVE, is used to realize the interaction between the virtual environment and the user interactively and immersively. Students from the Civil Engineering were invited to play the game and give feedbacks using a questionnaire. Positive comments were given by the students showing that they were very interested in playing such a technical game. Most of the students were willing to spend more time in finding answers after playing that game. In this way, the benefits of the research could be: (1) Enhancing the understanding of conceptual design ideas and how to make better designs in urban planning, architecture, and civil engineering domains; (2) Better accessibility to more realistic structural products in a large scale; and (3) Improving professional skills such as teamwork and communication in the VR-aided learning-by-doing process.
1 INTRODUCTION

The Civil Engineering department aims to incorporate “active learning” into all its modules, which means students engaging with teaching materials instead of passively listening. Among them, a CDIO concept is introduced based on a commonly shared premise that engineering graduates should be able to: Conceive – Design — Implement — Operate, which is complex value-added engineering system in a modern team-based engineering environment to create systems and products. A good example in the department is CEN101 - Design for Engineers, where the students design and construct cardboard bridges by “hand-on” activities. Students learn the structural design through material strength testing, using structural analysis software packages, and testing their final product with designed load. Students enjoyed and learned more. However, the scale covered through that module is limited to small truss bridges only. Large scale design activities should be provided to the students and a diversity of design projects should be incorporated into this module.

In addition, Civil Engineering students need to collaborate with other built environment related professionals in their career path, such as urban planner and architects. It is essential for the students to learn in an early stage how to efficiently cooperate with students from other disciplines, especially within the built environment cluster.

In the department of Urban Planning and Design (UPD) and Architecture (ARCH), design-related issues (e.g. scale, 3D perception, etc.) are usually taught in a studio-based environment. However, it is very difficult to allow students to challenge (or even fully understand) some design principles (e.g. how to create a pedestrian friendly working environment? And more importantly, why should it be designed like that? etc.) in the given learning environment. A range of tools have been developed and applied in order to solve this problem. These include Computer-Aided Design tools (e.g. CAD/SketchUp models), physical models, case studies of best practice, etc. Yet their effectiveness is still questionable, especially to beginners such as junior UPD or ARCH students.

Based on above mentioned experience in the built environment cluster, we would like to propose a Virtual Reality (VR) based teaching and learning tool, which can efficiently improve students’ active learning capability by allowing students interact with their designed ‘virtual built environment’ directly and immersively. By doing so, it can inspire students’ imagination and support their design thinking. At the same time, structural design practice will be integrated to allow students to do simplified structural analysis but for a real product (e.g. building, bridge, etc.) in full scale. The structural analysis results may need a revision of architectural design to meet the stability and safety purposes. During the cycle, students from different majors learn from each other and work together to produce more realistic products in the end. The VR-based environment can be used to help the students to understand the impact from different design scenarios. By using this teaching and learning tool, we expected that students learn more through these active and hands-on activities; emphasize more in problem formulation and solution. In addition, previous research [1] also showed that the application of VR techniques can facilitate the communication across different stakeholders involved in a design project and thereby efficiently support participatory design or decision-making. As a result, by using VR techniques to support learning and teaching in the built environment cluster, it can help students verify some design theories in practice and, in return, improve their capability of applying, analyzing, synthesizing, evaluating or even creating new design principles. A case study of
using VR in learning and teaching at XJTLU UPD can be found from Chen and Chen [2]. In addition, a game was developed to guide the students to explore a virtual construction site by answering technical questions and carrying on tasks resolving safety hazards on site. Students from the Civil Engineering were invited to play the game and give feedbacks using a questionnaire. Positive comments were given by the students showing that they were very interested in playing such a technical game. All of them wanted to play more rounds in order to improve their performance and to find answers to the questions they failed to answer correctly earlier. Most of the students were willing to spend more time in finding answers after playing that game. The results of the project had been published and presented in two international conferences [3][4][5].

2 AIMS AND OBJECTIVES

The fundamental aim of the proposed project is to strengthen the learning-by-doing approach. A VR-based design and construction environment will be developed as a teaching and learning tool. The objectives are: (1) to build a VR design environment for students to experience corresponding impact from different scenarios, which will help the students understand and investigate different design theories and schemes; (2) to build a VR construction environment for students to investigate how the building is built and how the design will affect the user experience in reality; and (3) to provide a CDIO activity for design and construction through a complete building project featuring active and experiential learning.

3 METHODOLOGY

As shown in Figure 1, the VR environment is designed to comprise two main groups of structures, which are Communities and Infrastructures. Communities will be used for planning and design purposes to include a large scale of area. Different buildings will be designed to form communities. Meanwhile, Infrastructures consists of bridges and roads, which will be a necessary part to be considered in the built environment. Level of Details (LoDs) will be decided to meet those different requirements.

Design projects in different scale can be assigned to students to fulfill different needs in terms of urban planning (large scale, which can include communities and infrastructure), architectural design (Intermediate scale, which can include several buildings), or structural design (small scale, which can be one building or one bridge). Once the design projects have been done, a construction activity can be triggered to show a virtual construction site of the buildings or the bridges, and roads. Construction progress will be simulated by attaching time information for individual components of the structure.

Navigation and interactions will be developed to enable the students to explore and change the VR environment freely and get instant feedbacks, such as Environmental Impact and User Experiences. With the integration of some simulation tools, impacts from different design scenarios, such as traffic flow, daylighting, views, etc. can be presented in the VR environment. Since the students will be immersively stay in the virtual environment, which means that they can experience the impact in a much more realistic way, compared with traditional ways. Those experiences will help the students improve their design and gain better user experiences.
3.1 Requirements Identification

First of all, requirements for the development were identified in terms of design, construction of a building project based on teaching experiences. Students who involved in the development from the Built Environment cluster and the Computer Science department (CS) were asked to work together to design the VR environment settings according to the requirements as if they are working on a design project in a module. The VR settings were developed by the CS students by using the VIVE VR toolkits and programming language. The difference between the VR-based design and the traditional design is that, in a virtual environment, the user experience is more realistic and, in return, more feedback can be given instantly.

3.2 Create Existing Buildings

To give the students spatial awareness in the virtual environment, existing environment should be created. Building models are created via SketchUp with detailed layers on different components constructing the building. Figures 2(a) and 2(b) are examples for buildings in a university campus. To convert SketchUp models into virtual reality environment, we have to export the model into a readable file format by Unity Editor. There are two file formats that commonly supported by Unity and SketchUp software, which are `.obj` and `.fbx`. The former one stores Mesh and Textures into two separate documents, thus might cause some material missing problem. Therefore, it is suggested to use the .fbx format, under which the model and its relevant materials are combined into one file. Besides, a 3D model covering a large area is created by using taking pictures using a drone and reconstructed by using image processing. However, due to limited resolution, this model is only used for a top view and not for detailed design work.
3.3 Navigation via Teleport

Teleport is chosen as the main navigation technique to prevent motion sickness and nausea that usually take place during translations in virtual reality environment. By pressing the trackpad of the left controller, a curved raycast will be shot out. The point where the ray hits the ground will be considered as the desired destination. Then by releasing the trackpad user will be moved to the position selected instantly, as shown in Figure 3. The maximum distance allowed for transportation can be defined freely within the Unity Editor.

![Ready for Teleport](image1) ![After Teleport](image2)

**Figure 3:** Navigation using Teleport

3.4 Designed Functionalities

A set of functionalities have been designed to facilitate the users to apply the similar functionalities for design.

3.4.1 Selection Panel

Figure 4 shows the UI that designed for selecting a single mode on the right controller. The trackpad is divided into four quadrants, each specifying a mode for interacting with the

![Selection Panel](image3)
architecture. The white quadrant is for indicating current selection on the specific function mode. The selection is made by: 1) moving the finger into the quadrant area which the desired function belongs to; 2) pressing the trackpad. Then the white indicator will automatically rotate to be aligned with the quadrant of the selected mode, indicating the success of selection.

**Figure 4:** Selection Panel on the Controller

### 3.4.2 Distance Measurement

After selecting this function, a straight ray will be cast from the head of the controller. The vertical height of the point that the ray hit will be displayed above the controller. In reality, height is a very abstract conception, which is sometimes hard to estimate only by observing. While in VR environment, it would be possible to train students’ ability to feel and explore the sense of "height" by visualizing it with data.

**Figure 5:** Measuring Distance

### 3.4.3 Make Notes/Comments by using Virtual Keyboard

Again Raycast is used as the selection technique. User can leave a comment by pointing the ray to the desired position. Then after pulling the trigger, a blue tag will appear together with the virtual keyboard for input. The input text will appear on the tag. User can click on the "Enter" on the keyboard to confirm the input. Then the tag with the input text is fixed at the selected point. The tags will rotate according to current head orientation of the user, so the view of the tags would never be occluded.
3.4.4 Create New Objects

The function of design buildings is developed starting from drawing rectangles on the ground. As shown in Figure 7, firstly, switch to "Draw" mode by pressing the trackpad. Secondly, point the ray to the ground, with the point being hit as the initial vertex for constructing the rectangle. Thirdly, press the trigger and move the controller to change the hit point. A rectangle will be formed with the initial point and current hit point serving as the diagonal vertices. Finally, release the trigger to finish constructing the rectangle.

Next step is to stretch the solid by pressing the trackpad to switch to “Stretch” mode. Then point the ray to triangle surface just created, followed by pressing the trigger and moving the controller up/down to lift/drop the surface. Then a solid will be automatically formed by the
surface on the ground, and another surface you are manipulating. Finally, release the trigger to finish constructing the solid.

3.4.5 Other Functionalities

Besides the basic functionalities introduced above, other functionalities are also developed to enable the students design in this VR environment. Such as changing material of the façade, simulate the sunlight, calculating the FAR, etc.

3.5 Testing

A prototype system is developed and several students are invited to experience the VR Design Environment. Figure 8 shows a student is using the prototype and his design result of a group of buildings.

![Figure 8: Testing the VR Design Environment](image)

4 GAME DEVELOPMENT

To enhance the engagement of Civil Engineering students and encourage active learning, a virtual construction site investigation game is developed as well. 3D construction site environment is built based on BIM models and relevant objects common on construction sites are created to enhance the realistic. Navigation and Interactions are developed to enable the students to explore the virtual sites freely and get instant feedbacks. Different modules, such as Questions and Tasks, are developed to exam how well the students master the domain-related knowledge, as shown in Figure 9. The architecture, mechanism and the implementation are described in detail in [5].

This pedagogical methodology aims to improve the quality of learning by transforming traditional instructional delivery techniques into technology-based active learning. Students’ engagement in the learning process is improved by establishing a contextual connection between ordinary textbook materials and technologies that students use in their daily routines.
5 DISCUSSION

Comments from the students were collected based on their experience of using the VR-based techniques. Since the team includes the students from different domains, such as urban planning, architectural, and civil engineering students, communications between those students are different in a VR-based environment instead of using sketches, 2D drawings, etc. These differences were identified and analyzed to check the effectiveness of the VR-based learning and teaching tools. By analyzing the feedbacks collected through a questionnaire, we got some preliminary results, which shows that Civil Engineering students are more supportive in collaborative design by getting more understanding from urban and architectural design.

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REFERENCES


COLLABORATIVE WORKSHOP: SUSTAINABLE CIVIL ENGINEERING PROPOSALS FOR REAL SETTINGS

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Key words: Service learning, teamwork, social agents, complex urban realities.

Abstract. The objective is to familiarize students with real civil engineering problems as posed by social agents (e.g. a city council, a neighbourhood association, etc.) and to foster social responsibility, active and cooperative learning, teamwork and sustainability. A multidisciplinary team accompanies students in finding solutions to problems affecting a region, with the goal of training them in how to sensitively deal with complex urban realities and understand the possible impacts and conflicts of their projects for their region and society. Methodologically, this training strategy is based on active teamwork and cooperation applied to a real case. It is also influenced by service learning in that local stakeholders explain their problems to the students and ask for solutions. This initiative is not part of any study plan but is a complementary teaching activity organized by the Civil Engineering School of Barcelona and worth 3 ECTS for participating students. In 2016-2017, the workshop —covering problems related to harbour design, water quality, pedestrian bridges and retaining walls— was conducted in Marina d’Empuriabrava on the Costa Brava, proving to be a very satisfactory experience for students, teachers and local stakeholders in terms of learning and proposals. In 2017-2018 the workshop has been held in El Vendrell (Tarragona). In the next editions, it is planned to make ongoing improvements in terms of time organization and teamwork evaluation.

1 INTRODUCTION AND OBJECTIVES

The engineer working in the field of civil and environmental engineering develops a professional practice related to the construction of new infrastructures. These projects induce a series of socio-economic and territorial impacts, both positive and negative. Facing a social reality with a large number of conflicts linked to these types of projects [1], there is a need to improve the engineer’s awareness of environmental and social issues.

The engineer should be able to work in teams under interdisciplinary conditions with good communication skills to explain the complexities of their works. Thus, one of the teacher's basic responsibilities is, precisely, to provide the student with an analytical capacity and a critical
vision in the process of territorial intervention.

This is the main objective of the educational initiative that is hereby presented, which aims to bring the student closer to real problems in civil engineering and to foster the skills of teamwork, sustainability and social commitment, through active and cooperative learning. Thus, it seeks to train sensitive professionals to deal with complex urban realities and with the social needs and the conflicts that their projects can generate.

The learning objectives involve integrating and applying the knowledge acquired during the Bachelor’s Degree in Civil Engineering and in Public Works Engineering in a real context. To this end, a collaborative workshop has been designed, in order to propose solutions to specific stakeholders’ demands. Thus, the students are offered a unique opportunity to get in touch with real problems before graduating and entering the professional world.

In this process the values of sustainability and social equity are questions of great complexity and transcendence that must be dealt with both directly and openly (speaking and discussing them in the classroom), as well as indirectly, through teaching methodologies that promote collaboration and teamwork. As pointed out in the precepts of Education for Sustainable Development (EDS from now on), these issues are essential to train competent and capable professionals to build a better future [2, 3]. The EDS demands participatory methods of teaching and learning that motivate students and give them autonomy. It also encourages skill-development such as critical thinking, the development of scenarios for the future and supports collective decision-making. The EDS demands major changes in the pedagogical methods that are currently applied.

2 DESCRIPTION OF THE INITIATIVE

The learning process is based on active and participatory methodologies, encouraging collaboration and permitting students to get in contact with multiple disciplines and stakeholders, in order to generate creative solutions to the problems raised [4]. In active methodologies, the common denominator is to transform the student from a mere spectator into an active subject. The approach of this initiative seeks to simulate scenarios or real life problems, in order to implicate and motivate the students in their learning process, since bringing them closer to real and contemporary problems increases their interest [5].

Methodologically, the learning process is based on the case study approach, which creates an activity around a real case that must be developed in groups, where the theoretical questions studied during the Bachelor’s Degree programme are applied to analyse and solve problems related to civil engineering. Likewise, the activity also has an influence from the service learning because the students are immersed in a complex and real situation where social agents will ask them to propose solutions.

This initiative is not part of any study plan but is a complementary teaching activity organized by the Civil Engineering School of Barcelona and worth 3 ECTS for participating students.

It consists of several stages and activities:
- Diagnosis and organization: It starts with a technical visit where several actors accompany the students allowing them to get to know first-hand the problems that must be addressed (Figure 1). Later, in a classroom session, the problems and the observed
needs are shared. Students organize themselves to share all available information (plans, documentation, photography, etc.), identify shortcomings and knowledge needed to proceed with the preparation of proposals. Then they look for experts and professors of the Civil Engineering School that will be invited to the next session to obtain advice or interview them. Problems are prioritized and work groups are created to be effective in finding solutions. The main purpose of this stage is to turn the student into an observer and active subject, to be able to assess the problems at stake.

- Elaboration of proposals: It consists of two face-to-face sessions and independent work out of the classroom. If the students consider that they need support, they contact with other experts or professors at the Civil Engineering School. Moreover, guest lecturers are invited to the class to discuss the ideas with the students, in order to confirm or reject proposals to addressed problems.

In the second session, the proposal phase comes to the end and the presentations for giving back the proposals to the municipality are prepared.

- Return: A return session is held at the stakeholder’s facilities, those who have made the request (social entity, town hall, etc.), where other agents of the territory can be invited. This activity is very important for both parties, as it makes visible the work done and highlights the effort of the students. At the same time, the students provide their ideas to the stakeholders’ demands as if they were engineers, simulating a real situation.

- Assessment and feedback: On the one hand, both the municipal technicians and the teaching staff involved give a qualitative feedback to the work done by the students and on the other hand, a questionnaire of satisfaction is distributed among the students and technicians, in order to collect their feedback of the activity.

3 IMPLEMENTATION OF THE INITIATIVE

In the course 2016/17 the experience was carried out in the context of the Costa Brava, specifically in the Marina d'Empuriabrava. The Community of landowners invited a group of students to assess the civil engineering problems that the marina have, coinciding with the 50th anniversary of its construction (Figure 1).

The participating students (twelve) worked in 4 groups, in a cooperative way to make proposals applicable in the field of structures (walls and bridges), water quality, urban planning
and port engineering. These proposals were elaborated in collaboration with the stakeholders, professors of the Civil Engineering School and other experts of the corresponding topics. It was publicly presented at a round table organized by the same Community of Landowners on June 17.

During the course 2017/18 the initiative has been replicated in another territorial context and with different stakeholders and problems. The scenario this year has been in El Vendrell (south of Barcelona) and the interests have focused on urban planning conflicts, rainwater management, mobility and the protection of coastal areas without urbanization. In this case, the city council consisting of 8 technicians (3 architects, 2 engineers, 1 assistant and 1 environmental scientist) accompanied 15 students, proposing problems and commenting on the proposals (figure 2).

4 ASSESSMENT OF THE INITIATIVE

The expected results have different dimensions, one more technical and easily evaluable, as a result of applying theoretical knowledge obtained during the studies in real situations, and another one more social, which involves acquiring transversal skills such as teamwork, sustainability and social responsibility. The latter is more difficult to evaluate as it requires an holistic appraisal and time.

In this initiative, the evaluation is based on attendance to the activities (which has always been above 80%) and the assessment of the reports and proposals presented by students. There is a wide variability in the quality of the proposals, the final ideas are creative and applicable to the problem studied, but there are groups that clearly have taken the activity more seriously than others have, which reflect a lesser effort and dedication. An indicator of this has been the little time dedicated to autonomous work that has an average of 11 hours (question asked in the satisfactory questionnaire). One of the main problems is that this is a complementary activity and therefore, the level of engagement is lower which, especially, decreases during the exam periods. Therefore, for future editions, the planning and schedule of the workshop should be improved.

![Figure 3: Evaluation of the initiative by the students.](image)

In this year’s edition, on the last day of the workshop a satisfaction survey created ad-hoc for the occasion was designed to collect the satisfaction of the participants. The survey was
short and direct. The students were asked to evaluate the different activities carried out (Figure 3) and indicate what they liked most and what they would improve.

The scores obtained from the student are high in general - from 7.7 to 9.5 - and the overall mark is 8.6. They highlight the support and advise of professors and the contact with the local world and the real problems. The least valued would be the sessions in the classroom with a 7.7, which shows the need and the good reception of this type of initiative based on bring the student closer to the real problems. Table 1 shows the positive comments and suggestions of improvement that the student has considered about the Workshop of El Vendrell:

<table>
<thead>
<tr>
<th>Positive Aspects</th>
<th>Improvement Suggestions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immersion in the future of work environment</td>
<td>Conciliation with other exams and tasks</td>
</tr>
<tr>
<td>It helps to conceive ideas to solve real problems of a municipality</td>
<td>Focusing directly in the solutions in the classroom sessions</td>
</tr>
<tr>
<td>Exposure of ideas and solutions in front of professionals and members of the city council</td>
<td>More interaction with the City Council; to know how they work, internal organization and how to carry out a project</td>
</tr>
<tr>
<td>Effective search for solutions to real problems</td>
<td>To understand clearly what should be the result of the workshop and the scope of the work to do since the beginning</td>
</tr>
<tr>
<td>Access and contact to Public Administration</td>
<td>Proximity of the municipality</td>
</tr>
<tr>
<td>The possibility of working on issues at municipal scale relate to urban planning</td>
<td>Creation of more debate in the classroom sessions instead of formal presentations</td>
</tr>
<tr>
<td>To apply the knowledge acquired during years to solve a real problem, with the advice of teachers.</td>
<td></td>
</tr>
</tbody>
</table>

The main positive aspects are the contact to the local environment and the real problems solving as well as the seeking for solutions and advice of professionals in the sector. Regarding the suggestions for improvement, it is varied but there is general concern for the conciliation of the workshop with the study plan.

To receive feedback from experts and stakeholders, they were also asked to indicate what they liked most and suggestions for improvement. In general, getting closer to the academic world is highly valued: "the interaction with students" and the "fact of exploring ways of doing and seeing things in a more open-minded way", while also proposing that the initiative could be exported to main courses to improve depth and reflection on proposals, which are sometimes too superficial.
5 CONCLUSION

This type of initiatives induces the synthesis, integration and implementation of the knowledge acquired during the degree in real situations. The initiative combines students and stakeholders as co-producers of knowledge to improve the built environment, infrastructures, technologies and offer holistic solutions to the challenges of society. Starting from a real demand of the society specially motivates and stimulates students. In addition, teamwork, in a multidisciplinary and cooperative way, promotes values that are necessary in the professional world.

Both editions, the case of Empuriabrava and El Vendrell, were very satisfactory to all the participants, including the stakeholders, the students and the professors. Participatory learning, peer learning and collaborative methods make it easier for the student to be in contact with multiple perspectives and generate creative responses to the problems posed. Critical reflection on the values and assumptions in some cases can rise to what is known as 'transformative learning', that is necessary to deal with complex problems and conflicts of values in our society. In addition, the disclosure of this type of initiatives contributes to enhance the role of the Civil Engineer and the Civil Works Engineer in our society at a time that, for contextual reasons of economic crisis and social change, its image has been affected.

However, in future editions, improvements must be made in the field of the evaluation of results and the transversal competences achieved, the time-planning and its coordination with the academic calendar.

These methodologies specially those related with service learning are not enough extended in the university, despite its recognition. We are aware that service learning requires an institutional involvement which may represent a challenge. However, we are convinced that it is worth the effort to integrate these pedagogical frameworks as they contribute to increase environmental awareness and social responsibility among participants.

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THE AUGMENTED REALITY SANDBOX AS A TOOL FOR THE EDUCATION OF HYDROLOGY TO CIVIL ENGINEERING STUDENTS

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Key words: Augmented Reality, Sandbox, Education, Civil Engineering, Hydrology.

ABSTRACT

The introduction of new technological tools in higher education seems to be of outmost importance since it enhances the ability of students to understand the function of natural phenomena or technical structures. Augmented reality tools offer the advantage of actual – or rather virtual - participation increasing the interest of participants and thus, their level of understanding. In this paper, an advanced application of the Augmented Reality Sandbox is presented.

The original A.R. Sandbox was the result of an NSF-funded project on informal science education for freshwater lake and watershed science developed by the UC Davis’ W.M. Keck Center for Active Visualization in the Earth Sciences (KeckCAVES), together with the UC Davis Tahoe Environmental Research Center, Lawrence Hall of Science, and ECHO Lake Aquarium and Science Center.

The application developed by the authors is adjusted to the educational needs of teaching hydrology to Civil Engineering students. Several improvements of the A. R. Sandbox have been developed by the authors, in order to provide to Civil Engineering students, the ability to better understand the concept of a watershed, of surface flow, of flooding and of the impact of constructions in the flow regime of rainwater.

The improvements made on the A. R. Sandbox developed at the Division of Hydraulics and Environmental Engineering, of the Department of Civil Engineering at the Aristotle University of Thessaloniki, refer to the introduction of simplified and user-friendly ways to change the scale of the map, the water level, and the intensity and duration of rainfall, the evapotranspiration etc.

Another significant improvement is the introduction of an automated procedure for the development of a 3-dimensional model and its direct transformation in order to be seen through Virtual reality (VR) glasses.
1 INTRODUCTION

The introduction of new technologies is very important nowadays in all levels of education, from kinder-garden to university. Children of all ages are so acquainted with computers that they are more acceptive and adaptive to educational procedures based on new technologies.

Augmented Reality (AR) devices have already infiltrated and altered traditional educational practices and appear to have a vast field of applications in several sectors. According to Milgram et al [1] the virtuality continuum is a continuous scale ranging between the completely virtual and the completely real. The reality–virtuality continuum therefore encompasses all possible variations and compositions of real and virtual objects. The area between the two extremes, where both the real and the virtual are mixed, is called mixed reality. This in turn is said to consist of both augmented reality, where the virtual augments the real, and augmented virtuality, where the real augments the virtual.

![Mixed Reality (MR)](image)

The field of education of engineers, and more specifically Civil Engineers, provides a very good field of application of this reality-virtuality continuum. The object of studies of Civil Engineers lies between the analysis of natural phenomena and the development of technical structures, with both lying on the real environment edge of the reality-virtuality continuum. At the same time, the development of computers during the past decades shifted the object of studies to computer-based simulation models, reaching the other end of the continuum, that of the virtual environment.

The representation of natural phenomena and technical structures with computer-based simulation models extends to all fields of study of Civil Engineers. The field of Hydrology is simulated for example with the Hydrologic Engineering Center - HEC series of models [2]. One of the most wide-spread model for the simulation of groundwater aquifers is MODFLOW [3]. A series of Civil Engineering constructions are simulated with the finite-element software ANSYS [4]. And this is just an indicative, and of course non-exhaustive, list of simulation software used in the education and professional practice of Civil Engineers.

This approach, leaves a significant field of development for applications within the so-called Mixed Reality space in the Reality-Virtuality continuum. As very emphatically stated by Bower et al. [5], “Augmented Reality is poised to profoundly transform education as we know it. The capacity to overlay rich media onto the real world for viewing through web-enabled devices such as phones and tablet devices means that information can be made available to students at the exact time and place of need. This has the potential to reduce cognitive overload by providing students with “perfectly situated scaffolding”, as well as enable learning in a range of other ways.”

One of these Augmented Reality applications attracting the interest of Engineers, is the A.R Sandbox. More details about the A.R Sandbox will be presented in the following paragraphs.
2 DESCRIPTION OF THE A.R. SANDBOX

The augmented reality (AR) Sandbox combines 3-dimensional visualization applications with a hands-on sandbox to teach earth science concepts [6]. The AR sandbox allows users to create topography models by shaping real sand, which is then augmented in real time by an elevation color map, topographic contour lines, and simulated water flow. The system teaches geographic, geologic, and hydrologic concepts such as how to read a topography map, the meaning of contour lines, watersheds, catchment areas, levees, etc.

The AR Sandbox comprises the following hardware components:
- A computer with a high-end graphics card, running Linux.
- A Microsoft Kinect 3D camera.
- A digital video short-throw projector with a digital video interface, such as HDMI or DVI.
- A sandbox with a way to mount the Kinect camera and the projector above the sandbox.
- Sand.

A typical arrangement of the projector and the Kinect 3D camera above an AR Sandbox is shown in Figure 2. The short-throw projector is mounted at the same height as the Kinect camera, but above to the rear long edge of the sandbox to account for its above-axis projection [6].

![Figure 2: Typical arrangement of an AR Sandbox [2]](image)

Raw depth frames arrive from the Kinect camera at 30 frames per second and are fed into a statistical evaluation filter with a fixed configurable per-pixel buffer size. The resulting topographic surface is then rendered from the point of view of the data projector suspended above the sandbox, with the effect that the projected topography exactly matches the real sand topography. The software uses a combination of several GLSL shaders to color the surface by
elevation using customizable color maps, and to add real-time topographic contour lines [7].

At the same time, a water flow simulation based on the Saint-Venant set of shallow water equations, which are a depth-integrated version of the set of Navier-Stokes equations governing fluid flow, is run in the background using another set of GLSL shaders. The simulation is an explicit second-order accurate time evolution of the hyperbolic system of partial differential equations, using the virtual sand surface as boundary conditions. The simulation is run such that the water flows exactly at real speed assuming a pre-defined 1:100 scale factor [7].

The software that performs all these tasks is available for free download from the developers at UC Davis [8].

3 IMPROVEMENTS AND ADJUSTMENTS OF THE A.R. SANDBOX

The AR Sandbox of the Aristotle University of Thessaloniki was developed with co-funding by the Erasmus+ Program of the European Union, «Educational Lab – Big Machine – ElBigMAC» [9]. It was originally developed following the detailed instructions provided by the UC Davis [6, 7, 8]. A series of changes and improvements were then developed by the authors in order to adjust the AR Sandbox to the needs of Hydrology courses for Civil Engineers. These adjustments are described in the following paragraphs.

![Figure 3: The A.R. Sandbox of the Aristotle University of Thessaloniki](image)

3.1 Scale of the map

The AR Sandbox has a pre-defined scale factor of 1:100. The scale factor does not affect the topographic representation, but it affects the water flow. This relatively small scale, provides an impressive, but not very realistic, representation of the water flow. The authors added an external button to the device through which the user can adjust the scale factor to a level more suitable to the map of the area under investigation.
3.2 Water level

The water level is a contour that separates areas of the map covered by water, from dry ones. Depending on the level of water, more or less areas of the map are presented to be below or above water. This level can be adjusted by changing the respective values within the code of the software. This is not very easy to do and thus we decided to add another external button through which the user can adjust the water level. Thus, by turning left or right the button, the user sees the water rising or dropping.

3.3 Intensity and duration of rainfall

The ability of the user to define the intensity and duration of rainfall is very important for a realistic hydraulic simulation. This was accomplished again by introducing buttons that simulate rainfall when pressed. Rainfall “stops” when the button is released. One of the future developments that we plan to introduce, is to connect the AR Sandbox to on-line meteorological stations and represent actual rainfall phenomena.

3.4 Evapotranspiration

In the same way as above, a button introduces evapotranspiration, reducing the amount of rainfall that actually outflows along the slopes of the watershed.

3.5 Three-dimensional model

Last of the improvements we have introduced to the original AR Sandbox, but definitely not least, is the introduction of an automated procedure for the development of a 3-dimensional model and its direct transformation in order to be seen through Virtual reality (VR) glasses. Through a special software we introduced, the topographic surface is transformed into a 3-D model and adjusted so that it can be viewed through VR glasses. This was tested with a set of HTC VIVE VR glasses (figure 4).
4 APPLICATION OF THE A.R. SANDBOX IN HYDROLOGY

The AR Sandbox of the Aristotle University of Thessaloniki was suitably adjusted in order to be used by students following Hydrology classes at the Department of Civil Engineering. The procedure followed is the following:

The map of a watershed with known characteristics is selected and it is projected through the short-throw projector of the device, onto the sand. The students try to replicate, using the sand, the topographic surface of the watershed adding or removing the sand across the sandbox. In order to achieve that, they change the projected image between the map of the watershed and the image recognized by Kinect.

After completing this task, it is assumed that the distribution of the sand across the sandbox actually represents the topographic map. The scale factor is set according to the one of the topographic map and the water level is suitably adjusted.

The next step is to simulate rainfall using all the additional buttons that were introduced. Thus, the users can change the intensity and duration of rainfall and reduce runoff by increasing evapotranspiration.

Then the AR Sandbox’s software solving the Saint-Venant set of shallow water equations, which are a depth-integrated version of the set of Navier-Stokes equations governing fluid flow, represents the flow of water. The students can actually see water flowing along the slopes of the watershed and across the riverbed. When the amount of water exceeds a certain level, then flooding occurs.

Students can also introduce flood-preventing measures, like small dams, or water deviations, to investigate their impact and usefulness.

By adjusting the water level value, students can also simulate the effects of sea water rise due, for example, to the impacts of climate changes.

Future plans include, the connection of the AR Sandbox to on-line meteorological stations operated and managed by our department, in order to make rainfall simulation more realistic. Also, an even denser discretization of the scanned by Kinect, area will result in more detailed representation of the watershed’s characteristics. The only problem with this option is that, denser discretization will result in more complex systems and may cause a delay between changes made in the sand and their projection by the device.

The final intervention made to the Sandbox, is the three-dimensional analysis of the topographic map, its suitable transformation and its projection through the Virtual Reality glasses. The whole procedure is uploaded to a cloud server and it can be downloaded and used...
simultaneously by students located all over the world. This was already successfully tested with university students located in another country. The only problem is that due to this time-consuming procedure, the response was not immediate, but it took a few minutes from the moment the users of the AR Sandbox made some changes to the moment these changes were viewed by the VR glasses users.

The result was that students located far away from the AR Sandbox could “see” the watershed and virtually move around it viewing all the characteristics of the landscape.

5 CONCLUSIONS

The introduction of new technologies is definitely the future of education. In order to attract the attention of students of all ages, teachers need to improve and modernize their practices taking advantage of the opportunities arising from the development of new technologies. In between the actual experiments, characterized as real environment and their simulation models, characterized as virtual environment, lies the space where actual intervention of users is combined with the virtual environment. This space is known as augmented reality. The profession of Civil Engineering is a typical example of parallel applications of experiments and simulation models. This is why, augmented reality systems have a very wide field of applications in Civil Engineering.

In this paper the Augmented Reality Sandbox developed under the original instructions of UC Davis but improved and extended by members of the Aristotle University of Thessaloniki, is adjusted to the educational and research needs of the scientific field of Hydrology for Civil Engineers. The results, but also the comments and reactions of the students who had the opportunity to use the device during their Hydrology classes, indicate the opportunities that arise from future implementation of augmented reality technologies in higher education study programs.

6 ACKNOWLEDGMENT

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CHALLENGES OF THE EDUCATION IN CIVIL ENGINEERING

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Key words: Education, Civil Engineering, Entrance examination

Abstract. This paper presents a new strategy to organize the entrance examination at the Universities. It is based on the idea of free movement inside the university, following the interest and success of each student individually. It guarantees in addition that each discipline and department will get students with relevant basic education without any compromises. The strategy is very liberal and gives a student a possibility to choose his/her field by taking into account their own interest, but is then strict with all the requirements set for the education. It will also smooth all compulsory courses, which do not support directly the objective of major studies.

1. INTRODUCTION

Civil engineering has traditionally been rather theoretical and based strongly on Mathematics and Physics. Nowadays however, the basic education, starting already from high schools, has as compared to previous education, only restricted contents of Mathematics, yielding huge gaps in mathematical capability and in logical problem solving preparedness of new student generations.

As a teacher of Structural Mechanics, I meet continuously Master-students who do not know what trigonometric functions are, or how to differentiate them, or even worse I meet students who have still more fundamental lacks for example in calculating with numbers. It is extremely challenging to teach them successfully some more sophisticated theories of mechanics. I see that the role of mathematics is irreplaceable in the development process of a young student to use his/her own brain and thinking, in addition to give tools to solve various mathematical equations encountered, and also as a tool to develop individual's capability to logically formulate and solve various problems.

Civil engineering has not been the most popular subject between students when they are after the high school studies choosing their discipline for the future and entering Universities. Therefore, those ones who are not most talented nor interested in mathematical subjects, will often apply for engineering sciences, including both civil and mechanical engineering. The general opinion is believing that computers are taking care of all unattractive computation needed in the area. In the studies then, the weak fundamental knowledge of basics does not generate bigger interest in theoretical studies and the study years will increase. But because the Universities have defined at the same time their goal in shortening the years students will use for their studies, it is more or less forbidden to let them fail in examinations. This would catastrophically lengthen the study times. Finally, this path lead to the situation where the traditional knowledge of the graduates is alarming low. The results can be seen more and more
often in collapsing roofs and structures and numerous other problems and accidents in construction field.

Another problem inside civil engineering is due to the continuous need to extend the action field, covering many areas, which belong as a matter of fact to other disciplines as biosciences, chemistry etc. Consequently, the need for the contents of Bachelor studies on various areas of Civil Engineering is very different. However, at the Universities, the idea about common fundamental studies for all civil Engineering students is very strong, and therefore the contents adopted must be a compromise, which actually does not satisfy the needs of anybody.

2. HISTORY

The concept of Engineering has been originally devoted for Civil Engineering only, because no other engineering field was yet discovered. It covered all the activities on technical or theoretical technology for civil purposes - as opposed to the war technology. At Aalto University, Finland, even the student union was named as Engineering Guild, because no competing engineering area did exist. Much later, the concepts of Mechanical and Electrical Engineering guilds were launched and founded. Civil Engineering guild however saved the name Engineering Guild. In some countries, for example in Sweden, the concept of Civil Engineering covers all of the engineering areas, including Mechanical and Electrical Engineering.

Originally, the concept of engineering was connected to construction technology only. It covered erection of bridges, palaces, cathedrals, roads, water pipes and channels, etc. Civil engineering, in the way it is defined nowadays in Finland is a continuously and rapidly expanding area. It has never been a scientific discipline but serves as a field of applications for pure sciences, Mathematics, Physics, Chemistry, etc.

If we go backwards in the history, architects have been responsible of the design of structures, and also of building them up. They never needed any mathematical tool nor any calculations. Everything was based on experiences from previous generations and on the existing knowledge. When Galileo as a scientist started to study – actually as the Professor of Strength of Materials or Structural Mechanics – and developed various models to describe the behavior of structures under various loadings, the architects resisted strongly this kind of development by saying, that all the existing bridges, cathedrals and palaces were built up without any mathematical equation, and it is thus unnecessary to change the working practice.

Isaac Newton, who was a Mathematician realized in his time

‘Structural Mechanics is the paradise of mathematical science because here we come to the fruits of mathematics’.
Following Newton, the development in the design of structures was directed in increasing amount to mathematical applications and novel theories were invented continuously. Building up the American railways was a huge step forward in bridge engineering, and thus in Civil Engineering.

At the Universities, the development of the education in Civil Engineering was strongly based on Mathematics up to 1980’s. Starting from the primary and secondary schools through the high schools, Mathematics and Calculus, including Algebra and Differential Geometry, were the corner stones of the whole education path in engineering field.

In the 1970’s, when I started my studies at the University level, the basic education of Civil Engineering was composed of the same courses of Mathematics as the syllabus of students of Physics. Consequently, the whole study path was strongly mathematically oriented. These generations got a really strong theoretical education in Civil Engineering. The development has ended up in recent times to the situation, where the contents of Mathematics has gone down and covers only about ten percent of that presumed 50 years ago. The high school education has gone down in Mathematics as well, giving a very weak basis for students to find the enthusiasm in this area. The problem has come immediately to Universities as well. This development cannot be argued by the rapid development of numerical computation technique and effective computers. Vice versa, understanding well the results obtained from numerical computations requires a many-sided fundamental comprehension about the correctness of the results and methods applied.

The syllabus of Civil Engineering education at the Universities is very problematic. As a discipline, Civil Engineering is not very popular. Young people who are interested in pure sciences direct their studies to Theoretical Physics, Mathematics and Chemistry. Those ones, who are more interested in Economics, will study Industrial Economics and Management etc. Among students, there is a competition on these most popular fields, and consequently, Civil Engineering is often the looser in this competition. The students coming finally to Civil Engineering are not the most talented ones nor interested in mathematical subjects.

The biggest problems concern those areas in Civil Engineering which are dependent in Mathematical analysis. Thus, the Structural Mechanics, where a strong basis in Mathematics is a necessity, is in problems. This is really not the first comment of this fact. It was noticed for example by Stephen Timoshenko who wrote already about hundred years ago:

‘Later at universities in America, as a professor I encountered students who lacked proper mathematical training. I saw how this affected the level of teaching, which had to be lowered, adjusted downward to the students’ level of preparation. Insufficient mathematical training has undoubtedly exerted great influence on the attitude of students toward the science of engineering. The American student, in most cases, is not interested in deducting any kind of formula, or in the basic assumptions underlying such deduction. All he wants is the final result – a formula which he can apply mechanically, without thought, to solve practical problems. It is my belief that the defectiveness of the mathematical education offered in American secondary schools during the early part
of this century was one of the main reasons for the low level of development of the engineering sciences in the United States’.

Civil Engineering is a discipline, which is expanding rapidly. The original areas for the first Professorships were Bridge Engineering, Road Engineering, Water Resource Engineering and Geoengineering. To the recent times, new fields have been created, and will be created continuously. Biggest changes are concerning Building Technology with at first, separate professors and majors concerning all the building materials, concrete, steel and timber. Very important part has been Design of Structures, Structural Mechanics and Numerical Analysis. In addition, Majors in Building Economy, Management, Building Information Modeling (BIM) and Real Estates have been established. Still, Fire Safety Engineering, Building Physics, Building Services Technology, Heating Ventilation and Air Conditioning (HVAC) and Acoustics have own fields and professors. Newest areas in Civil Engineering are Inside Air Technology with links to Micro Biology, Clean Technology and Green Building Technology. The Geoengineering has expanded to the Geology, Geophysics and Rock Mechanics. In addition still, Transportation Engineering, Traffic Psychology and Environmental Techniques have widened the concept of Civil Engineering. A question will arise, in what way is the concept of Civil Engineering actually defined?

Fig 1: Map over Civil Engineering

It is not difficult to understand, that the need and requirements for the basic education in all these subfields is very different. Building up a common Syllabus for Bachelor studies in this way is impossible, or it will be a strong compromise, which does not satisfy anybody’s needs. This is however the practice adopted in most Universities.

3. A NOVEL MODEL TO ORGANIZE BACHELOR STUDIES

When renewing the syllabus for Bachelor studies at Aalto University in 2011-2013, an alternative model was introduced. The most important pushing power or goal for this proposal was to move simply to the students themselves, the responsibility of their own studies. But at the same time, to give them the freedom to control and steer their own study paths up to the
Master level. One obvious goal for this proposal was also that every single major topic at the University will get in students provided with the necessary and relevant basic education – opposite to the strong compromise between all areas.

Practically this can be realized in the way where every single major subject at the University on Master level will choose those basic courses, which form necessary pre-requisites for studies, and allow successful continuation in this major. But it is fully free for a student to choose his/her major subject according to his/her own interest or success or any other reason. The size of Bachelor studies is all together 180 credits, of which we can assume that 60 credits will be taken by some general studies and Bachelor thesis. There are then 120 credits to be used for preparing professional studies. If we assume that each course consists of 10 credits, there are twelve courses covering the Bachelor education. Now, each major field can fix, say eight courses, which will be presumed to be passed before starting studies in this major. Four courses can thus be chosen freely by the student to support and complete the preparedness for the major he/she has chosen. Appropriately, this means that choosing the major a student has fixed eight courses for his/her Bachelor studies. This keeps the door open to the major chosen. By choosing the four additional courses, a student can open the door to some other majors. Doing this choice cleverly, he/she can prepare the entrance to the major alternatives, which are placed on the second and third place in his/her interest list. It will be very useful to do wise choices if for example the most interesting major is as popular that all interested students can not be accepted. Thus the qualification will take place according to the success in studies generally.

Later in the continuation of studies, a student can find out that he/she has done a wrong choice, and would like to choose some other major to replace the previous choice. Then, he/she can remove those courses from his/her program, which are no more conditional, and replace them with the courses to follow the requirements due to the new main major alternative. Those courses, which have been done already, will be utilized, and nothing will be loosed. This operation will close the door to the major area chosen at the first step, but open doors to some new major alternatives. And everything will be done according to the own interest of a student to be graduated in the field of his/her own interest. The contents of the study program will be changeable until the final term of Bachelor studies.

It will be emphasized that a student will have a possibility to choose the contents completely according to his/her own interest. The system takes care that the Master studies will always have relevant starting point with fixed prerequisites, and there is no need any more to talk about compulsory courses, which are not useful nor necessary in the studies on certain field.

At Aalto University, where three separate Universities have formed a merger allowing technology to meet art and economy in common surroundings, it is still possible to take a couple of additional steps. Each of these three fields have traditionally had own examinations for students to get into the University, and the requirements have been built up to support the goals of each field separately. The contents of the studies have however been assumed to be chosen mainly from the supply of each area separately. Now, it would be interesting to liberate still the praxis, by allowing all the students choose their studies on the supply of the whole University, independently of which type of examination they have attended to get into the University. This would fully release us from the limiting thoughts that only artistic people can have creativity, and vice a versa, as the situation is for example in the cooperation between architects and engineers. All the properties of young people could be utilized effectively.
4. CONCLUSIONS

The level of Universities and of excellence of graduates has been decreasing rapidly. Something really has to be done in the continuation to guarantee that we will still have excellent capable engineers on all the fields of Civil Engineering. The situation is at least very worrying when more and more complicated monumental buildings, bridges and other structures will be designed. It is a necessity that anyone can go without fear of the collapse into any building or walk underneath any bridge.

REFERENCES

TEACHING AND EVALUATING GENERIC STUDENT OUTCOMES AT THE SCHOOL OF CIVIL ENGINEERING IN VALENCIA (SPAIN)

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Keywords: Education, Civil Engineering, Generic Student Outcomes.

Abstract. This paper presents a review of teaching and evaluating methods of generic student outcomes in the Civil Engineering degrees at the School of Civil Engineering in València (Spain). First, the institutional project of Generic Student Outcomes that is being implemented at the Universitat Politècnica de València is described. Second, teaching and evaluation methods of generic student outcomes that are being applied in different Civil Engineering courses are analyzed. Methods more suitable for basic and engineering courses are identified for each generic student outcome. Conclusions regarding advantages and limitations of using each teaching and evaluation method are outlined.

1 INTRODUCTION

The project on UPV Generic Student Outcomes [1] (UPVGSOs henceforth) is a Universitat Politècnica de València (UPV from now on) initiative supported by the UPV2020 strategic plan, in which the university assumes its first challenge:

... the Universitat Politècnica de València aims to progress towards training models which allow its students to acquire the skills needed to become suitably employable. This training should be seen from a wide perspective, linked with the full education cycle of each person, addressing both undergraduate and postgraduate studies.

To a small and large extent, the specific Student Outcomes are taught, worked on, and acquired by students; they become qualified by passing different subjects in the degree programs. However, other types of skills included in the definition of these degree programs do not receive the same attention. In general, they are assigned to different subjects/courses, but it is difficult to ensure that they will systematically be worked on and evaluated; therefore, it cannot be guaranteed that they will be acquired.
On the basis of the definition of the 13 Generic Student Outcomes, UPV considered that all its graduates should acquire these outcomes having finished their studies. Therefore, the following objectives are addressed:

- Systematize and guarantee the procurement of UPVGSOs in the training of students using different complementary paths or strategies.
- Design systematic UPVGSOs evaluation processes and strategies which consider both the individual results of each student and the aggregate information for analyzing and possibly improving the degree.
- Accredit and make the set of results acquired by students more prominent.

2 UPV GENERIC STUDENT OUTCOMES

The UPV Generic Student Outcomes correspond to skills which are key and transferable in relation to the wide variety of personal, social, academic, and employment contexts encountered throughout graduates’ lives. In this sense it constitutes a fundamental part of the professional and formative profile of all or the majority of degrees. It deals with the skills which include a set of cognitive and metacognitive skills, and instrumental and attitudinal knowledge which are of great value to the knowledge society (Andrews and Higson, 2008).

UPV Generic Student Outcomes are characterized as being:

a) Integrative, given that they favor the integral training of our students.
b) Transferable in the contexts of academia, employment, personal, social, etc.
c) Interdependent, because when they work on a skill, it is normal for them to develop other related skills.
d) Multifunctional, meaning students become versatile and capable of tackling different types of problems.
e) Assessable, because the outcomes should be broken down into leaning results allowing the accreditation of the level achieved by each student.

The thirteen UPV Generic Student Outcomes, which encapsulate the competency profile of all UPV graduate students, are as follows (Table 1):

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<th>Table 1. UPV Generic Student Outcomes.</th>
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<tr>
<td>1. Comprehension and integration</td>
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<tr>
<td>Demonstrate an understanding and integration of knowledge in both the student’s own specialization, and other wider contexts.</td>
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<td>2. Application and practical thinking</td>
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<td>An ability to put theoretical knowledge into practice and plan the process to be followed, develop and conduct appropriate experimentation, and analyze and interpret data to draw conclusions.</td>
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<td>3. Analyzing and solving problems</td>
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<td>Analyze and solve problems effectively by identifying and defining the significant elements of which they are composed.</td>
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<td>4. Innovation, creativity, and entrepreneurship</td>
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Innovation and entrepreneurship in the form of a satisfactory and original response to personal, organizational and social needs and demands.

5. Designs and projects
Effective design, control, and evaluation of an idea until it becomes a specific project.

6. Teamwork and leadership
Work with and lead a team effectively in order to achieve common objectives while contributing to the personal and professional development of its members.

7. Ethical, environmental, and professional responsibility
Show ethical, environmental, and professional responsibility towards oneself and others.

8. Effective communication
Effective oral and written communication with proper use of the appropriate means, and bearing in mind the requirements of the situation and the person receiving the message.

9. Critical thinking
Develop the ability to think critically and consider the fundamental concepts behind student’s and others’ ideas, actions, and judgements.

10. Awareness of contemporary issues
Identify and interpret contemporary issues both in student’s own field, and other fields of knowledge.

11. Life-long learning
Strategic, independent and flexible use of knowledge in accordance with the desired objectives throughout student’s professional career.

12. Planning and time management
Appropriate planning to make the best use of the time available, programming the required activities to reach the desired academic, professional, and personal objectives.

13. Specific tools
Select and apply as appropriate the tools, technologies and, in general, the instruments available in any operations related to design and projects in student’s professional field.

3 CIVIL ENGINEERING DEGREES AT THE SCHOOL OF CIVIL ENGINEERING IN VALÈNCIA

The School of Civil Engineering at the Universitat Politècnica de València offers Bachelor’s degrees in Civil Engineering and in Public Works Engineering, and a Master’s degree in Civil Engineering (Figure 1). Bachelor’s degrees envisage four years with 60.0 ECTS (European Credit Transfer System) credits each, for 240.0 credits. Required courses, where UPVGSOs are included, comprises 208.5 credits, which are classified in Basic Courses (76.0 credits), Common to Civil Engineering courses (63.0 credits), and Civil Constructions Specialization (46.5 credits). Bachelor's Degree in Public Works Engineering program contains 12.0 Basic Credits less than its Civil Engineering counterpart. Bachelor's Degree in Public Works Engineering includes 57.0 ECTS of elective courses in third and fourth year, which permits students to specialize in Civil Constructions, Hydrology or Transport and Urban Services.

Once the degree is completed, students will be able to access the Master’s degree in Civil Engineering, which is taught in two academic years and 120.0 ECTS Credits. Required courses for those students that access from the Bachelor’s degree in Civil Engineering includes 97.5 credits. If the student accesses from Bachelor’s Degree in Public Works Engineering, then the number of required credits are 115.5, which include 18.0 additional credits on Selective Elective courses to complement their Civil Engineering specialization.
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(*) Maximum of 4.5 Credits of External Internships

### B.Sc. DEGREE: CIVIL ENGINEERING

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(*) Maximum of 4.5 Credits of External Internships

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**Figure 1:** Civil Engineering teaching scheme at Universitat Politècnica de València. Bachelor’s degrees in Civil Engineering and Public Works Engineering, and Master’s degree in Civil Engineering.
4 TEACHING AND EVALUATION METHODS OF UPV GENERIC STUDENT OUTCOMES

A variety of teaching methods and techniques to evaluate the degree of acquisition of generic student outcomes exist [3, 4, 5]. In this section, we review and analyze the teaching and evaluation methods used in Civil Engineering degrees at UPV.

4.1 Teaching methods

The teaching method to develop UPVGSOs most frequently used in basic courses of the Civil Engineering degrees at UPV is Laboratory Activities (see Figure 2). Basic courses include many hours of this type of activities, so it is logical to take advantage of them to develop UPVGSOs. Group Activities is the second most utilized teaching method. Other important teaching methods are Site Visits, Readings, Problem Resolutions, Lectures and Writing Reports. There is a great variety on teaching methods, which reflects well the diversity of contents included in basic courses in Civil Engineering degrees.

![Figure 2. Teaching methods in basic courses of Civil Engineering degrees at UPV](image)

Common to Civil Engineering courses utilized largely Writing Reports to teach UPVGSOs (see Figure 3). Frequently, those reports include the resolution of problems directly related to any of the Civil Engineering field of work. Laboratory and group activities are also important teaching methods in this type of courses. Other methods are oral presentations, discussions and questions and problems.
Figure 3. Teaching methods in Common to Civil Engineering courses of Civil Engineering degrees at UPV

Laboratory Activities is also the main teaching method to develop UPVGSOs in specialization courses (see Figure 4). In this case, Lab Activities are more related to the resolution of practical problems using computer rooms. Projects is an important teaching method in this type of courses. Others teaching methods are Group Activities, Oral Presentation, Writing Reports and Cases Studies.

4.2 Evaluation methods

The method to evaluate the degree of acquisition of UPVGSOs most frequently used in basic courses of the Civil Engineering degrees at UPV is Oral Presentations (see Figure 5). Control Lists and Multiple Choice questions are also utilized. Other important evaluation methods are Open-Answer Questions and Writing Reports.

On the other hand, Rubrics is the main evaluation method to develop UPVGSOs in Common to Civil Engineering courses (see Figure 6). Writing Reports and Observation are important evaluation method in this type of courses. Other evaluation methods are Laboratory Activity methods, Cases Studies resolution, and Control Lists.

Writing reports is the main method to evaluate the degree of acquisition of UPVGSOs in Specialization courses (see Figure 7). Other evaluation methods are Laboratory Activities, Rubrics, and Oral Presentations.
Figure 4. Teaching methods in Specialization courses of Civil Engineering degrees at UPV

Figure 5. Evaluation methods in basic courses of Civil Engineering degrees at UPV
Figure 6. Evaluation methods in Common to Civil Engineering courses of Civil Engineering degrees at UPV

Figure 7. Evaluation methods in Specialization courses of Civil Engineering degrees at UPV
5 CONCLUSIONS

This paper describes the institutional project on Generic Student Outcomes (UPVGSOs) of Universitat Politècnica de València, and how it is being implemented in the Civil Engineering degrees of the School of Civil Engineering. All UPV students should have acquired 13 UPVGSOs when they finish their degrees.

Two Bachelor’s and one Master’s degrees in Civil Engineering are offered in the School of Civil Engineering at the UPV. Both Bachelor’s degrees comprises courses classified into Basic Sciences, Common to Civil Engineering, Specialization, and Bachelor’s Thesis, with a total of 240 ECTS credits. The Master’s degree in Civil Engineering includes courses classified into Basic Sciences and Specialization.

More than ten different teaching and evaluation methodologies are used to develop UPVGSOs in all Civil Engineering degrees. Laboratory, Group Activities, Writing Reports and Projects are the most used teaching methods. Oral Presentations, Writing Reports, and Rubrics are the most used evaluating methods.

The School of Civil Engineering is working to improve the adaptation of each teaching and evaluation method to the UPVGSOs and the objectives of each course. In particular, other teaching methods that best suit to particular generic student outcomes will be promoted. Examples are Creativity Techniques, DAFO Analysis, and Learning Agreements.

REFERENCES


NETWORK INTERACTION OF RUSSIAN UNIVERSITIES

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Keywords: integration of science and education, international cooperation and interaction.

Abstract. There are presented models of network interaction between russian and foreign universities of Russian Academy of Architecture and Construction Sciences (RAACS) in the implementation of educational specialists’s programmes in a priority development direction of "Urbanistics". In the article are given examples of network implementation models with the participation of the department "Building production and geotechnics" of Perm National Research Polytechnic University.

Introduction
The modern conditions originate a necessity for training of highly qualified engineering staff in one of priority directions of scientific and technological complex of Russia "Urbanistics". The main difficulty in solving of this problem is the lack of resources for the logistical support of modern scientific and laboratory facilities of higher education institutions (HEI) and the lack of a sufficient number of scientific and pedagogical staff - doctors.

Russia national research universities (NRU) network Development has created the necessary scientific and laboratory facilities for the preparation of engineering and scientific personnel. At the moment rapidly establishing research and educational centers (RECs) within the integration of education and science, combining the resources of several universities, with the participation of leading Russian and foreign experts on various priority science, engineering and technology directions. Traditionally, they are created for the main scientific direction, specific to the region, the university, the scientific school, which are the basis of the REC. Their goal is to achieve world-class scientific results on a wide range of research, consolidation in the field of science and education of scientific and pedagogical personnel, the formation of effective and sustainable research teams [1].

The following options are proposed for possible universities network interaction models in the preparation of engineering and scientific personnel on "Urbanistics" priority direction.

1. Model of network interaction within the interuniversity cooperation

Within the interuniversity cooperation the simplest model of network cooperation between universities with the Russian and foreign experts involvement is presented. There is a consolidation of higher educational institutions into the system, in which the university, being before the former completely independent unit, is becoming accepted as one of the cells. At the same time network of such cells is very different, and the cells themselves are too.
The network interaction advantage of this type is that it allows to realize specific basic educational programme training in the framework of higher education by breaking it into separate educational modules, which could be learned in various universities. In this case, the student has the right to choose a place of learning a particular individual educational module in the university, where, by his opinion, there is a competitive advantage and is guaranteed the highest quality training in this section of the educational programme. This allows to provide an students academic mobility, which is an important mechanism for implementing competence-modular approach in education.

Within the framework of interuniversity cooperation, Russia is represented in the European Network for Accreditation of Engineering Education (ENAEE) and, along with the public-professional organizations of Great Britain (ECUK), France (CTI), Germany (ASIIN) and other countries, has right to assign to accredited programs European quality mark EUR-ACE® Label http://www.enaee.eu [2]. This network interaction contributes to exchange of students and established in teaching on the dual educational programmes particularly well. Students, which are studying in this network, get a wider scientific and technical high level education, together with the cultural experience by visiting educational institutions in two or more leading technical universities.

At present time there are signed the contracts of mutual cooperation between the Perm National Research Polytechnic University (PNRPU, Russia), Technical University of Vienna (Austria), University of Applied Sciences (Germany), Volgograd State University of Architecture and Civil Engineering (VSUACE, Russia), Kazan State University of Architecture and Construction (KSUAC, Russia), Novosibirsk State University of Architecture and Construction (NSUAC, Russia), St. Peters burg State University of Architecture and Construction (S-PbSUAC, Russia), Northern (Arctic) Federal University (NFU, Russia), South-Russian State Technical University (SRSTU, Russia), Poltava National Technical University (PNTU, Ukraine), Technical University of Prague (Czech Republic).

Fig. 1. The BPG department teaching staff participation in international and domestic public organizations
A new form of educational and scientific activity is a short-term involvement of leading professors of Russian and foreign universities in the organization of master classes with the participation of leading experts of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE), the International Geosynthetics Society (IGS), the German Geotechnical Society (DGGT), Russian Society for soil Mechanics, geotechnical and Foundation-building (RSSMGF).

In the framework of studies on the higher education problems development the employees of the Building Production and Geotechnics department participated in All-Russian National Conference with international participation “Deep footing and geotechnical problems of the territories” in the period from May 29 to May 31, 2017. The conference was held at Perm National Research Polytechnic University (Russia).

Master classes of leading European geotechnical specialists were held:
- Mario Mansero (Italy), The Polytechnic University of Turin professor with the report “The swelling and osmotic properties of clay soils Modeling”;
- Erol Guler (Turkey), Bosphorus University professor with the report “Advantages of using geosynthetics”;
- Rolf Katzenbach (Germany), Darmstadt University of Technology professor with the report “Optimized design and independent peer review of foundations and other complex underground structures”;
- Serge Varaksin (France), the “Menard” company director with the report “European contribution to soil improvement related to major historical events in the quality control field and application in Russia”.

Fig. 2. Participants of the summer geotechnical school on the basis of PNRPU (Russia) together with the Magdeburg-Stendhal University of Applied Sciences (Germany) on June 13-17, 2017

25 German students of the Civil Engineering Faculty from the Saxony-Anhalt state capital accompanied by professors Ulrich Turchinsky and Sven Schwerdt listened to leading
geotechnical experts lectures, got acquainted with the laboratories, new master's programs and research results carried out at the “Building Production and Geotechnics” department.

In addition to valuable scientific knowledge, the school participants received unforgettable impressions from visiting the Perm museums, the planetarium and the Kungur ice cave.

- It was an unforgettable trip. We really liked Perm. We visited many interesting places. Also we listened to the lectures of leading specialists, visited the laboratory of the “Construction Technology and Geotechnics” department. I and my group mates seriously thought about the possibility of studying at a magistracy at Perm University, - the Magdeburg university student (Christian Dannenberg) shared.

At the “Building Production and Geotechnics” department it is proposed to establish scientific and educational center to support the construction of urban areas within the priority development direction "Urbanistics" for carrying out world-class research and development, for implementing effective principles and integration forms of building science, education and business.

On the internships scientific and pedagogical staff basis there is carried out the scientific and methodological support of the international scientific and educational cooperation. There have been further developed joint scientific and educational programmes and projects with foreign partners. The problems of harmonizing regulations of construction documents in Russian and Germany with the geotechnical aspects in the construction in large urban agglomerations are investigated.

2. The regional model of networking of higher education institutions on the national research universities basis

At the present stage of economic development, the construction industry in Russia and abroad is experiencing a significant need for qualified specialists in the design and implementation of construction works "zero cycle" in dense urban areas. The current situation in the market of construction services shows that the most attractive thing for potential investors is the construction at central regions in large cities. Transition from standard construction on the free territory to reconstruction and new construction in difficult conditions of dense urban development is an urgent task for all participants of the modern construction complex in Russia, in the near and far abroad and in the Perm region in particular.

Therefore, at the present time, both for the construction contractors and for designers there is the challenge in the speedy implementation of modern Geotechnology construction, providing on the one hand, production work sparing modes on the existing buildings and engineering structures, and on the other hand guarantees the newly constructed building objects high reliability. One of the limiting factors in the widespread development of such technologies in the Perm region of Russia is currently the lack of civil engineers capable of solving complex geotechnical problems for the development of underground space and urban areas, taking into account the existing historical and cultural development.

One of the important mechanisms for the scientific principle implementation is research and education integration, which results in the creation of scientific and educational center on "Urbanistics" priority direction.

It should be emphasized that the scientific and educational center results should not be the new scientific product only, but a graduate student also, who can introduce scientific development into real production. In this sense, Education and Research Center (REC) is a business incubator that allows young researchers to inculcate the skills of innovation.
It can be distinguished the following types of research and educational centers:
1. Independent institutions realizing research, education and innovation.
2. Interuniversity research and education centers.
3. Independent innovation division leading university, implementing interuniversity cooperation in the selected research directions.
4. Research and Education Center at the university that is developing fundamental scientific directions.

The scientific and educational center is created as a structural subdivision of the University to perform the following tasks:
– meeting the needs of the individual in the intellectual, cultural and moral development through the receiving of higher and postgraduate education;
– meeting the needs of enterprises for qualified specialists with higher education and highly qualified scientific personnel;
– organizing and conducting fundamental, search and applied scientific researches on priority direction of "Urbanistics”;
– attracting highly qualified specialists of sectoral international research institutes and the Russian Academy of Sciences in joint educational activities;
– development of new programmes and methods to advance implementation of international practices in the university effective integration of science and education;
– development of programmes to support young scientists.

The regional network interaction model of Higher education institutions on the basis of REC NRU is presented in Fig. 3.

Fig. 3. A regional model of network cooperation between universities on the basis of REC NRU
The network interaction is carried out in the preparation of masters in the direction of "Construction", carried out on the basis of the REC at the Department "Building production and geotechnics", which was created in PNRPU (Perm), together with the Research Institute BashNIIStroy (Ufa), VSUACE (Volgograd), KSUAC (Kazan), NSUAC (Novosibirsk).

The realizing Master Programme "Underground and Urban Construction" focused on the specifics of the subjects participating in this educational network, on the needs of the regional labor market, distance learning technologies and scientific innovation tasks of networking in the framework of the development "Urbanistics" priority direction [3].

The Master program meets the requirements of the criteria of international social and professional accreditation of the Accreditation Center of the Association of Engineering Education of Russia (AEER). It provides for the knowledge of a foreign language at a professional level, deepened fundamental training in the disciplines of general scientific and professional cycles, the mastery of modern information and computer technologies, the formation of a set of competencies, knowledge, skills, methodological culture, internships in Russian and foreign universities providing training for undergraduates to conducting applied research in the framework of research activities in the field of underground and urban of construction in Russia and abroad.

The main employers are:
- design and construction organizations;
- customer services of operating organizations;
- departments of administrations of municipalities;
- development organizations.

Graduates of the master's program "Underground and urban construction" are published in scientific journals that have international and Russian citation indexes, and are prepared for professional activities in the field of design, erection, operation and reconstruction of buildings and structures, design and survey works, design of foundations and foundations, the development of technologies necessary for the construction of underground structures, construction in urban areas, construction on karsttopas and additional territories, a survey of the technical condition of buildings and structures, the conduct of scientific research and educational activities.

Competitive advantages consist in formation of such unique specialized competence of masters, as:
- readiness for professional operation of modern research equipment and instruments that allow controlling various parameters of structures during construction and operation in the underwork and karst-dangerous areas;
- the ability to analyze the data of engineering and geological surveys and, on their basis, to select the most rational methods of construction in urban areas;
- mastering the skills of assessing geotechnical risk and forecasting the geotechnical situation when building on an urbanized territory.

3. Model of network interaction of universities on the basis of the REC network within the integration of science and education and intercollegiate cooperation

The presented model best of all meets the requirements of Art. 14 Network Forms of educational programmes of the Law “On Education in the Russian Federation” № 273-FL
from “29” of December 2012. It defines the possible participants in the network form of educational programmes: scientific and industrial organizations with the necessary resources to carry out training; educational and production practices and other learning activities, provided with the appropriate educational programme.

Practically, this model is the union of the first two models. It should be noticed that the REC network is created on the basis of universities with different state status. Within the overall network are formed local networks, thus expanding the networking opportunities and to create conditions to better meet the needs of each student in the implementation of individual educational path [4].

On our point of view, networking has some significant advantages:

– exchange information on current developments in the educational process and scientific research;
– ensures the exchange of delegations of executives, the teaching staff, researchers, graduate students and students;
– organizes internships and retraining of scientific and pedagogical workers;
– creating innovative small groups in goal to carry out research on actual problems;
– organizes conferences and seminars to discuss the results of the joint projects;
– carrying out joint publications on the results of the completed research, review scientific works of the teaching staff, graduate students and students;
– providing the release of periodic joint publications on topical subjects, as well as monographs, educational and methodical manuals;
– joint participation in competitions for grants in the field of education and science;
– using the innovative educational technologies in the educational process;
– expansion of the nomenclature of suggested educational programmes by programme integration with other universities, including foreign;
– improving the quality of education, including with regard to monitoring the quality of education from the partner universities;
– the rating upgrade of the University within the country and abroad;
– integration of material and technical (audience, libraries, technical training aids, campuses, etc.) and human (teaching staff, educational, support and administrative staff) resources of educational institutions - participants networking.

Within the overall network there are formed local networks, thus expanding the networking opportunities and to create conditions to better meet the needs of each student in the implementation of individual educational path. This allows for a specific educational training programme within the framework of higher education by breaking it into separate training modules, which learning is possible in different universities and different countries. In this case, the student has the right to choose their place of study, taking into account the competitive advantages of universities. Thereby providing an academic mobility of students, which is an important mechanism of realization competence-modular approach in education.

Conclusions

The suggested model of network interaction of Russian and foreign universities have proved themselves during teaching in the dual education programmes, where students have an opportunity to double degree with advanced study of a foreign language in two directions (specialties) or two diplomas from various universities during the study of a basic educational programme on the basis of two universities.
The practical importance of carried out innovative research is that the international networking of Russian universities in realization of educational programmes in the preparation of engineering and scientific personnel on priority direction of "Urbanistics" has great potential in various regions of the world.

References


INTEGRATING SUSTAINABILITY AND SOCIAL COMMITMENT TRANSVERSAL COMPETENCE ACROSS CIVIL ENGINEERING CURRICULA THROUGH CASE STUDIES AND A COMMON EVALUATION RUBRIC

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Key words: Education for Development, Civil Engineering, Case studies, Evaluation rubric.

Abstract. The Civil Engineering School of Barcelona has a long tradition applying own experiences from international co-operation for development projects to teaching and learning activities. The continuous work carried out in this line has been supported by three pillars: i) motivated lecturers and professors, ii) institutional framework (including support for teaching innovation and Int. Cooperation for Development), and iii) increased networking with Education for Development (ED) partners. This paper presents a number of teaching materials, i.e. Case Studies, developed within an ED initiative supported by the Municipality of Barcelona during 2016-2017. The approach adopted is aligned with the European Global Dimension in Engineering Education (GDEE) initiative. Specifically, seven case studies are introduced, covering from first year of civil engineering to compulsory/master courses. The case studies include different kind of activities, which can be integrated and evaluated within the course, but also under the framework of a common evaluation rubric divided in three levels (basic, intermediate, final). This rubric makes operative the definition of Sustainability and Social Commitment cross-cutting competence at the Universitat Politècnica de Catalunya, UPC (one of the common competencies to all UPC studies). The teaching materials are the result of collaborative experiences of School’s students, lectures and professors. Some of them have been already implemented successfully in previous years and others are being tested during the year in course. This paper discusses about drivers and barriers for the development, application and consolidation of these materials.
1 INTRODUCTION

The Civil Engineering School of Barcelona (ETSECCPB) of the Universitat Politècnica de Catalunya (UPC) has a long tradition applying own experiences from international co-operation for development projects to teaching and learning activities [1, 2, 3]. Specifically, in the late nineties, UPC decided to launch a Development Education (DE) program (2000 - 2005) jointly with campus-based groups on co-operation for development [4]. The final goal of this program was to include a stable offer of DE activities specifically designed for engineers and technicians. This was co-ordinately carried out between engineering schools and engineering-focused organizations with links with the international co-operation for development sector (i.e. professional accreditation agencies/associations, non-governmental organizations, international agencies, third countries or privates) [4]. In parallel, UPC and its Co-operation for Development Centre (CCD, for its acronym in Spanish) have actively promoted the involvement of its academic community in co-operation for development activities, particularly through regular competitive calls for development projects, mobility grants and awareness-raising activities.

With this background, UPC has effectively adapted its DE program in the context of Bologna [4], paying special attention to the issue of evaluation by competences. Engineering competences were defined and assessed at various levels: the department, the engineering school, and the university. Their formulation process also included a common set of competences to be integrated in all undergraduate studies. Among them, Sustainability and Social Commitment (SSC) is a cross-cutting competence which is defined as i) the ability to know and understand the complexity of the economic and social phenomena typical of the welfare society, ii) the ability to relate well-being to globalization and sustainability, and iii) the ability to use technique, technology and economy in a balanced and compatible way [5]. The curricular goals are gradually presented in three acquisition levels, in consistency with different degrees of complexity [5]:

- Level 1: Systematically and critically analyse the global situation, addressing sustainability in an interdisciplinary manner as well as sustainable human development, and recognize the social and environmental implications of professional activities in the same field;
- Level 2: Apply sustainability criteria and deontological codes of the profession in the design and evaluation of technological solutions;
- Level 3: Take into account the social, economic and environmental dimensions when applying solutions and carry out projects coherent with human development and sustainability.

In 2013, the University Research Institute for Sustainability Science and Technology at the UPC coordinated the “Global Dimensions in Engineering Education, GDEE” European initiative, which aimed to increase the awareness, critical understanding and attitudinal values of undergraduate and postgraduate students in technical universities related to Sustainable Human Development (SHD) [6, 7, 8]. To achieve this, the focus was on integrating SHD as a cross-cutting issue in teaching activities by improving the capacities of academics and through engaging both staff and students in initiatives related to SHD [9]. This initiative was complemented by the implementation at the local level of two subsequent projects, funded with support from the Barcelona City Council.
The last of these two projects selected and accompanied a reduced group of professors in the effective implementation of the SSC cross-cutting competence, linking this to the global development framework provided by the 2030 Agenda for Sustainable Development [10] and the Sustainable Development Goals (SDGs). The major novelty in the methodological approach adopted was the collaborative definition of a new set of case studies, which were based on a common evaluation rubric, as an easy-to-use tool to implement SSC competence in the classroom. In this process, additional support from the ETSECCPB Teaching Innovation program and the CCD promoted the active participation and involvement of students. This paper presents achieved results, and discusses the main findings and lessons learnt during the process.

2 METHODS

The project promoted the co-development between faculty staff and project staff of case studies, as supporting teaching materials to be used by academics with students in the classroom [2, 6]. In terms of methods, the key implementation steps included:

• Dissemination of the initiative and enrolment of participants;
• Development of six working sessions (two hours per session), including i) theoretical background, ii) design of case studies, and iii) evaluation rubric proposal and discussion.
• Technical and pedagogical support during the design, implementation and documentation (about six months) of case studies.

To support the active engagement of participants, a closed follow up by project staff was regularly performed throughout the process. The project also provided editing services of case studies, including language correction or translation, ISBN registration and open source publication of the materials. Moreover, all participants received a participation certificate to acknowledge their merits during the accreditation of teaching innovation in academic evaluation processes (such as tenure track or similar ones).

3 RESULTS AND DISCUSSION

Case studies (CS) developed as teaching materials are all based on real-life experiences. They provide a practical resource to support students in the acquisition of the SSC cross-cutting competence. Each case study includes the following materials [11]:

• Description of the CS, including an introduction (disciplines covered and learning outcomes), the context - from a Human Development perspective and linked to related SDGs -, two teaching activities and useful annexes;
• Class presentation (in PowerPoint), to assist academics in the classroom with the introduction of the context and the description of teaching activities;
• Classroom activity, designed for a session of two hours. It includes work methodology and one possible solution. The classroom activity seeks to promote debate among students about the topic at hand, and also equips the student with the basic knowledge to carry out the homework activity autonomously;
• Homework activity, with varying teaching loads (ranging from twelve hours to one
semester). For the resolution of the proposed activity, the student will need to apply the technical and contextual knowledge acquired in the classroom;

- Evaluation rubric, as a practical tool to assess the proposed activities and students performance.

In total, seven CS were developed (see Table 1). Apart from the common features detailed above, other specificities define each CS. First, the academic degree covered. Second, the level of implementation as regards the SSC competence (see Table 2). Third, the application of specific software (i.e. Matlab, Autocad, Excel or R). Fourth, the possibility to employ the teaching materials in more than one subject. Finally, the translation of the case study into different languages.

### Table 1: Resulted case studies from project implementation

<table>
<thead>
<tr>
<th>Case study title</th>
<th>Academic degree</th>
<th>SSC level</th>
<th>Specific software</th>
<th>Interdiscip.</th>
<th>Multi-language</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tanzanian’s Rural Water Supply and Sanitation Programme: Introduction to Economy and Calculus for Engineering</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Algebra and Large-Scale Dam Assessment: The Case of Merowe Dam in Sudan</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exploring the Use of Recycled Aggregates in Concrete Mix Proportion: An Alternative for Haiti?</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Widening Horizons to the Design of a Pre-Stressed Concrete Slab: A Case Study in Barcelona</td>
<td>3</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimensioning a Drinking Water Distribution Network in Collique (Lima): Introduction to the Human Right to Water and Sanitation</td>
<td>4</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multivariate Analysis and Indices Construction: Data Mining Applied to the Rural Water and Sanitation Sector in Honduras</td>
<td>MSc</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assessing Faecal Flows in Low-Income Countries: The Case of Bure, Ethiopia</td>
<td>MSc</td>
<td>1</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

1: SSC refers to the transversal competence of “Sustainability and Social Commitment”
2: Interdisciplinary applies for materials which can be used in more than one academic subject
3: This case study was developed by professors of the Applied Math department, within the curricula of Industrial Engineering at ETSEIB, UPC. All the others by professors of the Civil and Environmental Department and within bachelor or master degrees driven by the Civil Engineering School.

One of the salient aspects, as previously mentioned, is the development of a common rubric to evaluate the SSC cross-cutting competence. In turn, this rubric was adapted to the singularities of each CS.
<table>
<thead>
<tr>
<th>Dimension</th>
<th>Level 3</th>
<th>Level 2</th>
<th>Level 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainability: Environmental aspects</td>
<td>REFLECTS critically on the professional practice from the ethical, social, environmental, economic, technical and temporal point of view</td>
<td>REFLECTS from the environmental, technological and temporal point of view</td>
<td>REFLECTS from the environmental, technological and temporal point of view</td>
</tr>
<tr>
<td></td>
<td>INTEGRATING knowledge and information of different nature</td>
<td>DESIGNING the solutions or proposals for improvement based on flow analysis (materials, energy, LCA)</td>
<td>IDENTIFYING the technical needs (evaluating them environmentally)</td>
</tr>
<tr>
<td></td>
<td>DEVELOPING engineering projects consistent with the promotion of human development and sustainability</td>
<td>REFLECTS from the social, technological and temporal point of view</td>
<td>AND DESCRIBING the direct and indirect environmental impacts of the decisions</td>
</tr>
<tr>
<td></td>
<td>AND EVALUATING the impact and the direct and indirect social, environmental and economic implications and consequences of the decisions</td>
<td>DESIGNING the solutions or proposals for improvement according to the needs of the most vulnerable groups</td>
<td>AND DESCRIBING the direct and indirect social impacts of decisions, and integrating the gender perspective</td>
</tr>
<tr>
<td>Sustainability: Social aspects</td>
<td>REFLECTS from the social, technological and temporal point of view</td>
<td>REFLECTS from the economical, technological and temporal point of view</td>
<td>REFLECTS from the economical, technological and temporal point of view</td>
</tr>
<tr>
<td></td>
<td>DESIGNING the solutions or proposals for improvement based on the direct and indirect economic impacts of the decisions</td>
<td>IDENTIFYING the technical needs (evaluating them economically)</td>
<td>AND DESCRIBING the direct and indirect economical impacts of the decisions</td>
</tr>
<tr>
<td>Sustainability: Economical aspects</td>
<td>REFLECTS from the economical, technological and temporal point of view</td>
<td>REFLECTS from the economical, technological and temporal point of view</td>
<td>REFLECTS from the economical, technological and temporal point of view</td>
</tr>
<tr>
<td></td>
<td>DESIGNING the solutions or proposals for improvement based on the direct and indirect economic impacts of the decisions</td>
<td>IDENTIFYING the technical needs (evaluating them economically)</td>
<td>AND DESCRIBING the direct and indirect economical impacts of the decisions</td>
</tr>
<tr>
<td>Social Commitment</td>
<td>IDENTIFIES the rights and aspirations of individuals and social groups</td>
<td>IDENTIFIES the rights and aspirations of individuals and social groups</td>
<td>REFLECTS from the ethical point of view</td>
</tr>
<tr>
<td></td>
<td>DEVELOPING projects that explicitly integrate cooperation mechanisms between parties and / or third parties</td>
<td>IDENTIFYING social, economic, environmental, technological, geographical inequalities, etc.</td>
<td>IDENTIFYING social, economic, environmental, technological, geographical inequalities, etc.</td>
</tr>
<tr>
<td></td>
<td>CONSIDERING criteria of sense of belonging, efficiency, impact, etc.</td>
<td>DESIGNING the solutions or proposals for improvement based on criteria of sense of belonging, efficiency, impact, etc.</td>
<td>PRESENTING historical and political arguments to explain them</td>
</tr>
<tr>
<td></td>
<td>AND EVALUATING the generation and transfer of technology and knowledge between the parties and with society</td>
<td>AND EVALUATING the generation and transfer of technology and knowledge between the parties and with society</td>
<td>AND DESCRIBING links with geographically remote societies</td>
</tr>
</tbody>
</table>

Table 2: SSC competence evaluation rubric proposal. Only maximum degree is shown for each level.
Table 2 presents the general rubric for the set of dimensions that need to be evaluated, and for three levels of SSC competence acquisition. For each dimension, and for each level, specific attributes are detailed. For simplicity, only the maximum degree of expected achievement is shown.

A grading score is proposed (from 1 to 4) based on the attributes addressed. To illustrate it, for instance, if the dimension of “social commitment” is to be evaluated at level 1, one point is given when the student carries out the proposed activities by considering the ethical point of view. This punctuation would be increased if social, economic, environmental, technological, geographical inequalities are identified within the resolution of the activities. In the same way, if these inequalities are explained by presenting historical and political arguments, an extra point is given. Finally, and in order to get the maximum score, students should complement previous aspects with a description of the links with geographically remote societies.

In other words, the rubric shows the knowledge that students are expected to acquire and the criteria that will be used to evaluate the resolution content associated with the activities proposed. It is worthy to note that students must be provided with the rubric in advance, prior to the implementation of the activities. In doing so, some guidance is given to students in relation to how the proposed activities will be evaluated. The rubric should be therefore employed to define the final punctuation.

It should be mentioned that only the first two levels are addressed in proposed CS. The third level is related to a more extensive work or research, such as the final project of undergraduate studies or master thesis. In order to ensure that the entire cohort deals with the competence on SSC, it should be enough to activate one case study for level one and another for level two in mandatory courses of the curricula.

4 CONCLUSIONS

The project has successfully completed two key deliverables; i) a set of field-based case studies, as supporting teaching materials aimed at integrating SDH in engineering courses, and ii) an evaluation rubric, which puts the SSC cross-cutting competence into a functional framework. A posterior analysis of the experience shows that the academic involvement required for case studies conceptualization, draft preparation, testing and final edition is high. The support of students through collaboration grants although extremely helpful is limited. Incentives for academics received reduced interest (conference fees, granted assistants). The involvement of academics seems more related to personal commitment rather than incentives.

This paper presents an overview of the case studies and a proposal of evaluation rubric to assess the SSC competence. The work done shows that bottom-up proposals can be devised; in concordance with the particularities of the case studies. Each level of the rubric has a specific grading system that is tuned up in each particular application.

We conclude that further work is needed to consolidate the proposal. Previous experiences show that teaching materials evolve in the process of appropriation by lecturers and teachers, as they will then adapt the materials to meet their teaching needs. However, once the first step is done, there are fewer incentives to pursue in the same direction, and the risk of involution from a teaching perspective increases as it is left to personal commitment of some academics. From an institutional perspective, the development of a strategy for continuous innovation is
mandatory to keep sustainability and social commitment close to the core of civil engineering studies.

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ACTIVE LEARNING FOR PROJECT MANAGEMENT IN CIVIL ENGINEERING

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Key words: Education, Civil Engineering, Methodology, Active Learning, Project Management.

Abstract. Higher Educations studies in Spain were very much impacted by the Bologna Declaration. This was also so for the Civil Engineering curricula (Ingeniero de Caminos, Canales y Puertos). When the European Higher Education Area (EHEA) was launched to promote homogeneous Civil Engineering programs in all European countries, structure of the studies changed from a five-year program to a four-year bachelor program followed by a two-year master. Not only duration, but also pedagogical methods were drastically transformed. The passive-learning professor-centred methods turn into active-learning student-centred ones.

In this paper, the example of an elective subject for Project Management of Civil Infrastructure will be presented. In this subject, Project Based Learning is the basic learning method. Students, by groups, have to work on a real project of a big civil engineering infrastructure (airport terminal, railway line, highway line). To do so, all the documents from a real project under construction are provided. Students, by groups, have to follow all the steps leading to a successful completion of the works, from proposing an offer for the bid, to the health and safety, quality and environmental management; from the technical and economic planning of the site, to the management of the relation with the press.

The presentation will address topics as various as the group motivation, the acquisition of soft skills, the learning methodology, the virtual visits to site, the interaction with BIM or the impact of the group size.

1 INTRODUCTION

Higher Educations studies in Spain were very much impacted by the Bologna Declaration. This was also so for the Civil Engineering curricula (Ingeniero de Caminos, Canales y Puertos).
When the European Higher Education Area (EHEA) was launched to promote homogeneous Civil Engineering programs in all European countries, structure of the studies changed from a five-year program to a four-year bachelor program followed by a two-year master [1]. Not only duration, but also pedagogical methods were drastically transformed. The passive-learning professor-centred methods turn into active-learning student-centred ones[2].

In this paper, the example of an elective subject for Project Management of Civil Infrastructure will be presented. In this subject, Project Based Learning is the basic learning method. Students, by groups, have to work on a real project of a big civil engineering infrastructure (airport terminal, railway line, highway line). To do so, all the documents from a real project under construction are provided. Students, by groups, have to follow all the steps leading to a successful completion of the works, from proposing an offer for the bid, to the health and safety, quality and environmental management; from the technical and economic planning of the site, to the management of the relation with the press.

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2 LEARNING METHODOLOGY AND CONTENTS

The students are provided with the design project of a big civil engineering infrastructure and they will have to work for the full term on it. A single project is proposed to the whole group for a given academic year. These infrastructures are normally in construction or already in service. Therefore, the students can see real pictures of different phases of the project and even visit the site.

The students form work groups of 3 to 4 individuals. In order to know the project in general, they analyse the available documents linked with the contract that includes: the contract draft, its annexes, tender specifications, the design project (construction plans, technical specifications, unit prices, bill of quantities, cost estimate or health and safety studies) and the work planning. All things considered, they propose an offer for the bid. This offer might include a reduction of the original construction estimation cost, incurring in an offer risk. To conclude, a real tender is proposed among the work groups to choose the best offer.

Secondly, each group are assigned a section of the project. This section is constituted of an independent construction unit (e.g. a diaphragm wall or an underpass). They will have to study deeply their section. Especially, they examine the plans and the technical specifications to design the construction strategy. They define the necessary resources (labor, equipment, materials) to build their own section. They have to produce a complete work plan of their section, which must fit in the global plan of the infrastructure schedule. They can use a Gantt Chart organization method or similar. For this reason, it is necessary to coordinate the tasks, the predecessors, the floats, the dependencies, the critical path and the dates.

Thirdly the work group resolves specific exercises about quality and environmental management. They prepare check point tables, in which they include the main quality and security controls they consider necessary to implement in their construction method.

An important part of the subject deals with Health and Safety. The construction hazard rate is higher than in others productive sectors. The students learn to identify the workers risks.
during the operations and to establish appropriate preventive measures. They choose a particular activity of their section and develop the correct prevention protocols. They present these measures in plans and diagrams to explain to the worker teams.

The students acquire transversal skills such as BIM (Building Information Modelling), which is a new technical collaborative strategy. In particular, they learn to work with BIM programmes like Revit. That way they are able to make a three-dimensional drawing of a building construction and produce several documents: plans, bill of quantities, working plan, among others.

Finally, another transversal discipline in the subject is the relation with the press. The students can know the most important advantages of answering questions correctly in a press conference.

The evaluation criterion takes 60% of the mark from the assignments and 40% from an individual exam. To foster collaboration between the groups and an effective exchange of information and actual co-working, extra points are provided if all individuals of the group get a minimum score. To motivate cultural and gender diversity extra points are also given to groups composed by students coming from different countries or with gender diversity.

Every year the students fill in a survey to detect possible improvements to include in next academic years. They agree with the general dynamic of the subject and the evaluation system. They value the acquired knowledge, because they think it is very useful for their career. Results will be shown in the oral presentation.

3 TECHNICAL VISITS

The students have the possibility to be involved in technical visits from three perspectives.

In the first place, students can go to the construction site linked with their project. In these visits, the technical team explain to them the project, the work plan and the main key points of the project in the site office. Then, students are provided with the personal protective equipment and visit the site.

This is very motivating for the students. However, present regulations of Health and Safety make very difficult such visits, as companies do not provide very willingly such chances. Moreover, such visits only provide a still photograph of the site, so different construction steps are missed.

Hence, virtual visits are also planned during the course. Technical personnel from construction site come to the University and explain the main characteristics of their project. In their presentation, they show execution pictures and the main problems faced on site. These presentations are very interactive and students can ask them any doubt about it.

Moreover, students visit the headquarters of a construction company. In this visit they can see the real dynamic in this kind of companies: how they propose a bid, how they manage human resources or how the technical department works.

4 SOFT SKILLS: COMMUNICATION

Soft skills are also taught in the subject plan. In the first place, press professionals teach students to face crisis situations, teaching them how to give a press conference and how to deal with the media. Students learn techniques to express correctly the facts in a press conference
and to answer questions. As an example they have to develop the communication strategy for different hot topic crisis experienced lately in Spain, the “no vull pagar” affair, where some citizens complaining about the highway tolls decided not to pay and the huge traffic jam experienced in a Spanish highway in 2017 due to the heavy snow.

Furthermore, students have to work with basic negotiation strategies, which are necessary to lead teams and to discuss with clients or suppliers.

Student’s surveys confirm that these soft skills are considered important for their education. Moreover, they have not received this kind of training during their academic studies.

5 CONCLUSIONS

In conclusion, Project Basic Learning allows students to complete their academic education with skills focused on their future career.

Students have at their disposal the design project of a big civil engineering infrastructure; on which they will have to do several assignments during the course. The exercises were about: bid proposal, cost estimate, Health and Safety, environmental measures, constructive methods or scheduling.

The evaluation criteria take 60% of the mark from the assignments and 40% from an individual exam. To foster collaboration between groups and an effective exchange of information and actual co-working, extra points are provided if all individuals of the group get a minimum score. To motivate cultural and gender diversity extra points are also given to groups composed by students coming from different countries or with gender diversity.

The students have the possibility to be involved in technical visits from three perspectives: to visit construction sites, virtual visits and to visit the headquarters of a construction company.

Soft skills are included in the subject plan in different times. The student’s surveys show the importance of these skills in their academic formation.

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ENGAGEMENT OF CIVIL ENGINEER STUDENTS IN THE FIRST ACADEMIC YEAR

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Key words: Education, Civil Engineering, Engagement, First academic year, Videos.

Abstract. Stronger student engagement or improved student engagement are common instructional objectives expressed by Higher Educational Institutions. They aim, in particular, at reducing the early dropouts of Science, technology, engineering, and mathematics (STEM) studies and to involve students in their own learning process.

This paper presents training resources and materials recently incorporated to the Calculus course of the first year of the Civil Engineering Bachelor at the Escola Tècnica Superior d’Enginyers de Camins Canals i Ports de Barcelona, in order to motivate and encourage students towards independent learning in mathematical topics.

One of these tools is a series of specific thematic math videos. They have different aims and scopes. On the one hand, they connect basic concepts of the Calculus course with relevant topics of Civil Engineering. On the other hand, they propose and state contextualized problems (pertaining to Civil Engineering) which are solved stepwise using Calculus tools and procedures. Moreover, there are different kinds of videos, namely: motivational, audiovisual workshops and audiovisual laboratories.

Producing and editing workshop videos required the cooperation of professors and also last year students in Civil Engineering. Being the speakers actual students, these videos convey to the target audience (first year students) a sensation of proximity and a potential easiness. Much more than if they were presented by a lecturer.

Initially, all of these videos were only accessible through the Civil Engineering School web portal, CaminsOpenCourseWare. Currently, the three collections of videos are already displayed on the YouTube channel, which provides more flexibility for access and allows controlling displays. They are also integrated into the web platform of the Calculus course, which allows students being immediately updated.
1 INTRODUCTION

Since the 1970s and 1980s, studies have been proposed as a major research project in the United States and British to analyze what characterizes the best universities, from the point of view of the experience and learning of their students. After the large research compilations carried out by Pascarella and Terenzini [10,11], Astin [1] and Kuh et al. [6,7] it was concluded that promoting high levels of student engagement is the most decisive factor from the point of view of student learning. [9]

In recent years the concept of student engagement has been becoming increasingly complex, while high-reliability measurement instruments such as the NSSE (National Survey of Student Engagement) in the North American field or the CEQ (Course Experience Questionnaire) in the British and Australian field appear. All these developments have made student engagement one of the priority attention points within universities and a methodological key to higher education research.

Student engagement has been described as the isolated variable that best predicts student success. Practically all of the policies and practices that research in recent decades has associated with high levels of student learning correlate positively with student involvement.

In the present paper we introduce the last resources and materials that we have incorporated in the Calculus course taught during the first year in the Civil Engineering degree at the Escola Tècnica Superior d’Enginyers de Camins Canals i Ports de Barcelona at the UPC BarcelonaTech. The lecturers of the Calculus course have always expressed our interest in providing a good learning of basic mathematics. We are interested in improving the quality of teaching and consequently we catch up on the latest teaching and learning improvements. One of our references is the International Conference Online Educa Berlin [8].

2 OPEN EDUCATIONAL RESOURCES FOR CALCULUS

Since 2003, we have been working on the development of mathematical content and implementing different educational tools in order to improve the teaching and learning of mathematics (especially Calculus) and the motivation of their students in the first year of the degree.

During this time, many resources and materials have been created and gradually incorporated into the Calculus course [4]. Among the varied resources that have been implemented since 2003 (a book [3] with the basic and fundamental needs to understand Calculus contents illustrated with a lot of descriptions, examples and both 2D and 3D plots; an interactive support based on Moodle and WIRIS technologies in order students can practice by themselves and even perform continuous assessment tests, online tutoring…), in this paper we present the latest upgrades, specific thematic math videos that, on the one hand, pretend to connect a basic issue of the Calculus course with a relevant topic of the Civil Engineering, and, on the other hand, suggest a contextualized problem (related to a Civil Engineering situation) which is solved step by step using Calculus concepts and procedures.
3 MOTIVATIONAL VIDEOS, AUDIOVISUAL WORKSHOPS AND LABORATORIES

In order to motivate the students of Civil Engineering to the Calculus study during the first year of this degree, and with the aim they really discover its utility and relevance in their future studies as the applications that this basic knowledge have in their future jobs, we edited some motivational videos for each topic of the Calculus course. Explanations of each of these videos are in charge of professors of the school, as well as distinguished PhD students of Civil Engineering degree, who explain their scope of work or studies and relate them with one of the different topics of the subject. As mentioned above, the goal is to establish a link between what is learned in Calculus lectures and its application in the Civil Engineering real world.

With them, we also aim to set the students closer to the topics that we suppose they have more interested in and, in fact, encourage them to initiates Civil Engineering studies. This allows really bring students the topics that from the academically point of view could be initially seeing very distant.

The fact that the application of the concepts studied in the Calculus first course displayed in those videos are given by a professional of the university school where students are studying and who are working in different fields of the degree, reaches a triple goal: closeness, motivation as well as to confirm the clear relationship and collaboration between different areas of knowledge (in this case, fundamental mathematics and the Civil Engineering field). A fact that not always is as evident as it has to be.

3.1 Motivational videos

The motivational videos associated to each one of the topics of the Calculus course are [2]:

- Unit 1. Metric Spaces. Topology: Basic Topology to create nets.
- Unit 3. Differential calculus of real functions of a real variable: Using generalized functions in beam theory.
- Unit 4. Differential calculus of functions of several variables: Differential calculus of functions of several variables in the optimal design of a public transport network.
- Units 5-6. Riemann integral: Riemann Integral. Application to hydraulic engineering field.
- Unit 8. Ordinary differential equations: The convergence - confinement method in ground -support interaction.
- Unit 8. Ordinary differential equations: Eigenvalue Problems and Applications to Structural Dynamics.

Positive results achieved with this type of videos encouraged Calculus staff to subsequently create a new type of videos, but which have something more added.
3.2 Audiovisual Workshops

We thought in the realization of a new kind of videos which includes a new added factor based on workshops. We call them audiovisual workshops.

To achieve this idea, fundamental topics of Calculus have been collected. In this sense, selected topics are not the most complicated ones but the ones that students have to dominate and not always they succeed in. Such audiovisual workshops have not to be a substitute of what is done in regular lessons. Not everything is covered in these videos, but the most important information and an overview of the presented topic is developed. The goal, as it is said, is to complement and help students to set up the groundwork of the most fundamental aspects that are a key for any Calculus development.

All of these audiovisual workshops have a specific structure. They are divided in three interrelated parts, which are detailed above:

- **Part I. Tools**: where a brief theoretical and transversal lecture of the different Calculus tools will be needed to resolve the problem. The aim of this first part of the videos are to emphasize the understanding of the subject as a "whole" and not as a sum of different topics.
- **Part II. Resolution of a problem**: In this part, it is developed, step by step, a difficult mathematical problem applied into engineering. The intention of this part is students to improve in the development of the problem in conjunction with the interactive lecture. The difficulty of the problem lies in the correct comprehension of it. It is not just looking for the assessment of Calculus knowledge but for the sufficient abstraction of the student to correctly interpret what it is set out.
- **Part III. Approach of a new problem**: Finally, it is set out a new problem, which is similar to the developed before in order students feel able to work on it and really try to solve it by themselves. The fact that the proposed problem is similar to the developed one, allows students to consolidate knowledge and methods of resolution.

For each topic, theory and problems (both resolution and approach) parts are set in two separated videos. This fact allows students watching the desired ones separately, or one after the other one (in the order they need).

The fact that the problems suggested in these audiovisual workshops are contextualized in the world of engineering, returns to the idea of motivation and ratify the evidence and the importance of the presence of mathematics in engineering, in this case Civil Engineering.

The edition of such workshop videos has enjoyed with the cooperation of students who are finishing the Civil Engineering studies degree. The fact that the presenter of each video is truly a student conveys to students of the first year of the degree a much greater closeness and security in themselves than if they were displayed by a lecturer.

At this moment, the edited and uploaded audiovisual workshops are the following ones:

- Conics and Quadrics (1). Theory.
- Conics and Quadrics (2). Problem.
- Differential equations (1). Theory.
- Differential equations (2). Problem.
- Function approximations (1). Theory.
- Function approximations (2). Problem.
- Riemann integral (1). Theory.
With the release of these videos, both motivational and audiovisual workshops, has always sought a direct and as comfortable as possible, interaction with the viewers (students) across the screen. This goal is achieved, on the one hand, through a neighboring language and no more than 15-20 minutes length per video. It is important to ensure that students who view the videos maintain their concentration throughout the duration of the lesson. During their exposure and development, students will have to feel comfortable in a quiet and relaxed atmosphere in order they can integrate well what is presented and worked. And on the other hand, the objective is achieved with the incorporation of different tools that technology provides.

The presenters of the motivational videos used a virtual presentation on which it is possible to do explanations, annotations, highlighting specific items... For the release of this second set of videos, for audiovisual workshops, the technology used is considerably expanded.

On the one hand, it is used a virtual pen. This smart pen allows displaying on the support presentation what one is writing on a sheet in real time. It allows viewers follow and reproducing developments and explanations at the time presenters are written on the presentation. This keeps the timing among the viewer students, leading to a positive effect on them. On the other hand, this innovative tool gives added value to the presentation making it more interesting and rich.

Other technological tools used are interactive applications, such applets. These resources engage viewer students. The given visual information combined with the explanation in real time multiplies the options for a proper understanding of the topic which is presented.

Initially, all of these videos were only accessible through the Civil Engineering Web School portal CaminsOpenCourseWare [2], but now this collections of videos were displayed on the YouTube channel, which provide more flexibility to students to access them and a real control of their displays. And, afterwards they have been integrating into the web platform of the Calculus course, Atenea in Moodle platform, which allows students be immediately up-to-date among them.
3.3 Audiovisual Laboratories

The last type of videos we have, are the Audiovisual Laboratories. In this videos we illustrate with a lot of descriptions, examples and 2D and 3D plots, exercises using WIRIS technologies. The students can practice by themselves with continuous assessment.

At this moment, the edited and uploaded audiovisual laboratories videos are the following ones:

- Basic Topology
- Calculation of Primitives of a function
- Functions of several variables
- Function sequences and series
- Multiple integral
- Real functions of a real variable
- Riemann integral
- Sequences and numerical series

![Figure 3: Audiovisual Laboratories](image)

4 RESULTS

We believe the facts that a) students can access these materials through different web portals, b) students can display those videos at any time, c) videos can be interrelated at any time, and d) videos can be stopped and replayed from any specific moment the desired times and whenever students want, enhancing the Calculus learning. Thus, if these three collections of videos are properly used, can be a very successful tool for the study and daily motivation of the Calculus course in the first year of the Civil Engineering Degree.

4.1 Motivational videos results

All the students (100%) who answered the motivational videos’ poll affirm both they know this collection of videos and they watched some of them. 50% of these students assure that they have seen three or four different videos, and 36%, five, six or seven (there are 7 videos) of them. All of the students assure that the videos they have seen provide them some help in their studies in some way (33% a little bit and the remaining, 67%, a lot of) [5]. According their responses, these videos provide them specifically:

- more interest in the Calculus topics studied in the course,
- real Calculus applications in Civil Engineering as well as in real life,
- a new vision of mathematics,
• more motivation and lively feelings in Calculus lessons
• a complement for the lessons explanations:
  a) better understanding of what is working in attending lessons
  b) a general idea of the concepts taught in lessons

Regarding from where students access to these videos, 68% affirm they saw them through the Calculus web platform, 27% from the OpenCourseWare and only 5% directly from YouTube [5]. This reaffirms that embed these videos in the Calculus web platform is the best and more reliable way students can easily access to them.

According to the obtained results, 97% of the students think motivational videos are both edited in a friendly and present the different topics in an understandable way.

Finally, we asked students their general opinion about the videos, and according their responses, we can conclude these videos are well accepted for them. (37% very good, 37% good, 23% regular and 3% bad) [5].

Some of the students who answered the opinion poll highlight some aspects that we think are important to be considered:
• Students who don’t visualize the 7 videos of the collection, highlight that they haven’t do it because of lack of time.
• They like lecturers remember that videos are hold on the web more often.
• They would like there will be more videos like them.

The number of times that these videos have been viewed can give us an idea about which of them was more useful for students.

4.2 Audiovisual workshops results

In this case 10% of the students who answered the poll who didn’t realize about the audiovisual videos. From 90% who affirms knowing them, 10% assures they saw all the videos (there are 10 audiovisual workshops), 6% most of them and 57% only some of them.

90% of the students who saw these videos assure they help them to revise, learn and consolidate some concepts, procedures and ideas taught in attending Calculus lessons, and the same percentage think videos are edited in a friendly and understandable way. On the other hand, through the opinion poll we notice that the more comfortable way for students to access to the videos is through the Calculus web platform, like happens for motivational videos.

The general opinion of these students about this collection of audiovisual workshops is also so good, (37% very good, 33% good, 26% regular and 4% bad) [5].

Regarding the plays of the videos of this collection it is clear that Conic and Quadrics audiovisual workshops are the most demanding for our students.

An assumption towards this evidence is that Calculus students need to manage Conics and Quadric expressions and representations, but on the one hand, it is not a specific topic of the course and on the other hand, students haven’t studied them before in Secondary school. This fact makes clear that audiovisual workshops are a really useful resource for Calculus students in order to get confidence in some topics that are not always can be emphasize in lectures.
4.3 Audiovisual laboratories results

This videos are recently uploaded and we think we need time to have conclusions. Years ago this kind of material was in the Calculus book [3], but nowadays Java has problems with the most popular browsers and this makes it impossible to access and that’s why we make this kind of videos.

5 CONCLUSIONS

At the Escola Tècnica Superior d’Enginyers de Camins Canals i Ports de Barcelona (ETSECCPB) the implementation of the new degrees implied a necessary review and improvement of the quality of teaching and learning activity. This change involves students to achieve specifically skills and abilities, like learning independently and communicate effectively. To achieve this goal, Calculus lecturers’ team carried out different improvements.

The edition of the three collections of Calculus videos contributes to the CaminsOpenCourseWare project improving the quality of teaching activity and therefore the learning process of our students. The good reception concerning these audiovisual resources received from both academic staff and students make us feel optimistic about the video project. It allows us to think that our goal can be covered with guarantees if we continue enhancing this kind of resources. The best is that, if the student like to work, he work harder and better, so the engagement is the key to learn.

We really believe this is the way towards we have to continue working: editing audiovisual materials and using technological tools, as well as implementing the necessary materials that allow us to constantly enhance the innovation in mathematical teaching and learning practices.

We are sure that this line of work will be interesting to apply in many other subjects in both our university school and other schools or faculties.

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Teaching/Learning Techniques for Calculus within the RIMA Project (UPC-ICE)


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Abstract. “Change is hard […]. But it’s worth it – and it’s working”. Thus ended Barack Obama’s section on education in the 2014 State of the Union address, after asserting that high school teachers from a number of states were making great progress when preparing their students for the new capabilities required by the new economy: problem solving, critical thinking, science, technology, engineering and mathematics. His words were followed by an announcement of a 2.9 billion USD investment for 2015 (a 3.7 % increase compared to 2014) in programs devoted to encourage training in the fields of science, technology, engineering and mathematics (summarized in the acronym STEM). The goal for the upcoming decade is to prepare 100,000 excellent teachers to obtain 1 million STEM graduations. What kind of problem has brought the first world economy to promote this initiative?

Every 20 or 30 years, matching successive revolutions or technological waves, societies in the most developed countries receive alarming messages about the risk posed by the available engineering pool not being able to satisfy demands by industry and research. After the recent wave, where digital networks, TIC and biotech have played leading roles, a new one is being announced associated to sustainable engineering, nanotechnology, renewable energies, fight against inequality, and biomimetism; its peak will be reached in the 2020 to 2025 period. Consequently, once again the alarm is ringing about the need to count upon enough engineers or STEM graduates in general to answer to the new challenge. This is why numerous reports commissioned by different governments and prestigious institutions have appeared, and all of them concur in forecasting a strong increase in the engineering demand for the upcoming years. Nevertheless, secondary education students’ vocations in most developed country drift away from engineering degrees, slowly but firmly. This observation, valid also in Spain, calls for a careful analysis and constitutes the essence of this paper.
1 INTRODUCTION

A few months ago, a nationwide radio program analysed the issue of the migration of young Spanish graduates to other countries. A young aeronautical engineer who was on the brink to travel to Germany to find the job he was not able to find in Spain spoke up. Just as him, he said, half of his class was packing to leave. The deep crises which we are hopefully leaving behind is the most visible cause among those which justify the noticeable drop in demand in engineering degrees in Spain, easily perceived, since many of them do not reach full occupation and in most of them the minimum admission grade has plummeted – in many cases, down to 5.5 over 10 (the minimum passing grade achievable). The number of bachelor degree students in Engineering and Architecture has dropped by approximately 26 % since 2008 [1], especially during the past five or six years, with a displacement in demand towards the field of Health Sciences. This situation, together with the tightening of the economic situation of most public universities after years of budgetary cuts and burdensome debt, brings with it the threat of structural reforms in centres which otherwise perform remarkably in scientific research and technology transfer. We can only hope, if the long-awaited economic recovery is as close as we would like, that this situation will correct itself little by little.

Blaming the economic crises for the decrease in interest for STEM degrees (some scientific disciplines other than engineering are also suffering a drop in demand) would be too easy, but it is not the full answer. In countries where crisis effects have not produced so much damage in the field of engineering a similar trend is also perceived: in the USA, Germany, Japan, the UK, Canada, Australia, Russia, Austria, Poland, Latvia or Estonia – all of them with an average GNP growth over the past few years of 2 % or higher – young high school graduates are not attracted toward engineering studies either, in spite of good wage expectations and a demand for engineers which in some cases has to be fulfilled by foreign hires (from countries such as Spain). The 2008 Eurobarometer, which was elaborated before the beginning of the crises, and various studies [2,3,4] show that in developed countries less than 2.5 % of young university prospects had an actual interest to study engineering – which in the case of women decreased to 15 %. The same studies show, however, that engineering is the majority preference of youths in developing countries (India, Malaysia, Brazil, Philippines… plus the Chinese giant), with a similar degree of acceptance among women and men. Which begs the question… what is the matter then?

2 PERCEPTION OF ENGINEERING STUDIES

Undoubtedly the economic cycle and short-term job expectations are decisive when choosing a professional orientation, though we often forget that actual professional performance will not take place until at least four years after first signing up for college (adding up to five or six if a Master’s degree is pursued); at that point, both the economic situation and the foreseeable future might have changed radically. To put it in another way, part of the engineering vocations follow trends approximately parallel to GNP growth. But many surveys carried out in Spain, Europe, Australia and the USA agree, showing that these factors are not the least important nor decisive when choosing a career. The image of engineering has progressively changed, paradoxically, opposite to the change engineering has brought about to
society. Quoting the German sociologist Kogon in 1971, “engineers are the camels on which businessmen and politicians ride” [5]. This is a way to interpret the social perception that an image of a triumphant, socially worshipped engineer, capable of undertaking transforming project, was being progressively demystified. This image might still persist in some developing countries.

A survey included in the 2009 barometer youth on science and engineering (German Academy of Science and Engineering) [6] covering thousands of German youths tried to establish which profiles and qualities were associated to an ideal job as opposed to those which, in their opinion, were characteristic of the different engineering careers. This survey shows small differences between both images in relation to traits such as practical utility, general wellness associated to job performance, social respect or the chance to acquire new competences. The gap is wider when looking at application of your own talent and work autonomy, where engineering falls behind the ideal job, or new developments, where engineering stands out. It opens even wider when wage expectations, networking or work-and-life balance are considered, three factors in which engineering is perceived at a much lower degree than an ideal job in the interviewees sight. But the issues with greatest perceived difference are those related to job security, perspective of a full career and activity diversification, where the image of engineering is clearly below the ideal job. The authors, as active engineers, were surprised to read some of these conclusions, especially when considering the overlap with the successful attraction shown by careers in health sciences, which were even worse graded in the aspects where engineering was deemed most apart from an ideal job.

Technology has a positive image among the younger population, though this does not imply a vocational interest. It is also associated to icons who have been the protagonists of the most recent technological revolution, that of the digital era, at the reach of millions of young persons as mere users. To sum up, digital technology is accessible and opaque at the same time, even in middle and high schools, where it is considered a simple tool, a means rather than an end. Also, overexposition to social media (dozens of digital television channels, journals and magazines from all over the world on the internet, social networks, messaging platforms, blogging…) easily creates stereotypes about success which influence youngsters’ attitudes, including those who nowadays are applying to college. Very few engineers are visible regarding their social projection and economic splendour, being the traits that best define success in society today, and when they are, it is frequently due to activities not directly related to engineering. Professor Marjoram, from Aalborg University and member of UNESCO, goes so far as to assert that in developed countries the image of an engineer is that of a “geek” [7], and especially, boring, as caricaturised by Scott Adams’s “Dilbert” character. In this context, the general perception is that engineering is not “cool”. The Institution of Civil Engineers (ICE, UK) has accepted the challenge associated to this situation and has recently published a video piece attached to a promotional campaign of civil engineering among high school students – a campaign backed by numerous and relevant companies in our sector. The message is simple and breaking: engineers are happy while practising engineering, designing and building extraordinary infrastructures for society [8].

Another question to consider among the influencing factors when choosing a career is the extended perception of difficulty associated to STEM disciplines. Generally, one can posit that engineering (or rather, the attitudes that define engineering) is far away, when existent, from middle and high school classrooms. Physics, Chemistry and Math are dark and elusive when
presented as a mere set of rules, which also has something to do with the decrease in interest in engineering.

3 SITUATION IN SPAIN

Aggravated by the crisis, the situation in Spain mostly shares the traits hereby presented. It is even more complex when adding to it the recent transformation of the regulatory frame of higher education which has turned the old short-cycle (3 years) and long-cycle (5 or 6 years) programs into 4-year Bachelor’s degrees and 1- or 2-year Master’s. Most engineering studies (technical and superior in the old denomination), easily identified and almost completely linked to regulated professional competences, have been replaced today by a variety of degrees with titles which identify their contents poorly and even worse their associated professional competences. Indeed, a few months ago around 300 000 students who met the requirements to sign up for college did so in one of about 3 100 verified Bachelor’s degrees available in Spain nowadays, taught in 345 campuses or sites in 82 universities, about 60 % of which are public. 35 000 graduates were dispersed over 4 700 verified Master’s programs, 20 % of which are taught in private universities [1]. Among Bachelor’s degrees, around 650 correspond to disciplines in the area of engineering, architecture and construction, hosting about 20 % of first-year students. Looking at the offer in public universities, 6 000 different official degrees may certainly seem too many. There will be even more if the reform allowing for 3-year Bachelor’s degrees, cautiously delayed by a pact between university presidents, is finally adopted.

It can be presumed that taking an educated choice in such a wide offer would entail gathering and processing a vast and probably unreachable amount of relevant information, even though boundary conditions such as geographic location or family economy have great weight. The scholarship policy, with a tendency towards more rigorous requisites, and the increase in university fees (the price of a Bachelor’s degree varies between 12 € and 40 € per ECTS credit, and Master’s degree between 31 € and 65 € per credit for first-time enrollment) frame in a different way the situation in each autonomous community, but vocation has usually played a primordial role when choosing any engineering degree.

Several externalities have already been presented, but the factors that depend essentially on the universities and engineering schools themselves cannot be avoided. The design of study plans and teaching, learning and evaluation methodologies have repercussions on pre-college students’ eagerness, particularly because of their incidence on the academic success index, on the average real number of years it takes to finish a degree and on how the productive sector values the graduate employees they hire. It is often put forward, not without reason, that the first encounter of novel students with the most theoretical and scientific disciplines (which constitute the base of technological studies, displaced towards the later years) abates the expectations of what engineering activity should be at the time of their first enrollment. The difficulty to overcome those classes must indeed be related to the students’ baggage in STEM fields and to the decrease in cut-off grades which has taken place over the last few years, and which in turn influences the dropout rate in the degrees in question. There are yet no statistically relevant data about this issue, since the implementation of the new degrees is still somewhat recent, and even less concerning the valuation that market forces will pose on the competences acquired by the new graduates. Engineers formed under already extinct plans in Spain were in general highly valued, though this did not hinder criticisms, shared by most European
engineering schools, about the limitations in practical contents and the capacity to apply theoretical knowledge. This is an old debate, and though its dialectics are easy to present, the design of an effective solution is not as simple. Quoting Charles Riborg Mann’s *A Study of Engineering Education*, prepared for the Joint Committee on Engineering Education of the National Engineering Societies, “Now evidences are multiplying to show that the time has come for a clearer definition of the relations among research, instruction, engineering practice, and industrial production. How to coordinate these elements most effectively is a large and pressing problem”. These words were coined almost 100 years ago [9].

4 STRATEGIES TOWARD STEM REINFORCEMENT

We have presented up to this point a complex lattice of motives that in their whole try to provide an answer to the slow and steady loss of scientific and engineering vocations. The USA initiative destined towards STEM strengthening has not been the only one, though probably the one with the largest funding. Already in 2004 the National Science Foundation had pointed out that, if the trend identified in 2004 were to stay steady, three things would happen [10]: (1) the number of jobs in the USA which require science and engineering knowledge would increase; (2) the number of Americans qualified to occupy those jobs would at best stay the same; and (3) the availability of qualified people from foreign countries would decrease due to immigration restrictions for national security reasons and the intense international competition over people with such qualifications. In 2012, the same institution reported that the number of employees in science and engineering sectors showed a steady increase for almost 60 years. Indeed, out of a 182 000-person workforce in 1950, it had climbed up to 5.4 million in 2009, which represents a yearly increase of 5.9 %, much larger than 1.2 %, which is the rate of increase of the over-18 workforce as a whole. Nevertheless, between 2000 and 2009 the growth in number of STEM workers dropped to a 1.4 % annually, much lower than in the preceding decades. 2004 predictions were thus corroborating, which gave birth to the funding line.

In Europe, the alarms went off few years ago, supported by the three axis of the *Europe 2020* strategy: smart, sustainable, cohesive growth. Reports and projects analyzing the situation and proposing lines of actions appear everywhere. Already in 2000, the European Commission turned STEM areas into strategic when creating the European Research Space, which until the Barcelona 2002 summit did not count with a working schedule. Nonetheless, this schedule established a line dedicated to STEM study reinforcement, quantified through the increase of GNP dedicated to research, from 1.9 % to 3 % [11]. This increase would supposedly have a repercussion in the form of a demand of up to 15 % new graduates. Later on, in 2004, the European Commission published an exhaustive report about the need to increase human resources in science and technology [12], dependent on a young population that did not see a promising future in these areas. In the form of 27 conclusions, the reporting workgroup stressed various lines of work. We will quote them here because they synthesize, without getting into too many details, the main strokes of the most ambitious programs that have faced the same issue:

- Creation of a human resources policy for the European Union.
- Promote new knowledge-based companies.
- Gender balance in STEM.
- Wage increase in STEM jobs as a means to retain graduates.
- Increase of external talent attraction while ensuring a majority of UE nationals in STEM.
- Improvement and promotion of academic careers, starting from Secondary school, in the different STEM areas, by increasing funding, private sector backing and teacher formation.
- Promotion of science and technology across society through museums, exhibits, mass media, etc., and popularizing role models of both men and women representative of careers linked to STEM disciplines.
- Boosting of the popularization capacity of STEM graduates, frequently non-existent.

The European Engineering Report, prepared by the Institute of German Business and the Association of German Engineers [13], showed in 2009 revealing data about the percentage of engineering graduates in the EU, which on average constituted 11.9 % of the graduate total (14.5 % in Spain) with extreme values in Finland, 20 %, and Cyprus, 3.7 %. The report remarks “Engineers’ contribution to technological innovation applied in the market place is indispensable for achieving higher economic growth as well as for creating new jobs, securing clean energy supply, sustaining natural resources and tackling the challenges associated with climate change. Thus, they will play an important role in putting into practice all three priorities set out in the Europe 2020 Strategy.”

Other national, European and worldwide institutions perceive the situation in a similar manner. Scientific and engineering organizations have prepared concurrent reports: the European Council of Civil Engineers [14], the British Royal Academy of Engineering [15], the Spanish Transforma Talento [16] and FECYT [17] foundations, the International Federation in Engineering Education (IFEEES) [18], the International Council of Academies of Engineering and Technological Sciences [19], the European Association of Engineering Education (SEFI) [20], the world education CDIO (Conceive, Design, Implement, Operate) initiative [21]... The number of documents that share the idea of boosting science and engineering as the engines of future development and under the threat of the lack of prepared, young people can be counted by the dozens. As it often happens, unfortunately, many of these studies cover the basics but very few actually develop and implement definite strategies. “Engineering education must reflect the interaction of engineers in industry and academia; universities must forge cooperative alliances with industry and national laboratories to promote the value of an engineering education”. This statement, hard to argue with, comes up in the CAETS 2013 report [19] and in many others with similar but different words. Very few actually point out who is to take on this task and how to do it, setting specific lines of work and specifying how to fund them.

From a larger perspective, the OECD and UNESCO have also joined this transcendental debate. In 2008, OECD published the well-known report Encouraging Student Interest in Science and Technology Studies [22]. Besides gathering already analyzed questions on diagnostics and treatment, this report brings forth evidence-based foundations about the perception of engineering among boys, girls and general society, with a clear conclusion: if women accessed STEM studies in the same proportion as men, the lack of resources we are foreseeing for the next decade would stop being a problem. This fuels a profound debate on the role/gender binomial, in which both society and the media that has become its reflection play an important role. UNESCO, in 2010, published a report on engineering in collaboration with the World Federation of Engineering Organizations, the International Federation of Consulting
Engineers (FIDIC) and CAETS [23], offering a wide perspective on the evolution of engineering and its role in world development. The data collected in this report are overwhelming: 2.6 billion people in the world lack drinkable water; 2.3 billion have no sanitation infrastructure; 1.6 billion have no electricity service and 1 billion live in slums. Consequently, almost 1.5 billion people have a life expectancy of slightly more than 50 years, so engineering in general and civil engineering in particular have to be strongly promoted, since they will be the protagonists of the sixth wave of technological development according to Kondratiev’s model [24].

5 LINES OF WORK IN STEM REINFORCEMENT

Various initiatives funded by different EU programs have tried to bring forth concrete ideas and solutions. The ATTRACT Project final 2012 report [25] details some general lines of Perception, Attraction and Retention, a worthy synthesis of the lines already detailed in the 2004 EU document [12]. The STIMULA project [26], also funded by the EU, which included the participation of the Universidad de Zaragoza, focused its work towards 14-year old students, with whom they worked for three years having them take part in different stimulus and orientation actions towards science and engineering. Their vision of STEM areas at the ages of 15 and 17, according to surveys taken after their activities, seem to reflect that the ages corresponding to Secondary school are the key moment at which they almost irreversibly opt for a vocational choice, that is, acceptance or rejection of STEM careers. In this choice, mass media, parents and school tutors have notable influence.

Other proposals have been developed in different countries to promote STEM areas. In Japan, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) is working since 2002 [22]. In the Netherlands, the Platform Bèta Techniek [27] links industry to high schools, and especially promotes the participation of girls, as does the francophone Les Petits Débrouillards [28]. The Swedish SciTech approaches science and engineering to society in a similar way as the German Sinus and Sinus Transfer [29], or the Belgian Chip, Chip, Chip, Hurray!, which uses interactive experimental boxes, and The Great sExperiment, which aims to break the gender barrier in STEM areas [22].

Among these various activities the ones organized in the USA and UK are the most salient. In the USA, the National Academy of Engineering, with the collaboration of powerful engineering companies, developed a website to boost the visibility of engineering under the motto Changing The Conversation (CTC) [30]. It includes an extensive activity program, including downloadable posters and stickers with the key messages it wishes to transmit (“Engineers help design the future”, or “Engineering is essential to our health, our happiness and our safety”, and even “Engineers make a different world”), besides keeping an active role in social networks. In a parallel effort, a number of executives in big companies instituted the Change The Equation (CTeq) foundation [31], with a similar objective and an even wider range of activities. Their website included very useful material to approach Secondary schools (presentations, experiments, multimedia…); it also explained hundreds of projects to bring science and engineering closer to all kinds of audiences, while infiltrating themselves in Facebook, Twitter and YouTube to spread their messages.

British initiatives have been led by the Royal Academy of Engineering, the Institution of Engineering and Technology (IET), the business lobby CBI, the ICE or the EngineeringUK
Foundation, whose patrons are the most relevant companies and scientific or engineering organizations in the UK. In all cases, one can see similar approaches as the ones from the USA: simple and clear messages about the impact of engineering, popularization of all sorts of engineering activities and basic orientation towards Secondary school students, their parents and their teachers. For instance, the Tomorrow’s Engineers program [32] reached 40 000 students from almost 1 100 schools all over the country. This seed has provided fruit, since from 2015 the statistics show a slight recuperation (or at least, the end of the decline) of the interest in engineering university degrees.

6 CONCLUSION: THE SPANISH CASE

So, what about Spain? The concern about the excess or lack of STEM graduates in the future has stayed in a secondary plane to the evolution of the economic crises, which has damaged the latest engineers to enter the workforce. Various national foundations develop directly or indirectly STEM discipline diffusion programs, among which we can point out FECYT, together with museums such as the National Museum of Science and Technology (Museo Nacional de Ciencia y Tecnología, MUNCYT) or the MC2 (Museos Científicos Coruñeses) network, but we still lack a national initiative which groups the individual actions that are undertaken with great effort and variable efficacy. Universities and their engineering schools have perceived the important decline in enrollment and the minimum cut-off grade of their new recruits, so they are probably the institutions that have first reacted to the mid- to long-term problem we can foresee. We have devised outreach programs for high schools, which, though positive, may fall among youths whose personal projects fall far from STEM disciplines since the mid school level. Very few of these activities are launched adding up efforts, and even less with a focus on 11- to 14-year olds. The Spanish university structure, organized by the autonomous communities, brings with it a few virtues to the system but renders difficult to engage in joint ventures, in spite of the existence of the Conference of Presidents of Spanish Universities (Conferencia de Rectores de Universidades Españolas, CRUE), that really attack the root of the problem. The Civil Engineering School of the Universidade da Coruña (Escuela Técnica Superior de Enxeñaría de Camiños, Canais e Portos) launched in 2013 an intervention program with a multi-pronged approach, taking advantage of synergies with MUNCYT and MC2 [33].

Because, the problem exists. The direct relation between investment in STEM education and research and national growth is proven, and future development solely based on the import of foreign talent is inconceivable. This is the reason that has alarmed societies such as the German, British or American, and state institutions, national organizations and associations, universities and, of course, businesses, have committed themselves to the task of putting out this fire.

The problem our society faces is not, in any case, the size of schools with less students than ten years ago. To destroy is easier than to build, even if it means blowing up a system that – though not without flaws – has given Spain a prosperity unknown in the previous decades. The real problem is that our nation is gambling with being or not in the first ranks of knowledge, with counting with a large enough cohort of young people ready to produce engineering here or anywhere in the world and with breaking the eternal imbalance between men and women in STEM disciplines. A spearheading national program is needed, led by public and private institutions, that can program activities, support teachers in all stages of education and repair
the weak image portrayed by science and engineering in society today. We need to engineer how to revive engineering.

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YIN YANG PROJECT. BUILDING ON A LARGE SCALE AND THEIR EDUCATIONAL POTENTIAL.

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Key words: Education, Learning by doing, Wood, Large-scale construction, Sistema Lupo, Building blocks.

Abstract.
The project is a reflection on the educational potential of the act of construction, specifically, large-scale construction, which is considered to be one capable of "competing" with the scale of the participants.

The conclusions and data obtained come from a series of experiences linked to the collective "Sistema Lupo". This group has developed many educational activities, related to the structures and other topics, from an empirical and experimental point of view.

The main material used is building blocks, on different scales and materials and delimited by a modular construction system [1] that allows infinite rigging.

The size of the blocks used emphasizes the need for a proper design and allows the participant to be aware of the functional and aesthetic aspects of a good structural design [2]. The scale of the constructions, larger than that of the participants themselves, requires a team effort and success or even failure is shared by all. The didactics also values the uniqueness of the individual in the group. It is a difficult interaction that includes participation, discussion, creativity and resilience as a result of the failure of demolition and its reconstruction.

The experiences have been developed in very different environments ranging from university to children's classrooms. The current proposal refers to a specific project developed over the last five years in the university context. The main material used is wood and, in addition to the above-mentioned topics, industrialization and the design, manufacturing and assembly processes are also included [3].

The educational program includes the study of structures and the evolution of the techniques of construction and assembly throughout history. The workshops start with a theoretical approach, go on a guided activity and end with a creativity phase.
1 THE PROJECT

The present document shows in detail the project of a series of participative workshops related to material (timber), teamwork, process, module and, also, creativity. It is an open project that professor Blanco uses every course since 2012 at IE University.

The originally seminary formed part of the Segovia Hay Festival in 2012, it was a result of a collaboration agreement between IE University and the American Hardwood Export Council. Its main objective is to show the properties of wood as a material that joins tradition and avant-garde in the field of architecture, design or engineering. This aim is achieved through education, in this case at university level, with students of architecture in their last year.

For this workshop, we propose two simultaneous activities in two singular points of the city of Segovia; the Aqueduct and the Casa de los Picos Palace, the headquarter of the Design School of the city and one of the official venues of the Festival.

Both workshops used Lupo System’s own didactic technique and geometric forms. Lupo is a didactic tool created by the architect Fermin G. Blanco, who is at the same time professor of Construction Systems at IE University and the coordinator of the Timber Seminar.

Rather than creating a sculptural piece, in this case we propose a participative project where the process is as important as the result. In fact, it is conceived as an ephemeral architectural system, with an infinite number of uses and possibilities.

Dismantling the structure is also part of the workshop, after this it can be reused in any location and with any other form and objectives.

The material proposed for all this activity, which can be seen as an art performance, will be tulipwood, whose properties of lightness, resistance and finish will be the protagonist of each step of the project.

Figure 1: Yin yang project

2 LUPO SYSTEM

Lupo is a modular system patented by architect Fermin G. Blanco.

It is a set of basic pieces with proportional forms and dimensions allowing a diversity of combinations.

Its original objective is a didactic game tool. THE PROCESS is fundamental for the activity and THE ACTION is the medium. Equilibrium and form are the elements that
enhance the ability of vision in 2D and 3D and intellectually challenging the user to stimulate coordination, memory, sociability and creativity.

2.1 Bigger scale

Timber Lupo is a project that multiplied by four the size of the Eco Lupo original model. It was created reproducing the original geometry of the pieces while adopting the joints and the manufacturing process to this change of scale.

2.2 Packaging

The manufactured material should be adapted to the transport conditions, not only for this workshop but also for future uses. In this way, pieces made during the manufacturing process will be packaged in cases made up by themselves.

Each case (400x400x420 mm) is adapted to European pallet, so each pallet contains 12 cases as it is shown in the figure. Due to their drill holes, the top and bottom lids of plywood boards can be used as a foundation for Lupo constructions.

The weight and dimensions of each case allow for being manipulated by one or two users. The packaging reproduces in a large scale the distribution system of Eco Lupo (19 pieces) as shown in the figures.
3 MANUFACTURING PROCESS

1. Manufacturing of boards from planks which are joined together laterally using finger joints and are glued together in three pieces to reach the height of 100 mm. (size of the finished element). The joints have to be put in alternative positions in order not to make continuous joints in the vertical section of the piece.

2. Compression and calibration of boards with dimensions 550 x 550 x 100 mm (depth).

3. Cutting of pieces following Lupo System’s patent supplied by authorized Lupo System personal. Cutting with CNC machine making use of the leftovers to obtain pieces and lightened boards.

4. Transversal drilling of pieces. Manufacturing of joint pieces between lightened boards.


6. Packaging the pieces for shipment in cases of size 400x400x420 mm, using European pallets (12 cases for pallet). The cases will contain upper lid and bottom lid for their manipulation and distribution.
4 INIA-CIFOR STRUCTURAL LABORATORY

The permanent challenge during the building process is the exclusive use of wood. This has been possible thanks to the collaboration with the structures laboratory of INIA-CIFOR.

Both the material and the finger joints made during the manufacturing process were tested in the laboratory. We tested separately the resistance of the frame and of the whole element and obtained surprising results (in spite of their fragile appearance).

After this, the experiment concentrated on the joints, trying to resolve through the same joint element the different situations that could appear in the structure. We wanted to find a piece that could work in tension or compression (depending on the case). After a study of traditional Japanese solutions like Komi-San or Hana-San, the final solution is constituted by the use of dowels and sleeves, all made in American ash.

![Figure 6: Test of the pieces in the INIA-CIFOR structural laboratory and results of the tests](image)
Table 1: Frame test, template test and templates and system joints test.

<table>
<thead>
<tr>
<th>Test</th>
<th>Section (mm)</th>
<th>Force (KN)</th>
<th>Deformation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frame test</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bending test</strong></td>
<td>100x27,5x550</td>
<td>0,53</td>
<td>12,58</td>
</tr>
<tr>
<td>Grain and load applied in the same orientation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Compression test. (buckling)</strong></td>
<td>100x27,5x550</td>
<td>9,59</td>
<td>5,43</td>
</tr>
<tr>
<td>Grain orientation perpendicular to load applied</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Template test</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Compression test</strong></td>
<td>100x550x550</td>
<td>4,94</td>
<td>5,21</td>
</tr>
<tr>
<td>Grain and load applied in the same orientation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Compression test</strong></td>
<td>100x550x550</td>
<td>16,19</td>
<td>11,36</td>
</tr>
<tr>
<td>Grain orientation perpendicular to load applied</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Templates and joints of the system</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cantilever test</strong></td>
<td>100x550x550</td>
<td>2,55</td>
<td>36,96</td>
</tr>
<tr>
<td>Grain orientation perpendicular to load applied</td>
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5 YIN YANG TULIPWOOD

The results are two complementary projects based on the same production process.

The Roman aqueduct replica built with the “positive elements” shows the capacity of wood as material ready for its shaping in the field of design and architecture. That is, a natural material easy to manipulate and shape, quite lightened (due to its density) and aesthetic.

The Sponge is a complementary project, built from the “negative elements” made during the manufacturing process of the pieces for the aqueduct. In this case, the pore structure shows the structural possibilities of wood. The structural challenge is attained the strategic organization of the 92 squared pieces riddled with holes (in a 60% of their surface).

![Yin yang project](image)

Figure 7: Yin yang project

6 THE AQUEDUCT

The Roman aqueduct of Segovia is one of the most important Roman constructions in The Iberian Peninsula and also the universal symbol of the city.
The aqueduct consists of a mount of 20400 big blocks of granite (7500 m³ of stone) shaped and organised according to their position in the structure. The shapes of these pieces not only depend on their structural logic, they are also made according to the construction process used. Each part of the aqueduct is different but at the same time constitutes a systematic whole where everything is organised from the process through cutting the blocks to their final placement in the structure.

6.1 Construction of the replica

Following the same logic as in the original one, the process of manufacturing and transport is systematized to build a replica of the aqueduct. The result will be the replica of the Roman aqueduct of Segovia, in a 1/10 scale, making a puzzle of 336 pieces.

In each of the six pillars, that make part of the replica, the position of the pieces is different, although the general composition is the same. As in the case of the original one, none of the pillars repeat composition; however, they are all the same shape and size thanks to the system. The replica reaches a height of 2.80 meters and a total weight of 453 kg.

7 SPONGE

In parallel with the construction using Lupos, the construction with the “negatives” allows us to test Tulipwood as a structural material. The Sponge is a completely lightened structure, fruit of the manufacturing process of Lupo pieces. Each board has been projected in order to obtain four squared elements (550 mm size). Each element has been tested in the laboratory together with the joints.

To organise the process of building the structure, we projected a system of different levels of assembly to be built by the students. The Sponge has a labyrinth structure (3.70 m size) which the visitors of the exhibition can walk through. Its elements are organized in the shape of a cube; the disposition of each element tries to meet different structural challenges using cantilevers and beams supported by a mash of pieces.

Since this project is inspired by the idea of the process and the complementarity of solutions, we have decided to link the two projects, the Aqueduct and the Sponge, during the building process. In the plans for the building process, we can see different abstract drawings that reproduce the original mason’s marks on the stone blocks of the Aqueduct. These marks,
which identify the work of each particular stonemason, can be seen even today in several parts of the monument.

7.1 Concrete Lupo

The need to ballast the Sponge structure was a new challenge that was solved through manufacturing the concrete pieces, in this case using timber as formwork.

Figure 9: Concrete Lupo

7.2 Joints

Most of the tradition of the use of wood throughout the world has been based on its own properties of resistance, which allowed wood to be very useful in structures. The discovery of new construction materials throughout the history has improved the solutions and the range of possibilities, but even in our days, wood is considered in the field of architecture and design as a contemporary material.

Figure 10: Sponge joints

7.3 The didactic balance.

This didactic project was conceived to explore the material and its possibilities. It was a challenge to try to build this structure without help of glue or metallic screws in joints, that is, in a traditional way by the exclusive use of wood. This method has allowed us to understand wood in all its magnitude, getting to explore its natural composition and its building qualities that allowed us to use it effectively in construction.

This project has maintained a balance between theory and practice, implicating the students in the different steps of its development.

The manufacturing process of the wooden pieces has been at the same time served as a test bank for finding necessary solutions. As a part of all the didactic process, in the carpenter’s workshop, we not only manufactured the pieces, but also carried out tests for possible solutions, which would also be tested using models and experiments in professional structures laboratories.
This project represents an overview of all components of construction, from innovation, through manufacturing, assembly to structural security, all constituting a logical mixture of professionalism and learning.

Figure 21: IE students during the construction process

8 HAY FESTIVAL OPENING DAY. THE HUMAN CHAIN

More than three hundred volunteers took part in the popular workshop by carrying the components of the Aqueduct replica to the Casa de los Picos palace where the pieces were stored in the negatives of the Sponge, that public engagement is important in this type of projects just to emphasize the social commitment of education.

Figure 12: Aqueduct replica, human chain and Sponge

9 FOLLOW-UP PROGRESS

Throughout the years following the 2012 workshop of the Hay Festival in Segovia, the collaboration between IE University and Segovia City Council has continued to generate new interventions. Every course new students come and participate in this workshop, during the theoretical part they create small groups and propose a project to build using the system, we
discuss every project and finally we merge all ideas into one. Second part of the seminar is the practical workshop where students have to build the idea in a collaborative way.


Opening the Lupo box means starting a teaching and educational process. As in every learning process, challenge is a motivating element that encourages teamwork towards a shared objective. The process offers infinite possibilities and repetitions but it always finishes at the same point, with all the material picked up, without any noise, promoting the reflection... Each time the box is dismounted, a new process starts…

Figure 14: Timber Lupo box.

REFERENCES
THE CIVIL ENGINEERING OLYMPIAD: A PROGRAM TO OPEN STUDENT VOCATIONS

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Key words: Civil Engineering studies, Student Vocations, Olympiads.

Abstract.

Five years ago the US Bureau of Labor Statistics predicted a much higher than average growth in jobs over the next decade in Civil Engineering (CE) areas, approximately 19%. This supposes a clearly need for qualified civil engineers to fill these jobs, however during the last decades the number of students interested on CE university degrees has decreased. In Spain, the economic crisis has aggravated the problem, in consequence the Professional Association of Civil Engineers (Colegio de Ingenieros de Caminos, Canales y Puertos) and four Superior Technical Schools of the universities of Granada, Sevilla, Alicante and Polytecnic of Valencia have joined together to develop a program to open secondary students vocations. The program has been named The Olympiad in Civil Engineering; it is a competition between teams of five students to overcome, in the shortest time possible, six tests related to different areas of CE: Hydraulic Engineering, Mechanical and Structural
Engineering, Environmental Engineering and Construction Engineering. Winner team of each university will compete in a national final. In May 2018 one of the participant universities has developed a pilot experience to check the tests and solve possible organization problems to celebrate the First Edition of the Olympiad of Civil Engineering in 2019 with a higher number of Universities. This is one way to increase the pool of gifted students who could study Civil Engineering degrees in future, as similar competitions and programs successfully developed during year, for example Mathematical, Biological or Chemical Engineering Olympiads, among others.

1 INTRODUCTION

Technological and Engineering university degrees will be, during the next decades, the ones that have the best job insertion and an exponential demand. However, fewer and fewer young people decide to choose them. This situation, which is known as "talent deficit", is already a problem in the area of Engineering and it is causing an imbalance between the professional offer and the needs of the labor market. Universities, companies and human resources consultants, warn that without the appropriate professionals, the economic consolidation could be put at risk. Randstad, a leading company in human resources, declared that in 2020 Spain will need 1.9 million highly qualified workers [1].

There are several reasons to explain this vocations crisis. On the one hand, the applied methods in primary and secondary education to teach the basic materials for Engineering (mathematics and physics) are not motivating; on the other hand, the non-choice of engineering studies is linked to the fact that this sector has lost its recognized high quality of work; besides, the salaries do not respond to the demands and they are not proportional to the difficulty of this studies.

In the case of Civil Engineering, this situation has been aggravated by the crisis, which has reduced, in Spain, public investment to unsuspected limits a decade ago. However, the professional with advanced training in the framework of Civil Engineering, the called Ingeniero de Caminos, Canales y Puertos in our country, has been characterized by a recognized training that has enabled him to adapt to different labor markets, not only the construction sector.

Therefore it is necessary to encourage vocations in this sector at increasingly younger ages showing that civil engineering has a great future in the development of infrastructures in developing countries but also in developed ones. They will also be key professionals in the technification and digitalization of Europe, and in particular Spain, since the technological revolution is already present in the infrastructures: waste and drinking water autonomous plants, waste management self-winding plants, intelligent bins to collect municipal waste, intelligent transport, etc. Besides, five years ago the US Bureau of Labor Statistics predicted a much higher than average growth in jobs over the next decade in Civil Engineering (CE) areas, approximately 19%. This supposes a clearly need for qualified civil engineers to fill these jobs [2,3].
Following the example of successful cases of competitions in Mathematical, Biological or Chemical Engineering areas [4], among others, the Professional Association of Civil Engineers (Colegio de Ingenieros de Caminos, Canales y Puertos) and four Superior Technical Schools of the universities of Granada, Seville, Alicante and Polytechnic of Valencia have joined together to develop a program to open students’ vocations. The program has been named The Olympiad in Civil Engineering (Olimpiada de la Ingeniería de Caminos, Canales y Puertos) and, after a pilot experience last May, the Professional Association expects to extend it throughout different Spanish universities to make visible the profession in secondary schools. This paper describes the initiative, as well as preliminary results of pilot experience.

2 DESCRIPTION OF THE OLYMPIAD IN CIVIL ENGINEERING

The Olympiad in Civil Engineering (Figure 1) has been designed as a team competition in which students from Secondary Schools compete in 6 events pertaining to various areas related to Civil Engineering activities (Figure 2): Hydraulic Engineering, Environmental Engineering, Structural Engineering, Civil Engineers and their constructions. These events should be properly developed in the shorter time as possible. Events will be developed as a gymkhana in teams of 5 students and supervised by a teacher who plays the role of referee.

Figure 1: Logo designed for the The Olympiad in Civil Engineering.
1. Build your future

A half-arch structure must be built to resist without falling for at least 5 seconds

2. Da Vinci Bridge

Da Vinci Bridge will be built and resist, without falling, to one of the member of the team during, at least, 5 seconds

3. Build a dam

A dam will be built and the time it takes to break once it is filled with water will be measured

4. Civil Engineers and their constructions

6 puzzles with pictures of engineering works should be assembled in the shortest possible time

5. ReLATIcicla

A 2 m sculpture with recycled cans should be built

6. Playing to be Engineers

It will consist in making a challenge with a construction videogame

Figure 2: Characteristics of events forming The Olympiad in Civil Engineering.

The Olympiad has been planned for three levels of competition: local, regional and national, described below (Figure 3):

- **Local level.** This phase will run by Secondary Schools to invite teachers and students to improve skills related with this area thanks to the practice of the 6 events designed.

- **Regional level.** In this case the selected teams will have to compete in each Superior Technical Schools that participate in The Olympiad. Teams that excel at regional petitions advance to the national level. During the participation, general and cultural activities will be also developed in the University Centre.

- **National level or Great Final.** Each year, one of the participant Universities will be chosen as headquarters to the final competition. Participant teams of different places of Spain will travel to the national headquarter to develop the same 6 event. Three final levels of winner will be chosen after the competition: Olympic Gold, Silver and Bronze Medals in Civil Engineering. During the participation, general and cultural activities will be also developed in the University Centre and in the city.

Figure 3: The Olympiad in Civil Engineering competition levels
3 DEVELOPMENT OF THE PILOT EXPERIENCE

In order to verify the six events designed by teachers from different universities, as well as the organization of the competition, a pilot phase was carried out in May 2018; during this phase students of 2º ESO from the Secondary School Cristo de la Yedra, in Granada, was invited to participate. Some organizers of the Olympiad visited the School to explain to teachers the objective of the competition, the development of the events and to give them some materials necessary to train.

After a month of training with the teachers of the school, 25 students were selected (16 girls and 9 boys) organized in 5 teams. These teams visited the High Technical School of Civil Engineering of the University of Granada, where they competed along one morning with another team integrated by university teachers. Six teachers of the High Technical School acted as referees for each of the events. Figure 4 shows some pictures of the competition during the development of the events.

Figure 4: Pilot experience of The Olympiad in Civil Engineering in High Technical School of Civil Engineering at the University of Granada.
The score of the different events was given in time. Table 1 summarized the name of each of the participating teams, as well as the scores obtained in the different events in minutes. The winning team was Cheese Team, the team that developed all the events in the lower time. The winner of each event and the final winner have been identified in this Table.

**Table 1**: Final scores for each team, in minutes

<table>
<thead>
<tr>
<th>Events</th>
<th>Teams</th>
<th>Efestivyonder</th>
<th>Picapedra</th>
<th>Team Cheese</th>
<th>TeamD team</th>
<th>Roquefort</th>
<th>Teachersteam</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Buildyourfuture</td>
<td>0.68</td>
<td>1.68</td>
<td>0.67</td>
<td>1.58</td>
<td>1.05</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>2. Da Vinci Bridge</td>
<td>7.25</td>
<td>2.2</td>
<td>2.88</td>
<td>3.06</td>
<td>3.63</td>
<td>3.75</td>
<td></td>
</tr>
<tr>
<td>3. Build a dam</td>
<td>3.87</td>
<td>3.27</td>
<td>1.46</td>
<td>2.2</td>
<td>1.63</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td>4. Civil Engineers and their constructions</td>
<td>10</td>
<td>12</td>
<td>11</td>
<td>11</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>5. ReLATIcicla</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>13.26</td>
<td>15</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>6. Playing to be Engineers</td>
<td>11</td>
<td>11</td>
<td>8</td>
<td>9</td>
<td>9</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

Final score: 47.8, 45.15, 39.01, 40.1, 40.31, 39.95

Final position: 6°, 5°, 1°, 3°, 4°, 2°

In order to know the influence of the Olympiad on the participating students, a brief survey was prepared and implemented before and after the event. It was designed to ask about the working area of Civil Engineers or the possible election of students to study to develop this profession, among others. Figure 5 shows that before the competition, be Civil Engineer was among the five first positions only in the case of three students (12%); however, at the end of it the number was increased to 7 (28%), that is, it was increased by 16%. On the contrary, the election 6th or higher positions were reduced by 16%, passing from 15 to 11 students. Therefore, it could be concluded that the competition opened up vocations among potential students to be Civil Engineers. It is important to note that, both before and after the competition, there were not girl who chose the profession of Civil Engineer among the top five positions. This result highlights the importance to encourage girls to study Engineering degrees in general, and Civil Engineering particularly.

![Figure 5](image-url)
in Civil Engineering in High Technical School of Civil Engineering at the University of Granada.

Regarding the knowledge that students have about the working area of Civil Engineers, Figure 6 summarizes results before and after the competition. Results have showed that, although there are some working areas of Civil Engineers are clearly known, for example the construction of roads, bridges, railway lines or ports, this profession is not always very well known by young people who, before the competition, thought they also built cars or airplanes. There were others working activities that are not so well known, such as the construction of large structures (football stadiums) or facilities for water treatment; however, after the competition, these working areas were selected by the students. It is possible conclude that the Olympiad has been useful to improve the knowledge of Civil Engineers working area.

![Figure 6: Knowledge about working area of Civil Engineers before and after the competition.](image)

The experience observed has allowed for improving some organizational aspects of the events, the organization and determine the cost of the experience. The final proposal has been sent by the College of roads to all Spanish schools with the aim of promoting an edition for the 2018/2019 academic year including local, regional and national levels. The estimated cost, with 5 teams participating in each regional headquarters has been estimated in 2,000 €/headquarter. The final cost of the Olympiad will be linked to the number of regional venues that finally decide to participate; it depends on number of students that finally will travel to the national headquarters. In the case that participate 6 universities, the total cost has been estimated in 22,000 €, including regional and national level organization. Most of the material needed for testing will be re-used in the following editions. Therefore, the total cost of successive editions will be reduced to approximately 12,000 €/year.

4 CONCLUSIONS

The developed of The Olympiad in Civil Engineering is an opportunity to spread and
clarify the role of Civil Engineers of Secondary Schools students and teachers.
- This program will encourage teachers of Secondary Schools to improve applied teaching of basic materials of Engineering (Mathematics, Physics).
- The Olympiad in Civil Engineering develops soft skills in Secondary Schools students: group work, deduction capacity, basic knowledge application, and creativity, among others.
- Local and national competition will be an incentive for students to participate and, in consequence, strengthen the objective achievement of this initiative.

ACKNOWLEDGMENT
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REFERENCES
THE GROUP OF PROJECTS: DESIGNING DIFFERENT FOOTBRIDGES FOR THE SAME SITE.

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Key words: Education, Civil Engineering, Methodology, Learning, Technology.

Abstract. This paper deals with the experience of the first author, who created the so-called “group of projects” at the Civil Engineering School of UPCT. This informal group was composed of five students (four graduate and one undergraduate) who wrote their thesis during the same term, advised by the author. All of them designed a footbridge over an artificial channel in Cartagena for their thesis. The main feature of the group is that all the designs were intended for the same site, but all of their structural typologies were different.

Since a small footbridge had already been built recently on the same site, actual data were available, such as topography, geotechnical reports or the location of existing sewage networks.

As a result of this strategy, the group developed a very inspiring and hard-working collaborative spirit that lead the students to develop jointly a lot of documents, design techniques, specific software, technical detailing, drawings, etc.

Besides, since the office hours were for the all the students simultaneously, the advisor could save time in the common tasks and devote more hours to the specific aspects of each project, such as the conceptual design.

As an additional consequence of this novel approach, the students could focus on the structural aspects of their projects, allowing them to achieve better results when understanding and designing complex structural typologies.

1 INTRODUCTION

This paper deals with the so-called “group of projects”, an informal workgroup created by the author in 2014, at the Civil Engineering School of the Polytechnic University of Cartagena, Spain. This group was composed of five students (four graduate and one undergraduate), who wrote their thesis during the same term advised by the author. All of them, who had chosen structural engineering optional courses, designed a footbridge over a channel in Cartagena for their thesis. The main feature of the group is that all the projects were intended for the same site, but all of their structural typologies were different.

Since a real footbridge had been built recently on the same site, actual data were available, such as topography, geotechnical reports or the location of existing sewage networks.

As a result of this strategy, the group developed a very inspiring and hard-working
collaborative spirit that lead the students to develop jointly a lot of documents, design techniques, specific software, technical detailing, drawings, etc.

Besides, since the office hours were for the all the students simultaneously, the advisor could save time in the common tasks and devote more hours to the specific aspects of each project, such as the conceptual design.

As an additional consequence of this novel approach, the students could focus on the structural aspects of their projects, allowing them to achieve better results when understanding and designing complex structural typologies.

2 ORIGIN AND ACADEMIC CONTEXT

3.1 Birth of the group: an “engineering” solution.

In the master program in Civil Engineering, professors do not advise a fixed number of students’ thesis per term, but the students ask for advisory to the professor they choose. The professor may accept them or not, depending mainly on his/her availability and the type of project. The limited number of students in our school and the variety of the topics that they learn (in three sub-programs about structural engineering, transport engineering and hydraulic engineering) make this system work without significant problems. The most common problem is the lack of time of a given professor to advise all the students interested in working with him/her.

This was the origin of the group of projects, when five students asked, simultaneously, for the author to be their advisor of their graduate and undergraduate thesis. All the students had attended courses taught by the author, all of them were motivated and brilliant, and, simply, the author did not want neither to miss the opportunity to work with them, nor, obviously, disappoint them. The main problem to advise all of them simultaneously is that all the master thesis are different, usually in different sites, and in the office hours the advisor meets with only one student at the same time. Therefore, to be honest, the group of projects was not a strategy planned beforehand, but it can be defined as an “engineering” solution, developed in order to solve, practically, an advisory problem.

3.2 Master thesis in Spanish Civil Engineering programs.

All the students had chosen the courses corresponding to the structural engineering sub-program and its optional courses. Thus, all of them had received advanced training in foundation engineering, finite element method, bridge engineering and structural typology, according to the organization of courses in the CE school of UPCT [1]. Our Engineering program, as it happens in Spanish universities, enables the student to become a professional engineer in Spain (the equivalent to a CE or PE in UK and USA, respectively) and to become a member of the “Colegio de Ingenieros de Caminos, Canales y Puertos” (a Spanish national institution similar, for example, to the ICE or ASCE).

According to the Spanish law that regulates the Master in Civil Engineering (“Ingeniero de Caminos, Canales y Puertos” in Spain) studies, the master thesis consists of a “realization, presentation and defense, once all the credits of the master have been obtained, of an original exercise carried out individually before a university committee, consisting of an integral project of Civil Engineering of professional nature in which the skills acquired in the teachings are
Therefore, the master and undergraduate thesis are usually construction projects, with a level of detail and difficulty according to its complexity, but always with a near-professional level of detailing. It easy to imagine that the work of the advisor is crucial for the final result and that a properly advised master thesis may demand a lot of time, both for the student and the advisor.

3 THE SITE

The site is located in Cartagena (Fig. 1), in southern Spain.

Figure 1: Geographical location of the site: Cartagena, Spain.

Figure 2: Benipila Channel (Source: Wikipedia commons)
The footbridge crosses over the Rambla de Benipila, an artificial channel (Fig. 2). A previous existing road bridge is very close to the footbridge to be designed (Fig. 3 and 4). This footbridge is a diagonal arch bridge.

Figure 3: Existing bridge and footbridge: View from the Pio XII street. (Source: Google maps)

Figure 4: Existing bridge and footbridge: View from the Real street. (Source: Google maps)

One of the main reasons to choose this site was that the documentation related to the construction project of the arch footbridge shown in Fig. 3 and 4 was available to us. Since, from the legal point of view, the owner of the technical documentation is the Cartagena City Council, all the people involved with the group were subjected to a confidentiality agreement that prevented the information to be divulged.
3 THE DESIGNS

The projects are shown in Fig. 5 and 6. In order to reduce the effect of floods, none of the bridges has intermediate supports in the artificial channel. Thus, the main span was approximately 50 m.

Similarly, the structures are designed independently of the existing concrete road bridge because this bridge, built approximately 50 years ago, will be likely replaced soon.

The designs are:

a) A Warren-type truss, where both chords are curved, which gives it a lenticular shape. The cross-section is composed of three steel circular hollow sections (CHS). The upper chord is composed of two semicircular CHS whereas the lower chord is a complete CHS (Fig. 6-b). The main span corresponds to the artificial channel, whereas the lateral spans are very short and provide some elastic clamping, to reduce the sagging bending moment at midspan.

b) A typical two girder composite bridge (Fig. 5-b). It is a frequent solution. However it has two features: In order to reduce the sensitivity to the level of the water in the artificial channel the depth of the beam is very strict. In order to reduce the depth of the girders, it also has short lateral spans with elastic clamping, in a solution similar to that used in the previously described solution.

c) The third solution is a spatial truss. The main feature is that the diagonals are attached eccentrically to the edge of the deck. Attached to the upper chord, a secondary horizontal truss helps to withstand a textile structure to shed the pedestrians. Thus, the cross section is similar to a C-shaped section (Fig. 6-c), which makes torsional moments to be resisted mainly by warping, as it corresponds to an open section. Since the separation between the deck and the roof truss is defined by the clearance requirements the structure could be relatively light.

d) A spatial arch bridge composed of a leaning arch attached eccentrically to the edge of the deck. The arch and the deck are linked by a Nielsen-Lohse cable arrangement (Fig. 5-d). The cross section is composed of a torsion bar with ribs that support the deck (Fig. 6-d).
Figure 5: Graduate students’ designs. Elevations.
Figure 6: Graduate students’ designs. Cross-sections.

4 LESSONS FROM THE EXPERIENCE

The main educational lessons the author learnt from the experience can be summarized as follows:

Office hours in groups.

In the office hours the author met with all the students simultaneously. Previously, the students knew the part of the project we were going to deal with (such as structural modelling,
welding design of foundations, etc.) so they could prepare the topic in advance. This is very demanding for the students, but, at the same time, the learning is deeper. Another advantage is that the questions could be answered by the author for all the students at the same time, a fact that saved a tremendous amount of time, because the questions are usually very similar for all of them. Besides, listening the questions of one of the students made the rest of them improve the understanding of the topic.

Additionally, the advisor can save time in the common tasks and devote more hours to the specific aspects of each project, such as its conceptual design.

**Design seminars**

Some of the meetings were devoted to the design seminars, in which a student describes briefly his/her design to the rest of the group. The student must justify the chosen design, from the technical, functional and constructive points of view, and answer the questions. At early design steps, the questions are very general. However, in the final steps of the design, the question may refer to very specific details of the design.

Of course, the communication skill of the students is greatly enhanced by this experience. Somehow, this could be understood as a “rehearsal” of the final presentation before a committee. By the way, they learn how to summarize the information to be included in an oral presentation, and, especially, how to justify, select and defend a technical solution.

**Individual office hours.**

Although reduced at the minimum, the individual office hours had no difference with the common role of an advisor. The individual office hours were also available for sub-groups of students with specific or similar problems.

**Public presentations**

In our School, for the sake of transparency and because of ethical motivation, the presentations of the thesis before a committee are public, and any person may attend, even non-related to the school. The audience may even ask questions to the students, provided the person who asks holds a master degree. In the group of projects all the rest of the group attended to the presentation of every student.

**Group behaviour.**

Perhaps the most interesting conclusions can be found when the students are part of this advisory strategy. The main features of the group behavior are:

- They tend to share all the information spontaneously. Before the second meeting all of them shared a Dropbox folder.
- They tend to “specialize” within the group. Without planning, one of the student chose to code not only his own software, but also to share it with the rest of the group and help them with their own codes. In return, other one became the “expert” in graphical design, etc. It the specialization is excessive it must be avoided by the advisor, since there is also a risk that the work is not totally personal.
- All of the members of the group tend to help one another apart from the advisor.

would much more difficult alone.

- The students achieve better results when understanding and designing complex structural typologies, because the students, as well as the advisor, can focus on the structural aspects of their thesis.
- As a result of this strategy, the group developed a very inspiring and hard-working collaborative spirit (Fig. 7), which can be an advantage in their integration into multidisciplinary teams.

Figure 7: A meeting of the Group of Projects

ACKNOWLEDGMENTS

For the author, the experience of creating and working in the group was a gift. The students who made it possible were, in alphabetical order: Jesús Aguilar Jiménez, Jesús Ato Yelo, Enrique Chereguini Portela, Juan Manuel García Guerrero y Sara María Saura Ródenas.

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REFERENCES


BENEFITS AND LIMITATIONS OF ADOPTING PROJECT-BASED LEARNING (PBL) IN CIVIL ENGINEERING EDUCATION
– A REVIEW

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Key words: Civil Engineering Education, Problem-based learning, Project-based learning.

Abstract. A lack of balance between theoretical and practical learning has been a systematic problem in engineering degree courses during the second millennium. The challenge for the third millennium therefore remains that of blending assimilation of knowledge with responsible application of theory in practice, during the formative undergraduate years. A report published at the turn of the millennium noted the serious decline in applications from bright young people to study engineering, especially built environment programmes, while drawing attention to a finding that programmes which attract the best students are those that encourage a high level of interdisciplinary thinking and project work. Inductive teaching and learning approaches include inquiry learning, problem-based learning, project-based learning, case-based teaching, discovery learning and just-in-time teaching. Such constructivist methods are deemed to be student-centred, placing more responsibility on the student for their own learning as they actively construct and reconstruct their own reality, while the teacher acts as facilitator in the process. Two approaches are slowly emerging as preferred in civil engineering education: problem-based learning and project-based learning. While they share commonalities, differences exist. Problem-based learning focuses on knowledge acquisition while project-based learning (PBL) emphasises the application and integration of knowledge. However, widespread acceptance of such innovative education strategies is not yet a reality and the relevance and effectiveness of both approaches in engineering education is still open to question. The body of literature on the topic continues to grow. This paper investigates recent evidence in civil engineering education and identifies trends that may be helpful in the successful reimagining of programme ethos and curricula. The study considers application context (e.g. final year capstone project, first year design project), data type (e.g. student feedback, tutor reflection), and measure of effectiveness model (e.g. qualitative/quantitative analysis). Dominant benefits and challenges are identified.
1 INTRODUCTION

A failure to achieve balance between assimilation of knowledge and responsible application of theory in practice in engineering education has remained elusive [1]. Interest in engineering careers, and particularly those of the built environment, continues to decline as we lose young talented people to programmes offering project and interdisciplinary experiences [2]. Interestingly, such experiences are intrinsic within learner-centred (i.e. inductive) pedagogies. Compared with traditional teacher-centred (i.e. deductive) instruction, modern cognitive science and extensive research make a case for the superiority of a learner-centred (i.e. inductive) approach to teaching [3-6]. A number of inductive teaching and learning approaches exist including inquiry learning, problem-based learning, project-based learning (PBL), case-based teaching, discovery learning and just-in-time teaching [4]. Such constructivist methods are deemed to be student-centred, placing more responsibility on the student for their own learning as they actively construct, and reconstruct their own reality, while the teacher acts as facilitator in the process [7]. A review of literature indicates that problem-based learning, and project-based learning, have emerged as the inductive teaching approaches in civil engineering education. While sharing commonalities, differences exist as problem-based learning focuses on knowledge acquisition while project-based learning (PBL) emphasises the application and integration of knowledge [4, 8]. Despite existing since the early seventies, widespread adoption of such methods is not evident [8] and reservations persist. In 2003, Mills and Treagust [9] were prompted to question the relevance and effectiveness of learner-centred approaches such as PBL. Their research considered PBL implementations within civil engineering and particularly research by Hadgraft [10-13]. The current research seeks to further examine if the question raised has been answered within published research on the application of PBL within civil engineering in the intervening period. Consequently, the research considers the 15 year period since the Mills and Treagust study [9] (i.e. 2003-2018) with dominant benefits and challenges identified.

2 APPLICATIONS OF PBL IN EDUCATION

A comprehensive literature search resulted in a total of 27 studies being identified for review as part of the current study [14-40]. A summary of key aspects of reported PBL applications within the discipline of Civil Engineering is included in Table 1 and is presented in chronological order commencing with the most recent. Aspects of the studies considered include year of study, topic of study, stage of study, data type/mode of collection (e.g. student feedback, tutor reflection), and measure of effectiveness model (e.g. qualitative/quantitative analysis). The rate of publication over the period considered is approximately three papers every two years. The maximum was five in 2015, while there were none in 2004, 2006, and 2009. In terms of publication type, 16 are peer-reviewed journal papers (i.e. 60%), nine are conference papers (33%), one symposium paper and one research article. The breakdown in terms of stage of study and topic of study are presented in Figure 1.
<table>
<thead>
<tr>
<th>Ref.</th>
<th>Data Collection Mode/Data Type</th>
<th>Measure of Effectiveness Model</th>
<th>Key Findings</th>
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<tbody>
<tr>
<td>[14]</td>
<td>Student Grades; Student Questionnaire</td>
<td>GPA and Assessment Grades</td>
<td>2nd year Soil Mechanics: Similar performance for PBL and control group but PBL brings greater student engagement, especially from those with relatively lower GPA.</td>
</tr>
<tr>
<td>[15]</td>
<td>Student Questionnaire; Student Focus Groups; Tutor Interviews</td>
<td>Author observations based on student and tutor feedback</td>
<td>Construction Engineering: Identifies for practitioners evidence-based strategies for PBL implementation, covering case studies, just-in-time, peer instruction, self-directed and cooperative learning.</td>
</tr>
<tr>
<td>[16]</td>
<td>Student Questionnaire</td>
<td>Mean values of number-based Likert scale responses; Student grades</td>
<td>2nd year Soil Mechanics: Students and staff find collaborative model of PBL better than cooperative. Collaborative model overcomes compartmentalisation of course contents among student team members; Effectiveness of PBL increases with repetition of PBL experience; PBL is effective academically; Workload neutral for students but higher for staff; Payback for staff comes in follow-on stages with students as more autonomous learners.</td>
</tr>
<tr>
<td>[17]</td>
<td>Student Questionnaire; Student Grades</td>
<td>Mean values of number-based Likert scale responses</td>
<td>3rd year Design: Recommends use of active learning to allow the students to fully engage in content knowledge prior to starting interdisciplinary PBL; Use of physical scaled models to facilitate understanding of concepts; Use of hand sketching to generate ideas, communicate designs, understand complex ideas and react during interdisciplinary discussions.</td>
</tr>
<tr>
<td>[18]</td>
<td>Student Questionnaire</td>
<td>Mean values of description-based Likert scale responses</td>
<td>Final year Design: Workload in PBL needs to be carefully managed – in case studies, use a medium scale project.</td>
</tr>
<tr>
<td>[19]</td>
<td>Student Questionnaire; Student Focus Groups</td>
<td>Mean values of number-based Likert scale responses</td>
<td>2nd year Concrete Technology: PBL was well received and can facilitate deep learning; PBL projects must be designed with specific graduate attributes in mind.</td>
</tr>
<tr>
<td>[20]</td>
<td>Student Survey</td>
<td>Mean values of number-based Likert scale responses</td>
<td>1st year Design: Recommendation is that students be required to take on at least two roles within the team during the PBL project to stretch their skills development.</td>
</tr>
<tr>
<td>[21]</td>
<td>Student Pass Rate; Student Attendance; Student Questionnaire</td>
<td>Mean values of number-based Likert scale responses</td>
<td>1st year Design: PBL brings greater student engagement and is very effective if clearly linked to competences being assessed in the module – which may require reducing number of competences to be developed in the module. Staff workload is a matter of concern – PBL was conceived for small groups of 8-10 students with a tutor per group.</td>
</tr>
<tr>
<td>[22]</td>
<td>Student Questionnaire</td>
<td>Extracts from students’ feedback</td>
<td>5th year (M.Eng.) Structural Form: [22]</td>
</tr>
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Table 1 (continued): Summary of PBL research in Civil Engineering

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<tbody>
<tr>
<td>[23]</td>
<td>Student Questionnaire; Student Grades</td>
<td>Mean values of number-based Likert scale responses; Comparison of student grades</td>
<td>4th year Transportation Geotechnics: PBL student scores higher than control group; PBL encouraged confidence, ownership of learning and clarified connections between different parts of the programme.</td>
</tr>
<tr>
<td>[24]</td>
<td>Student Grades</td>
<td>Statistical comparison (ANOVA) of grades.</td>
<td>3rd / 4th year Design: Impact of PBL on learning outcomes is not consistent; Generally, it can improve results but do not assume all learning outcomes in a module are equally impacted.</td>
</tr>
<tr>
<td>[25]</td>
<td>Peer assessment; Student Grades</td>
<td>Peer assessment vs tutor's overall module grade</td>
<td>2nd year Design: Peer-assessment grades in PBL correlate well with final project grades – both are heavily influenced by engagement rather than ability.</td>
</tr>
<tr>
<td>[26]</td>
<td>Grades for 'reflection' element of assessment</td>
<td>Grades compared</td>
<td>2nd year Reflection: Reflective writing is enhanced if guidance is provided but it requires time to teach authentic reflective writing.</td>
</tr>
<tr>
<td>[27]</td>
<td>-</td>
<td>-</td>
<td>4th year (MEng) Design: Students responded well to mastering a new technique (Building Information Modelling) through the use of PBL, combining core skills of quantitative reasoning, critical thinking, communication skills, team-working and information technology.</td>
</tr>
<tr>
<td>[28]</td>
<td>Student Questionnaire</td>
<td>Mean values of number-based Likert scale responses; Comparison of student grades</td>
<td>5th year (MEng) Design: High student satisfaction rating with PBL (70%) but the time input required by students and staff needs to be co-ordinated with other modules, especially in respect of submission deadlines.</td>
</tr>
<tr>
<td>[29]</td>
<td>-</td>
<td>Researcher’s reflection on PBL application</td>
<td>2nd year Concrete Technology: Use of PBL in laboratory exercises ensures engagement (no ‘free riders’) and greater connection between individual laboratory exercises and module learning outcomes.</td>
</tr>
<tr>
<td>[30]</td>
<td>Limited number of student feedback statements</td>
<td>Researcher’s reflection on PBL application</td>
<td>2nd year Design (Water Engineering; Geotechnical Eng): Impact of change to PBL from didactic teaching greatly exceeded expectations in respect of depth and rigour of learning.</td>
</tr>
<tr>
<td>[31]</td>
<td>Case study</td>
<td>Tutor discussion of application and observations</td>
<td>3rd &amp; 4th year Transportation Engineering: PBL increased student engagement but is resource hungry and peer-assessment may occasionally requires careful moderation by the module co-ordinator.</td>
</tr>
</tbody>
</table>
### Table 1 (continued): Summary of PBL research in Civil Engineering

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>[32]</td>
<td>-</td>
<td>-</td>
<td>Design: PBL recognized in promoting students’ creative thinking, improving analysis and problem solving ability and promoting lifelong learning</td>
</tr>
<tr>
<td>[33]</td>
<td>Method not specified</td>
<td>General (single) concluding statement based on feedback</td>
<td>Final year Design: Staff time commitment is a concern in implementing PBL. Monitoring students’ time management is also prudent; Team-building exercises between instructor and student may be needed to encourage open discussion.</td>
</tr>
<tr>
<td>[34]</td>
<td>Grades for key tasks within assessment</td>
<td>(a) Grade performance (b) Grade performance versus tutorial attendance</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; &amp; 2&lt;sup&gt;nd&lt;/sup&gt; year Structural Analysis: Attendance at tutorials has a significant impact on conceptual understanding.</td>
</tr>
<tr>
<td>[35]</td>
<td>Limited number of student feedback statements</td>
<td>-</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; – 5&lt;sup&gt;th&lt;/sup&gt; year Design: PBL complements traditional education in a very impactful positive way but requires lecturers who are both well trained from practice in engineering and are dedicated to teaching.</td>
</tr>
<tr>
<td>[36]</td>
<td>-</td>
<td>Researcher’s brief reflection on PBL application</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; year Design: PBL encourages early requests for clarification of understanding gaps; Consistency in peer-assessment is problematic.</td>
</tr>
<tr>
<td>[37]</td>
<td>Classroom observations; Student Questionnaire</td>
<td>Tutor discussion of feedback and observations</td>
<td>5&lt;sup&gt;th&lt;/sup&gt; year Administration Theories: PBL most beneficial if introduced early in the curriculum; Consideration may need to be given to increasing credits due to higher time commitment.</td>
</tr>
<tr>
<td>[38]</td>
<td>Student Questionnaire</td>
<td>Statistical comparison (ANOVA) of (a) feedback ratings and, (b) GPA</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; year Environmental Engineering: Some evidence that PBL may assist attracting under-represented groups to engineering courses by appealing to their learning style.</td>
</tr>
<tr>
<td>[39]</td>
<td>-</td>
<td>Comparison of PBL across three institutions</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; – 5&lt;sup&gt;th&lt;/sup&gt; year, various topics of study: Consideration needs to be given to collateral negative impact of PBL success in further discouraging students from putting time and effort into traditional lecture attendance.</td>
</tr>
<tr>
<td>[40]</td>
<td>Student Grades (Overall &amp; specific project marks); Student Questionnaires</td>
<td>Statistical comparison of (a) feedback ratings and, (b) Course grades</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt; year Design: Identified strong link between PBL success and the students’ choice of an engineering programme due to their inherent interest in projects</td>
</tr>
</tbody>
</table>
5 BENEFITS & CHALLENGES

5.1 Benefits

Based on student feedback, operating within a PBL approach assists in the development of graduate attributes and skills for professional practice [16, 19, 23, 24, 28, 32, 35-37]. Zeng and Xu [32] present a case study detailing various aspect of the application of problem-based learning in a civil engineering programme and highlight benefits in terms of innovation, communication, teamwork, project and time management. McCrum use PBL as a vehicle to encourage higher order critical and creative thinking in students [17], while others also concluded to such positive outcomes [27, 32, 36]. A comparison of graduates from the PBL based engineering programme at Aalborg University, and those from the traditional programme at Danish Technological University (DTU), found that Aalborg graduates were stronger in communication, team skills, ability to complete a full project, while DTU graduates were more capable of independent work but required more training [9]. In addition to such attributes, Mills and Treagust [40] conclude that students also develop competence in evaluation of alternative views, negotiation of understanding, and realise the importance of learning for understanding. Lopez-Querol et al. [23] concluded that the interdisciplinary aspect of PBL assists students in clarifying connections among different civil engineering disciplines. Despite limited feedback from a student survey of problem-based learning experiences, Ahern [31] noted that, in general, comments were positive with students stating that it helped them learn more about themselves.

As PBL approaches commonly used projects which are typical within an industry context, students consider the work as relevant and thus are more motivated to learn [14, 21, 28]. Increased interaction between faculty and students on a ‘one on one basis and small group informal sessions can benefit improved relationships [28]. In a study of the perceived curriculum, student feedback on their learning experience within a PBL course scored relevance and appropriateness of assessment highest as PBL enhances learning and critical thinking via working on projects in a ‘real life’ context, thereby achieving deeper learning [40]. Mills and Treagust [9] cite a study which indicates that the dropout rate in Aalborg University is 20-25% compared with a 40% dropout rate for traditional programmes in Denmark, with such a benefit also cited elsewhere [21].
5.2 Challenges

The introduction of problem-based learning can be challenging as students often dislike such an approach, finding it “difficult and messy” at first [14, 31, 36, 37]. When students complained of insufficient support during tutorials, Ahern [31] suggested that students’ familiarity with traditional tutorial sessions, where the tutors had complete solutions to set questions, was a likely source of the students’ frustration. An exploration of the combined use of traditional and project-based learning approaches gives credence to such opinion, as results revealed low motivation to embrace new pedagogies such as PBL among the majority of students, who instead preferred traditional methods as “they know what to expect from it” Initial reaction of students can be one of suspicion and rejection, however, this was overcome as students realised the positive effects on their preparation for future professional life [16, 37].

Engineering topics, including mathematics and physics for example, have a hierarchical knowledge structure meaning that missing a topic within a sequence can affect the ability to understand and learn in subsequent stages, thereby impacting programme wide implementation of PBL [9, 40]. A perception exists that PBL will involve a significant workload on the part of the individual student [9, 14, 16, 18, 19, 28, 30, 37]. In a case where students had the option of choosing between a project-based learning type assignment and a traditional assignment, student feedback indicated that they were reluctant to invest the additional time they felt would be required for a project-based assignment, indicating that the project-based learning type assignment required almost double the time [14]. In a study of 99 students undertaking a final year design course which implemented PBL, Kwan [18] reported that 56.5% of students indicated that the workload was excessive, with 69% spending 11 hours or more on the required project work. The issue of time is exacerbated when problem-based learning is partially implemented within a programme and requires ongoing management to limit potential adverse effects on other modules [30].

From a teaching perspective, while some view the implementation of PBL as little more than rethinking and reorganising of previously used content and timetabling, setting and grading of project work can prove extremely time demanding [14, 21, 22, 28, 32, 33, 37, 40]. Pinho-Lopes and Macedo [16] echo such concerns in terms of instructor workload but acknowledge that such approaches benefit students in the long run, better preparing them form more autonomous work, particularly at Master level. While enjoying the experience, Aparicio and Ruiz-Teran [35] highlight the additional effort required when compared with traditional methods, citing preparation of “ad hoc” materials for the diverse range of student projects and the significant assessment workload as examples. The issue of class size is also an issue as PBL typically suits smaller class sizes [21]. Challenges are also experiences in terms of resources such as teaching staff [31], technical support [29, 38], appropriate physical spaces to accommodate PBL activities [22, 39], and materials [22, 38].

Assessment methods require careful consideration, in particular the approach to grading of group work where there is disparity in the contributions of individuals [9]. It is important that instructors optimise the complexity of projects to address student workload concerns [15, 18, 24, 28] and enhance deep learning [19]. Shekhar and Borrego [15] highlight the importance of instructors optimising the complexity of projects to address student workload concerns, with feedback from students playing a key role, a sentiment echoed in other studies [18, 21, 38].
7 CONCLUSIONS

The majority of reported cases relate to application of PBL within individual courses as oppose to across programmes. Conclusions within the literature convey significant benefits in the adoption of PBL as a pedagogical strategy within civil engineering education. Consistently reported benefits include improved graduate attributes such as communication, teamwork, project management and time management. In addition, PBL is typically based on ‘real’ projects, thereby ensuring relevance and increased motivation. However, the prominent challenge for both learners and tutors is the increased time required to address the requisite workload.

In 2003, Mills and Treagust [40] noted that PBL was generally implemented by individual lecturers within courses and that evaluation of its effectiveness was limited to qualitative statements from student surveys undertaken upon completion of the course, thereby prompting the desire for a more rigorous evaluation within a framework from education theory. Based on the current research, the body of evidence demonstrating the effectiveness of PBL in civil engineering continues to be qualitative in nature. As with Mills and Treagust in 2003, the search for more rigorous and quantitative evaluation continues.

REFERENCES


INTRODUCING PROJECT MANAGEMENT PROCESSES AND SKILLS ON A PBL SUBJECT

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Key words: Education, Civil Engineering, PBL, Project Management, Risk Management, Active Learning.

Abstract. This paper describes how to introduce different project management processes and skills on a PBL subject where the students lead their own learning process even defining the statement of work for the project after negotiating it with the faculty. The subject ‘Workshop on Water and Environmental Engineering’, taught to students on the third semester of their Master studies, focuses on the Risk Management Knowledge Area [1] so students need to perform a risk analysis of an engineering system which is generally described only at a high level at the beginning of the semester. One of the key points is to engage the students in decisions related to setting the scope of the project. While working on the project, students are able to develop existing skills including people management, communication with stakeholders and project team, managing conflict among others and acquire new skills as they lead and learn (risk management, scheduling, negotiating, critical thinking or team building).

1 INTRODUCTION

The School of Civil Engineering of Ciudad Real (Spain) was born in 1998 with Project Based Learning as a key element in the learning process. Therefore, most students have dealt with several PBL subjects prior to taking the subject this paper refers to. But students are used to
having no say in problem formulation although they are able to lead problem solving and become more active on their learning process as they progress in their studies and gain experience on PBL subjects.

So, they are ready to face a new challenge: formulating their learning goals.

There are several types of project work depending on the degree of teacher-centred planning [2]. The best Project Based Learning should encourage students to explore project management skills leading much of their own learning experience and, so, try to avoid teachers making most of the decisions [3, 4]. This is the aim of the PBL subject described herein.

2 METHODOLOGY

In the subject ‘Workshop on Water and Environmental Engineering’, taught to students on the third semester of their Master studies, a maturity situation in infrastructure management is considered. Therefore, conservation, maintenance, restoration or dismantling are key points to be considered by civil engineers. Risk evaluation, especially those associated with climate change, is a very useful tool that allows prioritizing investments among the different alternatives proposed to reduce the risk levels of the infrastructure under study.

The subject focuses on the Risk Management Knowledge Area [1] so students need to perform a risk analysis of a civil engineering system which is generally described at a high level at the beginning of the semester: breakwaters or sanitation systems in coastal areas are a couple of examples.

The methodology is summarized in Figure 1 and the different stages are described below.

![Figure 1: Description of the methodology](image)

2.1 Initial statement

A general description of the system under study is given to the students. They also receive some general guidelines on what is expected from them regarding key words such as risk analysis or prioritizing investments and related deliverables. Mini lectures on Project Management processes and, especially, Risk Management are included.

To set the final scope of the project (subject), they need to inquire into the basis of the system under study and they should make sure to start creating a collaborative team environment while doing so.
2.2 Research

First, students need to identify what they know and what they need to know as well as how they can get to know it so they are required to do some research.

They need to understand how the system works, identify risks and potential responses as well as stakeholders and be aware of the constraints related to human resources, information, tools and time available for achieving all their goals. And they also need to select the site for the case study.

2.3 Statement of work

Their first task in this stage is to write a proposal to bring forward which should include the statement of work after inquiring into the basis of the system under study, data and tools available and risks identification. The second task is negotiating the proposal which they must adequately justify. Diplomacy, persuasion and negotiation with faculty are used to define the ultimate scope of the problem. Thereby, students are fully responsible for designing and managing much of their own learning.

The final task in this stage is submitting the first deliverable: the project charter which should include a list of stakeholders, high level risks, deliverables, roles including the project manager and any premises related to what must or must not be covered in the deliverables among others.

2.4 Risk analysis

The risk management processes included in the subject are: identifying risks, performing qualitative risk analysis, performing quantitative risk analysis and planning risk response.

Most of the risks have been identified during the research stage but new ones may arise at any time. They are all included on a risk register.

The qualitative analysis is applied to all of them combining the results from the probability and impact matrix into severity calculation and concluding which of them are prioritized risks and, therefore, must undertake a quantitative risk analysis.

Montecarlo simulation technique is used for the quantitative risk analysis. Understanding how the system works is a key factor for this process. The results of this step are risks levels.

Finally, planning risk response includes the definition of different alternatives trying to reduce risk level and the evaluation of their costs.

A methodological guide for risk analysis of the system under study summarizes all these procedures and becomes the second deliverable of the project.

2.5 Prioritizing investments

The starting base for this stage is the set of alternatives from the risk response plan and their main features: cost and risk level reduction achieved when implementing it.

Several scenarios are considered dealing with the available budget.

A methodological guide for prioritizing investments of the system under study is the third deliverable.

2.6 Case study

The final deliverable at the end of the semester is a report on a case study where the
methodology for both risk analysis and investment prioritization is applied. The students visit the project site to gather information and interview with stakeholders.

3 RESULTS

The evaluation is based on several areas such as personal development and attitude, report writing and oral presentations.

Key competencies for our students among the ones described in [5] are:

- critical thinking: as they work throughout the project
- research and analytical skills: when they look for and select information dealing with the problem being described
- conflict resolution: conflict is always present associated with team work
- professional responsibility: as they fulfill their roles in the project
- leadership: especially for the project manager
- ability to learn teamwork: creating a collaborative team environment
- planning and scheduling: while preparing the statement of work and during the project
- written communication: different types of professional writing which include a project charter, a report on the case study and the guides
- verbal communication: they present their work to the client
- environmental awareness: environmental risks are included.

4 CONCLUSIONS

Delegating responsibility to the students on formulating their learning goals helps them exercise their independence. They gain confidence in their own learning abilities, improve critical thinking skills and written and oral communication skills including professional report writing and technical presentations. They also acquire competencies such as decision-making, time management, research, analysis and synthesis of information.

While dealing with problems within one discipline (Risk Management on Water and Environmental Engineering), they must display the ability to show understanding and respect for one another, communication and listening skills, conflict resolution and reflect on their own development while creating a collaborative team environment.

At the beginning of the semester, students feel overwhelmed by the amount of undefined tasks lying before them but, ultimately, they are amazed at having been able to successfully reach their learning goals.

REFERENCES


BRIDGE DESIGN MASSIVE OPEN ONLINE COURSE

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Key words: Education, MOOC, Bridge design,

Abstract. In last years, the traditional blackboard teaching has been incrementally supplemented by visual aids like slide projectors and videos. The phenomenal growth of the internet has brought in new teaching media, such as Massive Online Open Courses (MOOCs) that open the educational experience up to a broader and more distant set of students. This easy access to education can increase motivation and it is a useful commercial tool for universities. Unlike other disciplines (such as economics or psychology), the MOOCs are rarely used to spread civil engineering courses. To fill this gap, and to encourage the use of MOOCs among civil engineering schools, this paper presents the experience of the MOOC for the multidisciplinary design of bridges created by the University of Castilla-La Mancha (Spain). This MOOC is an ambitious project of the civil engineering school of Ciudad Real that includes the collaboration of most of its fields (structural engineering, transportation, urban planning, geotechnical engineering, material science, project management, environment engineering, topography and hydraulic engineering).

1 INTRODUCTION

Throughout history, traditional teaching, in which a professor led the learning experience of the students with nothing but a blackboard, has been the most common educational methodology. Despite traditional learning has been quite straightforward, some variations have appeared in the last years. For example, since the 90s, some practical disciplines (such as medicine or engineering), complement traditional teaching with the Project Based Learning (PBL). In this methodology, the students are the ones leading the classes by using their recently acquired knowledge to solve proposed problems under the professors’ guidance, and through self-directed reflection, research and practice in solving them [1]. The popularity of PBL is an example that illustrates the advantages of adapting the educational methodologies to the different contents to be taught.

A major change in education history started with the computer revolution, as new and emerging pedagogies brought dramatic changes in the educational landscape. Since then, the phenomenal growth of the Internet has increased the popularity of computer based educational
tools, such as E-learning, which enable the students to learn anywhere and anytime. The endless possibilities of these new tools include the ability to share material in all kinds of formats, conducting live online classes (webinars), as well as enabling communications with professors and other students via chat and message forums. International associations (such as IABSE [2]) use E-learning platforms to spread Civil Engineering worldwide.

In this way and with these tools, it is intended to bring science and technology, and more specifically the design and structural functioning principles of bridges and buildings, closer to public outside the university, motivating participants to discover them in a pleasant and intuitive way. Two activities have been planned to be developed, based on the PBL methodology, and using mostly K'nex toy pieces (see Figure 1): (1) Bridges design contest for pre-university students from all over Castilla-La Mancha. (2) Building structures design competition, which will be launched during this year. In this contest, pre-university and university teenagers from the UCLM (Ciudad Real and Cuenca) and CEU San Pablo (Madrid), will design and build a structure in a seismic zone.

![Figure 1: Pieces of K’nex construction system.](image)

During the last years, in the first case, as a complement to the preparatory phase of the contest, we have conducted face-to-face classes, limited in time and with an eminently practical approach aimed to build the bridge. As a novelty this year the Massive Open Online Course (MOOC) presented in this paper, has been developed, to allow a much more complete, multidisciplinary and accessible knowledge about bridges to every participant.

2 PROJECT BASED LEARNING AND CONTESTS

Students demand an education that helps them to acquire the skills required by their employers, easing their early recruitment in construction companies. Aware of this necessity Aalborg University in Denmark incorporated the Project Based Learning (PBL) in its academic
program in the 70s. The Civil Engineering School of UCLM was the first one in Spain adapting PBL in its studies. Nowadays, both the Degree and Master on Civil Engineering offered by this School include a number of PBL subjects focused on each of the major professional areas (Structures, Hydraulics, Transportation and Urban Planning). A major concern of all these PBL subjects refers to those concepts already acquired in preceding teacher driven subjects [3].

On the other hand, The Civil Engineering and the Building Engineering schools have also incorporated the participation in national and international contests as part of their motivation strategies to encourage students.

As an example of implementation of this methodology also out of the schools, the following sections describes the contests of bridge construction with K’nex and building construction for high school students.

2.1 Contest on bridge construction with K’nex

The aim of the contest is to enable high school students of Castilla-La Mancha Region (Spain) to understand the number of disciplines involved in the design of bridges by building a scaled bridge in a certain location based on structural, economic, construction, environmental and aesthetic considerations. To do so, the students were provided with the construction toy system K’nex.

The contest was founded on his Third edition by the Spanish Foundation for Science and Technology (FECYT), UCLM, the company ProiMancha and Spanish Professional Association of Civil Engineering (Colegio de Ingenieros de Caminos, Canales y Puertos).

The contest is divided into two different stages [4]:
- Stage 1: Free bridge construction. The teams were divided into semifinals, where they were challenged to build in 1 month a bridge supported on two boxes (Figure 2). The participants fixed all design parameters based on the following sections: (1) Cost (20%). Each K’nex piece was assigned with a price in such a way that a symbolic bridge cost could be estimated. (2) Span (30%): The longer the span (and the closer to 180cm) the better. (3) Load (25%): The higher the loading bearing capacity of the bridge (and the closer to 6kg) the better. (4) Valuation of a group of experts (25%).

![Figure 2: Example of the Semifinal designs.](image-url)
Stage 2: Adapting the design for a certain location. The winners of each semifinals were challenged to adapt and built, following actual construction techniques, their initial designs in 6 hours (see Figure 3). All the teams have to use the same scale model (E 1:50) reproducing a section of the Tajo River in Toledo (Spain). In order to ease the excavation of the foundations these models are made of polyethylene (Figure 3). The winner was selected according to the following criteria: (1) Span (10%): All participants spanned 180cm, nevertheless this length might be reduced if intermediate elements (such as piles or pylons were used). (2) Cost (20%), (3) Bridge Depth (20%): The thinner the bridge depth the better. (4) Deflection during a loading case (20%): The smaller the deflection under 2kg load the better. (5) Valuation of a group of experts (20%), (6) Valuation of the public on an online survey (10%).

Figure 3: Suspension bridge design built on the 2017 contest.

All the designs of the Second Stage were included into an exhibition at the train stations of the main cities of the Castilla-La Mancha Region (Toledo, Ciudad Real and Albacete). A picture of the exhibition in Toledo is presented in Figure 4.
As presented in the following section, the built bridges were also used as examples to illustrate multidisciplinary design aspects on the developed MOOC.

3 MOOC AS A MULTIDISCIPLINARY LEARNING TOOL

Due to their unlimited possibilities, one of the most popular Internet learning tools are the Massive Open Online Courses (MOOCs) [5]. In addition to non-traditional course materials such as filmed lectures, problem sets, MOOCs might provide interactive user forums to support learning interactions, homework/assignments, and online quizzes or exams. Unlike other tools, MOOCs are based primarily on short (5-20 min) pre-recorded video lectures, which the student watches on a weekly schedule. Among the most popular MOOCs platforms it is to highlight Coursera [6], and edX [7].

3.1 MOOCs on Structural Engineering

Unlike other disciplines (such as economics or psychology), MOOCs are rarely used in Civil Engineering. To illustrate this conclusion the topics of the MOOCs listed on the main MOOC platforms (Coursera and edX) were analyzed. For example, in the field of “Structural Engineering” the number of MOOCs is significantly low (2 out of 669 in Coursera and 8 out of 1409 in edX). Some of these Structural Engineering MOOCs are listed in Table 1.
Table 1: MOOCs on Structural Engineering

<table>
<thead>
<tr>
<th>Title</th>
<th>University</th>
<th>Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamics [12]</td>
<td>Massachusetts Institute of Technology</td>
<td>edX</td>
</tr>
<tr>
<td>Introduction to Steel [13]</td>
<td>Tenaris University</td>
<td>edX</td>
</tr>
<tr>
<td>Elements of structures [16]</td>
<td>Massachusetts Institute of Technology</td>
<td>edX</td>
</tr>
</tbody>
</table>

The analysis of Table 1 shows that most of MOOCs in “Structural Engineering” are based on very specific technical concepts. In fact, the authors were unable to find more general courses focused on the design of bridges. To fill this gap, and to encourage the use of MOOCs among Civil Engineering Schools, next section presents the experience of the MOOC for the multidisciplinary design of bridges created by the University of Castilla-La Mancha (UCLM).

3.2 MOOCs for bridge design

This MOOC is based on the experiences learned during the three editions (2015, 2016 and 2017) of the bridge construction contest with K’nex for undergraduate students, and it is introduced as a novelty on the running fourth edition (2018). The aim of this contest was double. On the one hand, introducing potential students into one of the most encouraging works of a civil engineer, this is: designing and building a bridge in a certain location including structural, economic, construction, environmental and aesthetic considerations. On the other hand, introducing potential students in the key methodological teaching tool of this school: the PBL, by letting them do instead of telling them what to do.

Different areas from the Civil Engineering and Building Engineering Schools of UCLM participated in the elaboration on a MOOC addressing the considerations of their fields for the multidisciplinary design of bridges.

The developed MOOC [18] is divided into different areas (such as Structural Engineering, Hydraulic Engineering or Geotechnical Engineering). For each of these areas, the students will
have available different recorded lectures. The following lectures were recorded with the help of the C:TED: (1) Fundamental structural concepts: Compression, Tension, Bending, Shear and Torsion. (2) Bridge Typologies: Beam bridge, Truss bridge, Frame bridge, Arch bridge, Cable-Stayed bridge, Stress Ribbon Bridge, and Suspension bridge. (3) Urban Planning. (4) Geotechnical Engineering: Pads, and Piles. (5) Hydraulic Engineering: Laboratory test showing the piles excavation in a stream. (6) Material Engineering: Laboratory tests showing the behaviour of different materials. (7) Construction techniques of each bridge typology. (8) Transportation. (9) Topography. (10) Environmental Engineering. (11) Budget. Examples of some of these lectures are presented in Figure 6. Nowadays the MOOC is only available in Spanish by it will be translated to English in the near future.

![Figure 6. MOOC lectures](image-url)

Every lecture consists of one to five short videos, from 5 to 15 minutes, exposing the main topics of the area and illustrating with pictures the technical explanations. It has been of special interest the use of virtual models (K’nex connectors and rods have been modeled with blender) to make explanations more enjoyable and easier to understand technical concepts (Figure 7).
After understanding each area, the students will adapt what they learned to the examples of the K’nex bridge. They also have access to open forums where they can discuss directly with the professor in charge as well as with other students. Examples of these activities were answering forum questions or identifying the main structural stresses (compression, tension, shear, bending or torsion) in the different elements of everyday structures (such as the baby cradle presented in Figure 8).

The MOOC will be published into the most common MOOC platform in Spanish (Miriada X) in the coming months.
4 CONCLUSIONS

This paper presents the first Massive Open Online Course (MOOC) for the multidisciplinary design of bridges based on the experiences learned from the contest on bridge construction with K’nex for undergraduate students organized by the Civil Engineering School of University of Castilla-La Mancha (UCLM) in 2015, 2016, 2017 and 2018. This MOOC addresses the main issues for the design of bridges from the main civil engineering areas (such as structures, materials, hydraulics, transportation, urbanisms, construction technique or topography). These videos are based on short presentations (5 to 15 minutes) including virtual models developed in Blender. In order to strengthen the taught concepts a number of activities are proposed.

The MOOC has been developed in Spanish and it will be publish in the Miriada X platform in the coming months. In the near future it will also be translated to English.

We hope the published MOOC will strength the profession of Civil Engineering as hopefully will encourage young people to study it.

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https://www.edx.org/course/mechanics-review-mitx-8-mrevx


TEACHING EXPLORATION OF "CIVIL ENGINEERING CONSTRUCTION COURSE" UNDER THE OBJECTIVE OF CULTIVATING EXCELLENT ENGINEERS

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Key words: Civil Engineering Construction, Blended Learning, Massive Open Online Courses.

Abstract. This paper introduces the teaching reforms to Civil Engineering Construction Education in Tongji University, under the objective of excellent engineers cultivation, attempting to address current challenges in slow teaching contents update, teaching hours shortage, ineffective practice and the simple assessment criteria. The author explores the advantages of blended learning through designing diversified teaching contents, including the application of MOOC (Massive Open Online Courses), adjustment to teaching contents, the setting of practical class and the optimization of assessment criteria. The paper also discusses the teaching effect of this course accordingly.

1 INTRODUCTION

Since China State launched the "Excellent Engineer Education Training Program" in 2010, the Civil Engineering College of Tongji University has been making continuous efforts to deepen the Program. With a highly-skilled faculty and teaching teams and based on research and practices learning, the Colleague develops a training system known as “Commonality and Individuality Development”, leveraging the cumulated legacy in civil engineering from over
100 years teaching and experience shared from overseas universities. The system is designed to reinforce the fundamental knowledge, competency and quality universal for all students. It also caters for individual interest and development opportunity to help foster talents of specific capabilities[1].

In such a context, the Civil Engineering Construction, as one of the core courses, is facing new challenges. This course has many characteristics, such as extensive coverage, high practicality and fast knowledge evolving. However, there are a few issues in current teaching contents, practice aspects and assessment methods[2].

1) The renewal of textbook contents is difficult to keep up with the ever changing construction technology.

2) Number of hours for basic knowledge teaching is condensed.

3) The focused 4-week site practice program is not effective enough.

4) The final assessment based on the term exam score and regular assignments fails to reflect all aspects of learning.

5) The enthusiasm of students to learn is not high.

Therefore, it is imperative for Civil Engineering Construction curriculum to take changes in area of professional standards, teaching methods, knowledge, ability and personality of students.

In the framework of “Excellent Engineer Education Training Program”, the new civil engineering construction course aims to help students systematically acquire construction knowledge through different learning approaches and keep abreast with the latest technology development at home and abroad. In the meantime, the new program will enable students to experience and gain relevant knowledge of production practices through direct interaction with construction projects. Ultimately, the students will be better equipped and more adaptable to project's on-site work and make analysis, judgments and decisions according to site conditions. They will be more capable of handling or coordinating engineering emergency resolution.

Based on these considerations, in 2015, this course successfully applied for the Tongji University's education reform project “Research on Innovative Teaching Methods for MOOC Based Civil Engineering Construction Learning”, and conducted a pilot with 100-person class in the spring semester of 2016. The pilot achieved satisfying results through the introduction of MOOC learning, strengthened in-class teaching, establishment of off-campus practice class, and the increased hands-on ability training and other measures.

2 DIVERSE TEACHING CONTENT AND BLENDED LEARNING METHODS

2.1 Construction and application of MOOC
MOOC (Massive Open Online Courses) become the most popular vocabulary in the educational field globally since 2012. MOOC, comprised of Lecturer sponsored short video lectures, homework exercises, forum activities, notification emails and online exams accessible through Internet, supports large population of learners participation on line and is attracting increasing interest from more learners[3]. In response to different learners’ expectation, many world-known universities have launched MOOC platforms of their own or cooperated with suppliers to offer various types of MOOC courses. At the same time, MOOC has emerged and rapidly developed in China. In 2014, "Love Course" Network and NetEase jointly created "China University MOOC", the most influential online public course learning platform in China. Up to now, there have been more than 1,000 courses posted and 10 Million learners covered.

With reference to the prior developed high-quality courses, the Civil Engineering Construction course is refurnished and designed by its teaching team in accordance with the requirements of MOOC structure. During the course design, a great number of photographs from construction sites and associated explanations are supplemented in addition to regular teaching resources such as teaching videos, PPT courseware, inter-class questions, after-school tests, homework and relevant subject discussions. Live animations are also developed to visualize some abstract construction processes. In the end, the high-quality distance course is gradually developed. This free, fragmented and interactive learning style has brought challenges to traditional classroom teaching model, but also brought opportunities. Figure 1 is a learning page for this course on MOOC platform.

On one hand, due to the reduction in classroom time, many contents can’t be discussed in detail during class. With the introduction of MOOC, students can learn and explore by their own on the MOOC platform and receive knowledge that is not available in class. On the other hand, students don’t pay as equal attention to civil engineering construction as to other courses during classroom teaching. Building construction is often considered as a chore, resulting in insufficient concentration during class and consequently poor mastery of knowledge. The combination of classroom and online interactive learning methods significantly arouses students’ interest in learning and enhancing learning efficiency.

To Facilitate management, a SPOC (Small Private Online Course) is established in pair to the MOOC, so that special contents for the pilot class can be supplemented at any time and students' learning dynamics can be monitored[4]. In order to assess the students’ MOOC learning effectiveness, two 15-minute quizzes were arranged during the semester. The contents were all those covered and available in the MOOC. More than 90% of the students scored excellent grade.

As the pilot class has 100 students. A WeChat group is also established to offer another platform on smart phones for fluent information sharing and exchanges among teachers and students.
2.2 Arrangement and delivery of teaching contents

As MOOC platform provides tremendous volume of teaching resources, we have optimized the teaching contents and structure accordingly with intent to improve the classroom teaching effect.

(1) The course has changed from the original all-inclusive approach to a key and difficulty focused strategy. On completion of each chapter, a Q&A session (questioning and answering session) is conducted to encourage students’ motivation and initiative to reflect the knowledge just learned. The representative and high-quality questions put forward by students on MOOC often become good topics for Q&A session in class. It also makes up for insufficient clarity that may come from MOOC.

(2) Topics and discussions on new technologies in the field of civil engineering have been added. These topics include the development of construction in foundation engineering, pile foundation engineering, reinforced concrete engineering, masonry and decoration engineering, and structural lifting engineering. They also cover various areas of ground, underground, tunnels and bridges. The supplementary study has greatly expanded students’ knowledge.

(3) A practical class correlating to theoretical teaching is established. This allows students to visit and view actual construction site operation, timely digest and apply theories from classroom leaning to actual projects during a time span of over 4 months. This makes up potential regrets from subsequent shorter production practice. The great variety of project phases such as foundation stage, main structure stage, decoration stage, and reinforcement projects offer more exposure and enrich students' knowledge structure and help attain multiplied effect.
To facilitate discussions and exchanges within the practical class, every 10 students form a team connected with a dedicated WeChat group. Project Engineers from related projects are invited to each such WeChat group. The Engineers often share select pictures and video clips of construction sites. Every team member can observe and feel the changes and deepen understanding of the construction process without physically visiting the sites. In addition, for better time utilization, each team is assigned one primary project. Knowledge of projects under other teams’ focus is shared through team presentation and discussion at a later stage. In case an individual has particular interest in another group project, the responsible team leader may be approached to join their site visits or track progress through dedicated WeChat group.

(4) The past construction courses left many people with the impression of learning some construction techniques in classroom, completing few experiments and visiting construction sites within a couple of weeks only. However, as the current projects become more and more complex, there are often needs requiring detailed breakdown of design and research during the construction process. Therefore, according to the actual needs of current projects, the course designs three hands-on skills training topics, so that students can conduct detailed design and calculations by applying construction process knowledge, structural design concepts, CAD (computer aided design) drawing skills and calculation software. The training topics are summarized as follows:

1) Based on the size of pit and geological conditions, design a cement-soil mixing pile support. It is required to draw a plane and a profile, then use calculation software to verify the strength and stability.

2) Based on the size and elevation of the given beams and slabs, draw a profile of high formwork and a detail formwork of beams.

3) Using the equipment available such as baskets, cantilever cranes, orbit cranes, unloading platforms, tower cranes and external scaffolds, design the installation and construction process of frame curtain walls and unit curtain walls respectively, then draw the corresponding operating profiles.

Through these hands-on skills training topics, students gain deeper understanding of the professional skills needed by construction enterprises.

(5) Team Progress Review and Comment

Two team reports are arranged during the semester. The first one is a learning report for the practical class. Through data collection, site visits, engineers’ introduction and online communication between engineers and students, each team summarize and share their project overview, construction process, organizational design, schedule, and on-site photos or videos in class. In this way, students of the other teams also have a chance to understand other team projects. After the report, the teacher provides comments on every project, summarizes the key technologies and clarifies questions.
The second one is a learning report for the entire semester, including summaries of practical class, diaries of construction visits, presentations of hands-on skills training, learning comprehension and suggestions to blended learning methods. During the report, students review the learning contents, learning methods and experiences of the semester and are encouraged to share their reflection over the piloted learning approach. In the end, the teacher also makes concluding remarks on the teaching reform of the semester. The teacher and students have fully exchanged their thoughts of the pilot program. Figure 2 and Figure 3 are photos about two team reports.

2.3 Optimization of assessment criteria

<table>
<thead>
<tr>
<th></th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOOC's academic performance</td>
<td>30%</td>
</tr>
<tr>
<td>Unit test</td>
<td>10%</td>
</tr>
<tr>
<td>Hands-on ability</td>
<td>10%</td>
</tr>
<tr>
<td>Practical class</td>
<td>15%</td>
</tr>
<tr>
<td>Classroom discussion</td>
<td>5%</td>
</tr>
<tr>
<td>Final exam</td>
<td>30%</td>
</tr>
</tbody>
</table>

In the past, the course assessment followed a traditional model, that is, students were given an overall evaluation score based on the regular homework and a final examination to certain proportion. Many students didn’t have a solid grasp of knowledge at ordinary times, but before the exam, they made a cramming review of classroom notes, and could also achieve
good scores. However, they could still be confused with basic concepts, thus uncertain about construction processes and unconfident in solving problems on site. The reform has not only made changes to the way of teaching, but also made a few adjustments to the teaching contents. Therefore, we set the assessment criteria as shown in Table 1.

The assessment criteria arouse motivation of everyone to allocate and commit their time resources more appropriately in normal times. In the team reports, students fully affirmed the teaching reform. A majority of students appreciated that although they had spent more time and energy than those in other parallel classes, they had opened their eyes, enriched their knowledge, and aspired their way of thinking during the pilot. It has cultivated their ability to solve problems, and it has been able to improve their grades while gaining knowledge. This is a win-win outcome.

3 REFLECTIONS ON TEACHING REFORM

After the course, a questionnaire survey was conducted on the blended teaching model. A total of 78 valid questionnaires were received. The survey results show that all participants had a positive attitude towards the teaching reform.

3.1 Design of blended teaching contents

85% respondents agree the teaching content changes improve their interests in learning. 98% of them agree it is beneficial for their mastery of knowledge and the development of their abilities. 82% of them agree it is worthwhile to make more efforts than other parallel classes. 100% believe that the form of site visits is helpful for theoretical study. 88% believe that the WeChat exchange with Engineers can help understanding of the site. Figure 4 shows the benefits of this blended teaching pilot. Figure 5 shows the various abilities improved by hands-on skills training. However, 33% of people express hesitance in trying blended teaching method again. The main reason is the workload is so large that students need to spend a lot of time on just one single course. Figure 6 shows aspects that still need improvement in teaching.
3.2 MOOC platform course construction
Specific to the learning through MOOC platform, 90% of respondents agree that it can better adjust the learning status. Besides, most respondents agree that it can save class time and provide room for teachers to supplement more valuable knowledge. At the same time, they enjoy the flexibility to allocate their individual study and work hours. Especially in the homework review and correction process, by referring to the recommended answers and other students' problem-solving commentary, they can deepen the understanding of concepts and master the knowledge. Figure 7 shows areas for improvement on the MOOC platform suggested by students. This provides valuable insights for the improvement of MOOC construction in the future.

![Figure 7: Aspects needed improvement in MOOC construction](image)

3.3 Establishment of a new interaction between teachers and students

In a traditional university classroom, the teaching methods are largely prevailed by teachers. Teachers play a dominant role in the teaching process. They control the initiative to transfer knowledge, and students are passive recipients. Especially when the number of students in a class is large, teachers often lack in-depth interactions\(^5\). Therefore, civil engineering construction course adopts a blended teaching method. In addition to the tangible classes, teachers and students interact with each other using online class and practical class. Through Q&A (questioning and answering) room on MOOC, report of practical class, communication and discussion session and instant communication in the WeChat group, a new type of intersubjective relationship between teachers and students takes shape and evolves.

In the final exchange, the emotions of teachers and students have been sublimated. The students expressed their gratitude to the teachers, and the teachers also fully recognized the hard work of the students.

3.4 Reflection over problem solution
Firstly, the teaching reform was piloted in a teaching class of one hundred students. Due to the large number of students, the efficiency in practice, questioning and discussion was not satisfactory. Therefore, in order to enhance interaction between teachers and students, students and students, students and computers in classes and on-line, this teaching model that is different from traditional teaching model may be more appropriate for the class with a less number of students and for students of higher motivation.

Secondly, the use of MOOC platform and practical class undoubtedly increases the load on students. To achieve our purpose of teaching reform, appropriate time reduction to class can improve students' learning efficiency and maintain students' enthusiasm for learning without increasing students' burden.

Thirdly, since the teaching reform was conducted only for one teaching class, its teaching was organized by a professor with rich teaching and practical experience, so the effectiveness of the teaching reform was obvious. However, if it is fully rolled out, it will raise higher requirements for teachers. To sustain a large platform course, it is necessary to strengthen the teaching faculty and mobilize the initiative and creativity of all teachers so as to ensure the smooth development of the course.

Finally, we should give a careful thinking to the assessment criteria as a measurement of the online and offline blended teaching method. When this teaching model is rolled out, is the assessment criteria scientific and rational and can be readily adopted by all parties, including the school administration department, instructors and students? It is necessary for management department to consider the development trend and characteristics of the Internet teaching, gradually tailor the assessment criteria, elaborate quality standards, and optimize the index system to ensure the criteria help drive its initial objective.

REFERENCES

INCREASING THE PRESENCE OF A CIVIL ENGINEERING SCHOOL IN THE LOCAL AND SOCIAL CONTEXT: POPULARIZATION AND INSERTION ACTIVITIES

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Key words: Education, Civil Engineering, Outreach, High School, Middle School

Abstract. It is a widely recognized fact that over the past few years the interest for STEM studies in general and Civil Engineering in particular. In the particular context of the Escola Técnica Superior de Enxeñería de Camiños, Canais e Portos of the Universidade da Coruña this has translated from an excess in demand to an excess in offer regarding the number of spots to carry out a Civil Engineering degree. This fact was anticipated in 2013, so an intervention program was designed to take account of the shifting tide. While formerly students would steer towards CE studies by the prestige of the profession and high-paying job availability, the new context with an unfavorable job market and the decrease in profession interest due to the appearance of new, more “attractive” technical disciplines, the need appeared to raise awareness of the interest of our proposed studies, the job market and even of the existence of our School amongst Galician high-school students. The intervention program has been based on the following activities:
1. Outreach to middle- and high-school orientation services and recruiting initiatives as visits and talks among middle- and high-school students.
2. Presence in educational fairs.
3. Presence in Science Fair-type events with a stand devoted to Civil Engineering.
4. Participation in talk and activity programs within the A Coruña science museum network.
5. Funding requests for Citizen Science programs and Science Popularization programs from the national agencies.

These different activities are presented in detail, together with a description of the target groups and an attempt at an objective outcome evaluation in reference to the main goal of the activity program.
1 INTRODUCTION AND CONTEXT

We can date back to 2007 in the USA and 2008 in Europe the so-called official beginning of the economic crisis which has ruled over almost every aspect of society during the past few years. In the particular case of engineering education in Spain, the total number of students in engineering and architecture school has dropped by 26% during that period [1]. In the particular case of the Escola Técnica Superior de Enxeñería de Camiños, Canais e Portos (ETSECCP) of the Universidade da Coruña (UDC), the situation in 2007 was a full occupancy, with cut-off grades of around 7 in a scale of 5.5 to 10 in the selectividad average in both of the degrees that were taught at the time (Ingeniería Técnica de Obras Públicas, the 3-year degree, and Ingeniería de Caminos, Canales y Puertos, the 5-year degree). At present, after the reform which transformed all of the degrees in Spain into 4-year Bachelor’s degrees and 1- or 2-year Master’s degrees, we offer a 4-year, profession-oriented degree in Civil Engineering (Enxeñería de Obras Públicas, EOP); a 4-year, academy-oriented degree (Tecnoloxías da Enxeñería Civil, TEC), and the 2-year Master’s degree which leads to the profession of enxeñeiro de camiños, canais e portos (MECCP). While the Master’s degree is working as foreseen, with most of the students graduating from TEC signing up for MECCP, enrolment in the Bachelor’s degree has been stagnant over the past four years at an all-time low of around 45% of the available spots, with a cut-off grade of 5.5 out of 10 (minimum passing grade).

This trend was already foreseen by the authors in 2012, at a time when full occupancy was still achieved but with a drop in the cut-off grade. This grade, though not necessarily a predictor of individual achievement in university, is indeed related to the performance as a cohort for each promotion [2]. Since these studies are generally considered among the most difficult within the frame of Spanish university system, a concern was raised about whether the new promotions would be able to withstand the level of work needed to succeed in the newfangled degrees.

The ETSECCP-UDC is located in the town of A Coruña (Spain), in the autonomous community of Galicia. This factor is especially relevant when analyzing enrollment statistics, since the low mobility of Spanish students, due to the lack of sufficiently funded scholarships and the presence of at least one university offering each degree in each autonomous community, usually pushes them (once a particular field of study has been chosen) to enroll at the closest possible school. Galicia has a population of around 2 700 000 people, with around 400 000 living in the A Coruña metropolitan area. As of 2018, 95% of national students come from Galicia itself, which is a relevant datum when considering the potential audience of any outreach program.

A Coruña also boasts a remarkable singularity: being a city of only 240 000, we can find within the city itself four science museums: first, the National Museum of Science and Technology (Museo Nacional de Ciencia y Tecnologia, MUNCYT) (Figure 1a), the only Spanish national museum to have a site outside Madrid; second, the Scientific Museums of A Coruña (Museos Científicos Coruñeses, MC2) network, comprising the House of Sciences (Casa de las Ciencias) (Figure 1b), the House of Man (Casa del Hombre, DOMUS) and the Aquarium Finisterrae or House of Fish (Casa de los Peces). It is also home for the Galician delegation of the professional College of Engineers (Colegio de Ingenieros, Demarcación de Galicia).

The following description of the outreach program will show that all of these constraints and
singularity where taken into account into its design, working toward the objective of strengthening enrolment for 1st year students in the Civil Engineering degrees.

Figure 1: (a) MUNCYT (b) Casa de las Ciencias

2 MIDDLE- AND HIGH-SCHOOL OUTREACH

2.1 First wave: high school recruitment talks

The first approach undertaken, launched in 2012, was straightforward, which, in hindsight, also turned to be simplistic. Working from the non-evidence-based assumption that a better knowledge of what civil engineering is coupled with an attractive presentation would be a factor among Baccalaureate students (that is, the last two years of high school in Spain), a direct outreach program was designed. This would consist of the following:

- Forming a group of about 10 professors and 15 students (voluntary) on how to address teenagers. This formation was delivered by a specialist from Artestudio, a theatrical group and consulting company specialized in activities directed toward children and youths.
- Recording a series of professional video pieces which combined real prospective students asking questions about civil engineering, scenes from school life, engineering activities and time-lapse montages and interviews with former students.
- Contacting by phone, letter and e-mail with the high-school career advisor (orientador) in each and every high school in Galicia, which amounts to a total of about 300, offering the presence of a professor to give a talk to students any time along the school year.

This initiative was funded by a grant awarded to the Galician Foundation of Civil Engineering (Fundación de Ingeniería Civil de Galicia, FICGA) by the Galician Innovation Agency (Axencia Galega de Innovación, AGAIN). Funding covered formation, video production and travel expenses (note that talks to peripheral high schools in Galicia implies on occasion travelling up to 250 km).

Over the first two years, these talks were a two-person job, with a professor and a student in a point/counterpoint setting that eased high school students into participation and retention (Figure 2). During this period, high schools in the city of A Coruña that performed better in the selectividad test were prioritized, since we believed that they should conform the main source of first-year students for our school.
The success of this initiative was underwhelming. On any given schoolyear since 2012/2013, at most 35 centers would take up on the initiative, with the number dropping steadily since 2015. The reason for this drop was mainly the proliferation of education fairs, events that group together a number of higher education institutions in a “fair” context, with publicity stands, which maximizes efficiency from the point of view of invested school time. This type of event was almost non-existent in Galicia at the time our outreach initiative was launched. In addition, the University itself (UDC) had no similar outreach/recruitment program, a lack that has been increasingly corrected since 2014, when an institutional presence started to take place in such events.

Figure 2: High school outreach talk with the presence of a professor (left) and an undergraduate (center)

Coincidentally, after the first year of talks, the first major drop in first-year enrolment was registered, from 100% occupancy the previous year to only 65%. A series of surveys conducted in first-year students revealed that all the ones who hailed from high schools where a talk was delivered were aware of civil engineering studies and had decided to register before our talk, so the efficacy of this type of outreach was compromised. However, during the communication process to high schools, we discovered that a non-negligible (though not surveyed) number of career advisors were not aware that there was a civil engineering school at the UDC or that it was seeded in A Coruña, even among A Coruña metropolitan area advisors. There is indeed a cultural tendency to identify A Coruña with the architecture school and Ferrol (50 km away) with the industrial and naval engineering schools, all of them older than civil engineering, against which we discovered we have to work.

Since 2016, only about 10 of this type of activities are celebrated each year, in high schools with a tight link through family or tradition, and only one professor takes part (instead of the professor/student combination). This remaining presence is mostly kept as a service offered to high school career advisors rather than a proactive initiative from our school’s part.

2.2 Second wave: middle and high school outings

After establishing that delivering talks to older high school students was not an effective
means of directly improving recruitment and trying a more systematic approach through literature reviews on the subject [1], efforts were redirected to a broader audience, with the goal to improve perception of civil engineering in general and our school in particular. Even though, as previously stated, informative talks are still delivered upon request, in this second wave we mostly play upon one of our schools most visible strengths: the Center for Technological Innovation in Construction and Civil Engineering (Centro de Innovación Tecnológica en Edificación e Enxeñaría Civil, CITEEC), the high-level laboratory facility annex to the civil engineering school. Visits to this laboratory featuring experimental simulations at the wind tunnel laboratory, the laboratory of ports and coasts, the urban hydraulics laboratory and the construction laboratory (Figure 3a) are offered. Nowadays about 20 of these visits take place per year, with a high rate of repetition from year to year, meaning that they are popular both among teachers and among students. The amount of visits is limited by the high economic and time cost for peripheral institutions, so most of the groups come from local centers. Also during this year and for the first time three Primary school groups (with 20 to 25 8-year old children per group) were hosted (Figure 3a); this initiative was featured in local television [3].

Systematic evaluation of the outcome of this type of activity is hard to achieve, since its impact takes place on the overall perception of civil engineering and not directly in recruitment figures. However, the 100 % repetition rate and the increasing demand from middle schools to take part in this activity is an encouragement to its present and future development.

3 PARTICIPATION IN SCIENCE FAIRS

Science fairs are popular events during which schools and various institutions, both public and private, take advantage of an informal setting to portray in the form of interactive displays and activities the outcome of their Science studies (in the case of schools) or scientific aspects of their activity. In particular, two such events take place regularly in Galicia: the Day of Street Science (Día da Ciencia na Rúa) in A Coruña and the Santiago Maker Faire (sic) in Santiago de Compostela.

The Día da Ciencia na Rúa has a long-standing tradition in the city, reaching its 23rd edition in 2018, and has grown hand in hand with the MC2 network. It is organized yearly by the Friends of the House of Science Association (Asociación de Amigos de la Casa de las Ciencias, AACC). In the last edition over 50 kiosks from Galician schools plus 20 from other institutions were present. The ETSECCP-UDC is present in this fair since 2014 (Figure 4), being the only...
college-level stand, except for the Faculty of Biology & Chemistry. During the fair, which takes place every year on a single Saturday in May, the following activities are carried out:

- Construction (and deconstruction) of a sectional scaled (4 m long) cable-stayed bridge (Figure 5)
- Material testing in a small scale manual testing frame (Figure 6)
- Geotechnical engineering demonstrations: reinforced soil and liquefaction (Figure 7)
- Concrete mixing workshop (Figure 8)
- Computer-based bridge building games
- Displays with several engineering-based materials: geology expo, steel and composite materials, aerial stereoscopy…

The Día do Ciencia na Rúa proves to be an ideal setting to enhance and improve the image of civil engineering among the general population. Children of all ages become aware of the existence of the civil engineering school while associating it with a positive image. In the meantime, conversations can be held with accompanying adults about the field of civil engineering, research being done at our university, the situation of the job market…

The actual outcome of this activity is by nature almost impossible to quantify, but knowing that about 18000 people visit the fair in a single day, we can conclude that it is the single activity that raises awareness among the highest number of people, even though it is limited to the city of A Coruña.
The Santiago Maker Faire is a similar event, based on the promotion of the “maker” culture, which has been held on the past three years. This event has the added benefit of identifying civil engineering with a contemporary trend, surrounded by institutions and companies who promote technological development and “making” as a form of entertainment.

Figure 6: Model sectional cable-stayed bridge (patent pending)

Figure 7: Geotechnical engineering: reinforced soil and liquefaction

Figure 8: Concrete mixing workshop
5 COLLABORATION WITH NATIONAL SCIENCE AND TECHNOLOGY MUSEUM

Taking advantage of synergy with the ACHE (Asociación Española del Hormigón Estructural, Spanish Association of Structural Concrete) conference held in A Coruña in June 2017, our school launched a collaboration program with MUNCYT, our National Science and Technology museum. This collaboration consisted of a series of conferences and an activity program.

The conference cycle was mainly aimed towards an adult audience used to taking part in science popularization activities. The times were set to alternate Thursdays at 19:30 pm, enabling the audience to assist as an after-work activity while not “overloading” a potential repeat audience who might want to attend all of the talks. Three topics were chosen spanning different aspects of structural engineering:

1. Redefining the planet: great Civil Engineering works
2. Concrete: daring to create a rock in a few seconds.
3. Building with timber: a world of possibilities

The lecture cycle was advertised within MUNCYT’s own activity program Attendance to the lectures ranged from 40 to 60 people, composed mainly by students, former students or colleagues of the lecturers, together with their families. The outcome of this activity was satisfactory from the point of view of collaboration with the museum, but the main goal, that is, to appeal to a wider audience and increase awareness about Structural Engineering since the audience was mainly composed of people with a direct link to this area of knowledge.

The activity was conceived as an introduction to Structural Engineering for children. Five mini-lessons were devised, using as axes the history of Structural Engineering and the history of the city of A Coruña. The main tool for the development of these mini-lessons was a construction set consisting of a full suite of LUPO™ large size building blocks made from expanded polystyrene. The LUPO™ 7-piece system (http://www.sistemalupo.com, Figure 9) was created and patented by Fermín G. Blanco as a creativity and teaching tool for structural and architectural systems for both children and the general public wishing to delve into the basics of Structural Engineering. The system is available on a variety of materials and sizes and as a digital application for computers and smartphones; the version chosen as best suited for this activity was the one denominated Superlupo, which facilitates interactions between a number of children on the same construction through its larger size and reduced weight.

Figure 9: LUPO™ basic 7-piece set and assembly.
Each mini-lesson would start with a 10- to 15-minute introduction about the day’s topic, a 10-minute introduction to the building block system, and a 30- to 40-minute work session on the day’s structure or structures. Children were divided into two groups according to age (6 to 9-year olds in the first group, 10 to 12 in the second) after the introduction so each group could work on their structure separately (Figure 10). An exception to this was the last lesson, in which family groups with one adult per children at most were allowed.

![Figure 10](image)

Figure 10. (a) Aqueduct (b) Box girder (c) Obelisk landmark (d) Introduction to prestressing

This activity proved to be the most successful in the program. All the workshops were fully booked, and the museum was later contacted for repetitions. The activity was actually replicated in the Madrid site of MUNCYT with great success too. Children were highly receptive both to the introduction and to the gameplay session, getting to acquire basic structural concepts such as stability, the difference between flexure and compression, and prestressing. Also the perceived image and the importance of both civil and structural engineering in their everyday lives was enhanced, thanks to the inclusion of such components in the introduction and the presence of structures and buildings with which they were familiar.

5 “CAMINOS DE FUTURO”: A SYSTEMATIC APPROACH

Using the experience garnered during the past few years, presented in the previous sections, a more systematic approach was adopted. A project named Caminos de Futuro was presented to the Spanish Foundation for Science and Technology (Fundación Española para la Ciencia y la Tecnología, FECYT) grant call, and was awarded funding for its development. This project aims to familiarize students of secondary education, a key stage in the definition of vocations, with the world of civil engineering, within a social framework in which the stimulation of interest in education is recognized as fundamental for STEM disciplines. To do this, it seeks to highlight the basic role it plays in the development of civilized society; familiarize students
with scientific and technological concepts of civil engineering appropriate to their level of training and with immediate application; communicate the lines of research developed in civil engineering and the role they are playing in a sustainable, globalized and efficient society, and encourage the incipient vocations in civil engineering.

To achieve these objectives, three different actions are proposed:

1. Workshops on Civil Engineering and Society: face-to-face workshops given at secondary schools on safe and sustainable transport, water as a scarce resource and structural failures; Students are expected to analyze their environment from a scientific perspective. They are complemented with a general presentation about the world of civil engineering and research in that field.

2. Research in Civil Engineering in Galicia: organization of visits to the CITEEC.

This project features an approach that will allow the quantification and evaluation of the outcomes. A representative group of 30 schools will be selected to deliver the workshops. Out of these 30, 10 peripheral schools will be invited to visit the CITEEC. Priority will be given to those schools that are further away from Galician university centers.

Formal evaluation will be carried out through differentiated surveys conducted on teachers and students, before and after taking part in an activity program. In addition, surveys will be distributed to schools in Galicia that do not take part in the program, as a control group. A website and social media profiles will be established, which will allow measuring interactions and penetration in a different audience.

6 CONCLUSIONS

- A series of activities carried out by the School of Civil Engineering, Universidade da Coruña along the past five years to boost interest and awareness about the field of civil engineering among general audiences and children in particular with the ultimate goal of promoting enrolment in Civil Engineering studies has been presented.
- The straightforward approach consisting of recruitment talks to last year high school students has proven to be inefficient to achieve this goal.
- Outreach activities such as visits to the laboratory and workshops are very well received by teachers and students, even though their impact is hard to quantify.
- A systematic program funded by a national institution has been launched to achieve the aforementioned goals, together with a formal survey system to evaluate the outcome.

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THE IMPACT OF ERASMUS+ INTERNATIONAL PROJECT FOR THE DEVELOPMENT OF SCIENCE

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Key words: Preliminary Estimate, Energy Efficiency, Building Envelope, Renewable Sources of Energy, Extreme Continental Climate.

Abstract. This case study was developed in framework of "Master Degree in Innovative Technologies in Energy Efficient Buildings for Russian and Armenian Universities and Stakeholders" project. European, Armenian and Russian universities, including Ural Federal University named after the first president of Russia B.N.Yeltsin, and also EUCEET are members of a consortium. Construction of energy-efficient buildings becomes a top priority for many countries. Yet certain obstacles in achieving internal environment comfort standards remain in regions with extreme continental climate. In addition to engineering and economic challenges, there exist design process issues since design data should closely correspond with resulting performance of the building. This paper focuses on accurate energy demand estimation during design stage. Two types of buildings designed for Ural-Siberian region of Russia and for Kazakhstan are examined: detached and medium-rise apartment buildings. Most influential factors are taken into consideration and general recommendations on improving energy efficiency using effective combination of structural and engineering solutions are given. Adaptation of design procedure in terms of extreme continental climate made by means of simplified but precise Passive House planning tool is demonstrated.

1 INTRODUCTION

Energy efficiency became a topic of relevant interest for the policy makers in 1973, when there was the first oil crisis. In that period many countries realized that their development policies were linked to the decisions taken in the oil supply countries, therefore they understood that the simplest way to decrease their degree of dependence was to consume less energy, which means to implement energy efficiency policies.

Since than many research and technical efforts were employed to deploy innovative technologies and approaches aimed at reducing energy consumption.
Nowadays energy efficiency is a concept applied all over the world, because many countries, also those with a large availability of natural resources (e.g. natural gas, oil, etc.), realized the importance to preserve their resources, so that they can be exploited for a longer period.

In the frame work of international project “Master Degree in Innovative Technologies in Energy Efficient Buildings for Russian and Armenian Universities and Stakeholders” – MARUEEB junior stuff from Russian universities has been trained in European universities: the University of Genoa (Italy) and the Slovak University of Bratislava. In cooperation with the scientific supervisors research was conducted in the field of energy conservation in the conditions of Russia and Kazakhstan climate.

It is a well-known fact that buildings are responsible for at least 40% of primary energy consumption in EU and 45% in Russia and Kazakhstan [1]. Inevitable depletion of nonrenewable energy resources and increasing ecological awareness forces people to implement different legislative instruments at all levels of cooperation. Improving energy performance of buildings is a cost-effective way of mitigating climate change consequences and creating comfortable environment for residence. Considering great potential savings in building industry due to energy efficiency, they appear to be even greater in extreme continental climate. In recent decades a variety of approaches aimed at increasing energy performance of buildings has appeared. Choosing the most suitable approaches for climatic conditions and combining them effectively in order to achieve synergetic effect are challenging.

The aim of this paper is to study modified estimation approaches applied to predict energy consumption taking into account both internal and external environment. For this purpose, several objects located in extreme continental climate were considered, most of them being located in Yekaterinburg, Russia and representing detached houses [2], while the other objects are medium-rise apartment buildings and situated in Astana, Kazakhstan.

The benefits of predicting energy consumption are apparent as it helps to avoid additional expenses in cases when actual energy use is beyond expected levels. Furthermore, it provides accurate long-term planning and better-informed decision-making as showed by Hensen and Lamberts [3].

2 CLIMATIC DATA

 Territories with extreme continental climate can be characterized as isolated from World Ocean and having short summer with high temperatures followed by long winter season. Average humidity is, typically, low with rare precipitation [4]. The greatest challenge for building design is high amplitude of annual temperatures reaching the range of 65 °C and above. Therefore, one should take measures against heat loss in winter and potential overheating in summer.

Yekaterinburg (Ural) and Astana (Kazakhstan) were taken as an example of territories representing extreme continental climate conditions. In Yekaterinburg, for instance, average annual temperature is 2.4 °C above zero. Absolute minimum temperature is 47 °C below zero. Absolute maximum temperature is above 38 °C. Design temperature of the coldest five-day period is 32 °C below zero. The average temperature of heating period is 5.4 °C below zero, designed duration of heating season is 221 days. Total annual heating degree days (HDD) are
Among various existing simulation and calculation methods [5,6] the energy balance and Passive House planning tool 2007 (PHPP 2007) was chosen as the most appropriate one for reaching the abovementioned objectives. Despite major progress in simulation programs using transient equations there remain certain obstacles. Calculations of large-scale buildings are time-consuming and require high computing power. Evaluation based on building information modelling (BIM) is aimed at solving that problem but BIMs are not always introduced in design work [7,8]. Unlike BIM-based tools, PHPP design tool is light-weighted and simplified giving only 5-10% error in energy consumption assessment. Precision was achieved by utilizing calibration method based on computational fluid dynamics (CFD) simulations.

The main purpose of efficient design is to provide for comfort and primary energy savings. Certain strategies might be preferable according to the variety of factors such as building function and climatic conditions. Increasing insulation thickness and creating uniform thermal envelope are one of the effective strategies. In cases when creating continuous thermal layer is impossible it is recommended to apply heat-insulating load-bearing elements especially for cantilever constructions (Fig. 1).

$$\tau = \sum_{env/surface\ j} U_j \cdot A_j + \sum_{linear\ TB\ j} \Psi_j \cdot l_j + \sum_{point\ TB\ j} \chi_j \leq regular = \sum_{regular\ j} U_j \cdot A_j$$ (1)
where $A_j$ – surface area of $i$ building envelope element ($m^2$);

$\theta_j$ – heat-transfer coefficient of $i$ building envelope element ($W/(m^2 \cdot K)$);

$l_j$ – length of linear thermal bridge ($m$);

$\psi_j$ – linear heat-transfer coefficient for $k$ linear thermal bridge ($W/(m \cdot K)$);

$\chi_j$ – point heat-transfer coefficient for $j$ point thermal bridge ($W/K$).

Calculation methods adopted for passive houses and implemented in PHPP package enable to take into account all types of thermal bridges attributing them to respective part of the building envelope and thermal bridge groups.

**Figure 2:** Thermal bridges in the energy balance of building in PHPP 2007.

Thermal bridges calculated using internal dimensions can be transformed into external dimensions via embedded tool allowing to apply both Russian and European building norms [10]. Overall fraction of heat losses from thermal bridges might reach 10% of total transmission heat losses as shown in Fig. 2 and Table 1.

**Table 1:** Transmission heat losses from thermal bridges in PHPP 2007

<table>
<thead>
<tr>
<th>H-Value $\psi$, (W/K)</th>
<th>Temperature Weighting Factor $t_j$</th>
<th>Weighted $f_j \times \psi \times l$ (W/K)</th>
<th>Fraction of Transmission Heat Losses (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.88</td>
<td>1.00</td>
<td>2.878</td>
<td>0.61</td>
</tr>
<tr>
<td>-2.39</td>
<td>0.372</td>
<td>-0.888</td>
<td>-0.19</td>
</tr>
<tr>
<td>-0.49</td>
<td>0.372</td>
<td>-0.183</td>
<td>-0.04</td>
</tr>
<tr>
<td>-0.46</td>
<td>1.00</td>
<td>-0.457</td>
<td>-0.10</td>
</tr>
<tr>
<td>0.83</td>
<td>1.00</td>
<td>-0.830</td>
<td>0.17</td>
</tr>
<tr>
<td>9.24</td>
<td>1.00</td>
<td>9.240</td>
<td>1.94</td>
</tr>
<tr>
<td>1.74</td>
<td>1.00</td>
<td>1.736</td>
<td>0.37</td>
</tr>
<tr>
<td>0.15</td>
<td>1.00</td>
<td>0.155</td>
<td>0.03</td>
</tr>
<tr>
<td>0.21</td>
<td>1.00</td>
<td>0.212</td>
<td>0.04</td>
</tr>
<tr>
<td>-2.50</td>
<td>1.00</td>
<td>-2.498</td>
<td>-0.53</td>
</tr>
</tbody>
</table>
In order to achieve comfort and low life-cycle costs, the thermal quality of transparent elements such as windows must meet stringent requirements. The requirements are directly derived from the hygiene and comfort criteria for energy efficient buildings, as well as from life-cycle cost analyses. The greatest problem in regions with cold continental climate is meeting glazing energy criterion:

\[
eq_{eq} = g - g \cdot S_{zone}
\]

where \(\eq_{eq}\) – equivalent heat transfer coefficient \((W/(m^2\cdot K))\); 
\(g\) – glazing heat transfer coefficient \((W/(m^2\cdot K))\); 
\(S_{zone}\) – zonal solar transmittance; 
\(S_{zone} = 1,0 \ W/(m^2\cdot K)\) for cold regions according to classification by the Passive House Institute [11]. Following this criterion leads to values \(U_g \leq 0,55 \ W/(m^2\cdot K)\) which is attainable only utilizing efficient triple-glazed windows with inert gas filling and two low-emissive coatings [12]. This also means that minimum window surface temperature in most cases will deviate for maximum of 4.2 K, guaranteeing unpleasant cold air decent absence and acceptable radiant heat deprivation. Glazing with double low-emission coating filled with 90% argon was calculated in program Calumen II. Refer to Fig. 3 for the basic factors.

<table>
<thead>
<tr>
<th>Luminous factors (EN410-2011) : (D65 2°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmittance : 75 %</td>
</tr>
<tr>
<td>Outdoor reflectance : 15 %</td>
</tr>
<tr>
<td>Indoor reflectance : 16 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy factors (EN410-2011) :</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmittance : 51 %</td>
</tr>
<tr>
<td>Outdoor reflectance : 31 %</td>
</tr>
<tr>
<td>Indoor reflectance : 32 %</td>
</tr>
<tr>
<td>Absorptance A1 : 12 %</td>
</tr>
<tr>
<td>Absorptance A2 : 2 %</td>
</tr>
<tr>
<td>Absorptance A3 : 5 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Solar factors (EN410-2011) :</th>
</tr>
</thead>
<tbody>
<tr>
<td>(g) : 0.57</td>
</tr>
<tr>
<td>Shading coefficient : 0.65</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thermal transmission (EN673-2011) : 0° related to vertical position</th>
</tr>
</thead>
<tbody>
<tr>
<td>(U_g) : 0.5 \ W/(m²\cdot K)</td>
</tr>
</tbody>
</table>

**Figure 3:** Rated glazing factors obtained from Calumen II
Effective windows alone are not sufficient for comfortable internal environment. Potential overheating in summer due to high intensity of solar radiation requires exploiting different shading devices. Roller shutters with automatic control system, for example, allow regulating heat gain and loss in real time interacting with ventilation system.

3 HVAC AND OTHER ENGINEERING SYSTEMS

Efficient glazing and transparent components allow to create heating system without point heat sources (e.g. radiators and convectors) drastically increasing comfort and reducing temperature stratification.

Figure 4: Conceptual scheme of energy efficient building ventilation system

Conceptual ventilation system of energy efficient building (Fig. 4) is divided into 3 areas: first – incoming (supply) air area, which includes all living rooms; second – overflow area, which includes, for instance, passages and staircases. Third area – exhaust air area that connects all wet premises. Air velocity in ventilation slots of high-grade ventilation system is less than 1 m/s and air change rate \( n_{50} \) is less or equal than 0.6 /h. Air change rate is of great value due to high potential losses through ventilation exhaust. Increasing \( n_{50} \) from 0.6 up to 2.0 might result in 43% growth of specific space heat demand or even greater without recuperation. Air nozzles of long-range supply should be installed after sound attenuators (duct silencers) leading to a stable directed airflow from premises with supply air to premises with exhaust air passing through overflow area and additionally reducing overall air duct
length [13]. High rate of heat recovery (more than 75%) is an essential condition for energy efficient houses in cold climate. Performance coefficient of heat exchangers might be calculated through diverse approaches. We find most explicative the following:

\[
W_{RG} = \frac{\dot{\theta}_{ETA} - \dot{\theta}_{EHA} + P_{el}/(\dot{m}C_p)}{\dot{\theta}_{ETA} - \dot{\theta}_{ODA}}
\]

where \( W_{RG} \) – heat exchange efficiency coefficient (heat exchanger performance coefficient); 
\( \dot{\theta}_{ETA} \) – temperature of extract air (°C); 
\( \dot{\theta}_{EHA} \) – temperature of exhaust air (°C); 
\( \dot{\theta}_{ODA} \) – temperature of outdoor (external) air (°C); 
\( P_{el} \) – electrical total power consumption (W); 
\( \dot{m} \) – mass flow rate (kg/s); 
\( C_p \) – air specific heat capacity (J/kg).

Considering low winter temperatures the design of counterflow heat exchanger should be improved. The general concept is that basic parts of the design are three heat exchanger modules performing step-by-step heating of air. Combined with ground heat exchanger, the system does not require any icing protection and is able to operate up to 35 °C below zero. Another important quality is the purity of air ducts with fine filter after air inlet (class F7 or F8). Before air is removed from building, it passes through class G3 filter. With least maintenance even after 10 years, ventilation system remains hygienic.

Benefits of renewable energy sources should be reconsidered according to climate characteristics. Basic installations are solar collectors, photovoltaic elements (PVE) and ground-coupled heat exchanger with thermal pump. Calculations of PVE were made in PVWatts calculator. Annual solar radiation for Yekaterinburg is 3,95 kWh/m²/day which means that meeting most part of hot water or heating energy demand will require big amount of PV elements and is not always reasonable [14]. Vacuum tube solar collectors cover up to 50% of hot water demands and increasing their contribution in total energy balance of building is not cost-effective. Vacuum tubes are capable of performing at negative temperature and less affected by snow covering [15, 16].

Average wind speed and medium amount of solar radiation, not mentioning economic aspects, result in limited application of solar collectors, PV elements and wind turbines. Hence, geothermal energy should be relied on owing to the stability of energy output. Ground-coupled heat exchanger (GCHE) designed for the project of individual house (q.v. Introduction) has three loops with nonfreezing heat carrier 200-meter length each. All loops are buried into the ground for 3,0 meters deep that is below depth of frost penetration. GCHE either pre-heats and cools outdoor air when necessary or works as a ground source heat pump (GSHP) [17]. Heat pump produces additional energy using temperature differences and keeps the excess in thermal storage. Thermal storage uses water as a heat carrier and therefore can be utilized as hot-water supply and calorifer (heat exchanger) for heating system.

4 RESULTING PERFORMANCE AND CONCLUSIONS

Overall performance ratings of individual house and medium-rise building based on PHPP 2007 are shown in Fig. 5 and 6. These results reveal that various components and materials
combined correctly enable to achieve significantly low specific space heat demand. Nowadays, further decreasing energy consumption is not economically reasonable in extreme continental climate conditions but is definitely possible. Performing preliminary estimation of energy efficient buildings is both challenging and important as it often defines the viability of a project. In this paper, only general recommendations were reviewed. Each building component should be further examined in detail in order to achieve more accurate estimation results. Since technology is evolving, we are confident that in the near future passive houses and even net-zero energy buildings (NZEB) will become economically rational in regions with extreme continental climate making such studies relevant.

**Figure 5**: Performance rating of medium-rise apartment building in Astana (Kazakhstan)
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CALOHEE PROJECT AND CIVIL ENGINEERING:
ANALYSIS OF RESULTS

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Key words: Civil Engineering, Learning Outcomes, Competencies, Framework, Assessment.

Abstract. Paper describes the experience of leading the group dedicated to Civil Engineering of the project Comparing Achievement of Learning Outcomes in Higher Education in Europe (www.calohee.eu). There were four other subjects that were analyzed: History, Physics, Teacher Education and Nursing. The rationale for this project was built with the goal of searching for a more reliable model for evidence based learning and quality assurance and enhancement of the assessment of learning outcomes. When civil engineers enter the labour market with sets of competences based on their personal experiences and their studies are they really prepared for the jobs they go after? What are the demands of employers? Are they equipped to fully engage with their civic responsibilities? Are students trained to cope with the many uncertainties that life and work will bring to them? Do existing quality assurance instruments offer sufficient evidence to answer those questions?

Existing approaches to assess quality of learning tend to look at processes and not at achieved learning by civil engineering students. CALOHEE applied a forward looking approach, focusing on what a graduate should know and be able to do in order to function successfully in life and contribute to society (learning outcomes perspective). The chosen approach brought evidence-based accountability into the teaching and learning role of HE institutions by focusing on competences acquired by students, which meet the needs of society and the graduates. The assessment framework included four strands: 1) Knowledge (theory and methodology); 2) Applying knowledge and skills; 3) Preparing for employability and 4) Civic, social and cultural engagement. CALOHEE also developed a set of reference points at 1st and 2nd cycles levels. The sets of learning outcomes' descriptors were prepared by teams from the respective academic communities, in close consultation with stakeholders and open to public scrutiny.

1 INTRODUCTION AND TUNING APPROACH

It is presented in this paper the summary of two documents [1], [2] that builds on documents published in the past, in particular the publication A Tuning-AHELO Conceptual Framework of Expected Desired/Learning Outcomes in Engineering, documents of the European Civil

This work done in the subject area of Civil Engineering concern degree profiles and the tasks and societal roles graduates will take on, but also show how different degrees fit into the wider context of overarching qualifications frameworks. In other words, which are the essential elements that constitute a particular subject area in higher education? Among other aspects, the guidelines include general descriptors for the first and the second cycle, the bachelor and master, presented in easy-to-read tables, and are meant to be used as reference points for the design and delivery of individual degree programmes. According to the Tuning philosophy, each degree programme has its own unique profile, based on the mission of the institution and taking into account its social-cultural setting, its student body, and the strengths of its academic staff [3].

The Guidelines and Reference Points [1] are the outcome of a long and intense collaboration, starting in 2001, in conjunction with the early phases of the Bologna Process, which has now come to include 48 European countries. They are a result of the grassroots university-driven initiative called Tuning Educational Structures in Europe, or simply ‘Tuning’, that aims to offer a universally useful approach to the modernisation of higher education at the level of institutions and subject areas. The Tuning initiative has developed a methodology to (re-) design, develop, implement and evaluate study programmes for each of the Bologna cycles.

The Tuning methodology is based on student-centred and active learning approaches it has promoted since its very launch. Tuning’s mission is to offer a platform for debate and reflection which leads to higher education models able to ensure that graduates are well prepared for their societal role, both in terms of employability and as citizens. Graduates need to have obtained as the outcome of their learning process the optimum set of competences required to execute their future tasks and take on their expected roles. As part of their education graduates should have developed levels of critical thinking and awareness that foster civic, social and cultural engagement.

Using the Tuning reference points makes study programmes comparable, compatible and transparent. They are expressed in terms of learning outcomes and competences. Learning outcomes are statements of what a learner is expected to know, understand and be able to demonstrate after completion of a learning experience. According to Tuning, learning outcomes are expressed in terms of the level of competence to be obtained by the learner. Competences represent a dynamic combination of cognitive and meta-cognitive skills, knowledge and understanding, interpersonal, intellectual and practical skills, and ethical values. Fostering these competences is the object of all educational programmes. Competences are developed in all course units and assessed at many different stages of a programme. Some competences are subject-area related (specific to a subject area), others are generic (relevant for many or all in degree programmes). According to the Tuning philosophy, subject specific competences and generic competences or general academic skills should be developed together. Normally competence development proceeds in an integrated and cyclical manner throughout a programme.

The initial core competences of the subject area were identified in a consultation process involving four stakeholder groups - academics, graduates, students and employers - during the period 2001-2008. Since then similar consultation processes have been organised in many other parts of the world: these have been taken into consideration in developing this new edition. This
edition has been elaborated as part of the CALOHEE project (Measuring and Comparing Achievements of Learning Outcomes in Higher Education in Europe), co-financed and strongly supported by the European Commission as part of its Action Programmes for Higher Education. CALOHEE project aims to develop an infrastructure which allows for comparing and measuring learning in a (trans)national perspective. Besides updating and enhancing the reference points brochures it has also developed Assessment Frameworks which offer even more detailed descriptors than those presented in this document. The Assessment Frameworks are published separately.

To make levels of learning measurable, comparable and compatible across Europe academics from the single subject areas have developed cycle (level) descriptors expressed in terms of learning outcomes statements. In this edition, for the first time these are related one-to-one to the two overarching European qualifications frameworks, the ‘Bologna’ Qualifications Framework for the EHEA (QF for the EHEA) and the EU European Qualifications Framework for Lifelong Learning (EQF for LLL). In the CALOHEE project these two meta-frameworks have been merged into one model to combine ‘the best of two worlds’. While the EQF for LLL is focused on the application of knowledge and skills in society, the focus of the QF for the EHEA is more related to the learning process itself: it applies descriptors which cover different areas or ‘dimensions’ of learning: knowledge and understanding, application of knowledge and understanding in relation to problem solving, making judgments, communicating information and conclusions, and finally, knowing how to learn.

In developing the CALOHEE Tuning model, it was concluded that ‘dimensions’ are an indispensable tool, because they make it possible to distinguish the principal aspects that constitute the subject area. Dimensions help give structure to a particular sector or subject area and also make its basic characteristics more transparent. Furthermore, the ‘dimension approach’ is complementary to the categories included in the EQF for LLL, which uses the categories of knowledge, skills and wider competences to structure its descriptors. Thus, in CALOHEE terms, the three columns correspond to a ‘knowledge framework’, a ‘skills framework’ and a ‘wider competency framework’, linked by level. The last column, the ‘wider competency framework’, refers to the wider world of work and society and identifies the competences required to operate successfully in the work place and as a citizen. It builds on the first two elements: knowledge and understanding and the skills necessary to develop and apply this knowledge.

The use of the learning outcomes and competences approach implies changes regarding the teaching, learning and assessment methods. Tuning has identified approaches and best practices to form the key generic and subject specific competences. Some examples of good practice are included in this brochure. More detailed examples can be found in the subject area based Assessment Frameworks.

Finally, Tuning has drawn attention to the role of quality in the process of (re-)designing, developing and implementing study programmes. It has developed an approach for quality enhancement which involves all elements of the learning chain. It has also developed a number of tools and identified examples of good practice which can help institutions to improve the quality of their degree programmes.

The outcomes of the work done by the Subject Area Group (SAG) in Civil Engineering, which was established in the context of the CALOHEE project, are presented in a template to
facilitate readability and rapid comparison across the subject areas. The summary aims to provide, in a very succinct manner, the basic elements for a quick introduction into the subject area. It shows in synthesis the consensus reached by a subject area group after intense and lively discussions in the group [1].

2 TERMS OF REFERENCE IN CALOHEE PROJECT

In order to develop the sectoral and the subject area frameworks, the SAG started from the EUR-ACE programme (learning) outcomes recently re-defined by the European Network for Accreditation of Engineering Education (ENAEE) in the document EUR-ACE Framework Standards and Guidelines (EAFSG), approved by the Administrative Council of the European Network for the Accreditation of Engineering Education (ENAEE) on March 2016. The EUR-ACE programme outcomes (POs) are the basis for a European mutual recognition agreement, currently developed under the framework of ENAEE.

EUR-ACE programme outcomes (POs) and corresponding accreditation criteria have been integrated into national learning outcomes and accreditation requirements of thirteen European countries: Finland, France, Germany, Great Britain, Ireland, Italy, Poland, Portugal, Romania, Russia, Spain, Switzerland and Turkey. In addition, FEANI, the European Federation of Engineering Societies in 30 European Countries, recognises the EUR-ACE POs and accreditation results for their own index of accredited engineering programmes and the European engineering register of professional engineers.

EUR-ACE POs describe the knowledge, understanding and skills that an accredited engineering degree programme must enable a graduate to demonstrate. They are described separately for both Bachelor and Master degree programmes, with reference to the following eight ‘learning areas’:

- Knowledge and understanding;
- Engineering Analysis;
- Engineering Design;
- Investigations;
- Engineering Practice;
- Making Judgements;
- Communication and Team-working;
- Lifelong Learning.

First of all, the SAG has verified the capacity of the EUR-ACE learning areas to include the learning outcomes (LOs) established in the most influential LOs frameworks in the engineering field. In fact, that there is a common understanding throughout the world of what an engineer is supposed to know and be able to do is most striking and probably differentiates engineering from many other disciplines.

The frameworks that have been considered are:

- the Tuning-AHELO framework [4];
- the EUCEET framework [5];
- the International Engineering Alliance (IEA) - Washington Accord framework [6];
- the ABET framework [7];
- the Conceiving, Designing, Implementing, Operating (CDIO) Initiative framework [8];
• the National Society of Professional Engineers framework [9];
• the American Society of Civil Engineering (ASCE) framework [10].

Consequently, the SAG has assumed the EUR-ACE learning areas as ‘dimensions’ for constructing the sectoral qualifications framework (SQF) for the engineering domain, renaming them as follows:
• Knowledge and understanding;
• Analysis and Problem Solving;
• Design;
• Investigations;
• Practice;
• Decision Making;
• Team-working;
• Communication;
• Lifelong Learning.

Then, the SAG has checked the correspondence of the EUR-ACE POs with the LOs established in the considered frameworks. The members of the SAGS quickly came to the conclusion that, in spite of a different ordering, the EUR-ACE POs and the LOs established in the considered frameworks were highly compatible, but also that two major revisions of the EUR-ACE POs were necessary in order to improve the compatibility:
• the introduction of a PO regarding the ability to implement and conduct engineering activities;
• the necessity to provide better evidence to the social responsibility associated to the outcomes.

Finally, the EUR-ACE POs have been redefined, according to the template suggested in the context of the CALOHEE project, as described and shown in the next paragraph.

3 ASSESSMENT FRAMEWORK FOR CIVIL ENGINEERS

The Tuning-CALOHEE Assessment Frameworks for Civil Engineering offers an important and novel tool for understanding, defining and visualising the requirements for any degree programme in the Subject Area or closely related to it. It shows, in a detailed but also general and flexible way, which competences should be developed by such a programme (the AF for Civil Engineering does not shows competences), giving useful indications about the relevant learning areas: not only core knowledge content, including theories and methodologies, but also skills for developing and applying that content, as well as the level at which the graduate will be able to operate meaningfully in his or her profession and, more broadly, in society. It distinguishes between the first and second cycle degree (Bachelor and Master) in the Subject Area, clarifying the progressive nature of the learning process, and showing the connections between levels of learning to be developed.

The CALOHEE Assessment Framework comprises easily read reference tables containing descriptors covering knowledge, skills and wider competences [2]. These tables are an integral part of the Tuning Guidelines and Reference Points 2018 for the Design and Delivery of Degree Programmes [1].

The advantages of being able to refer to an Assessment Framework are numerous. Such a framework provides:
- a widely accepted comprehensive overview of the key learning topics a degree programme can include, developed by an international group of experts, and validated by peers and other stakeholders;
- a range of up-to-date strategies, methodologies and approaches to learn, teach and assess the topics of learning, formulated in terms of learning outcomes;
- different stakeholder groups’ insight into what could be usually covered in terms of learning in a particular subject area and a particular degree programme. Stakeholders include disciplinary experts, teaching staff, university and faculty management, professional organisations, employers, and (potential) students;
- a menu through which an individual degree programme at bachelor or master level can be composed and defined on the basis of motivated and articulated choices and a transparent decision-making process;
- a fair indicator of the completeness and quality of a degree programme which allows for different institutional missions and profiles;
- a reliable mechanism for quality assurance based on a robust reference framework based on well-defined sets of measurable learning outcomes;
- a format for comparing different degree programmes in terms of profile, content and approach;
- a robust and articulated framework for developing comparable diagnostic assessments which offer reliable evidence regarding the strengths and weaknesses of a particular degree programme benchmarked against programmes with comparable missions and profiles.

CALOHEE’s Assessment Framework can be seen as a general table providing a complete overview of the Civil Engineering in terms of measurable learning outcomes statements [2]. These statements, taken together, are much more precise than the more general Reference Points descriptors of Civil Engineering [1]. The focus in the framework is not only on ‘what’ to learn, but also on ‘how’ this ‘what’ can be learned. It represents the lowest, but at the same time most detailed level in the hierarchy of qualifications frameworks. This hierarchy starts with the overarching European frameworks, followed by national, sectoral and the subject area frameworks. As in the case of the subject area frameworks, the Assessment Framework organises its descriptors according to the categories knowledge, skills and competences distributed among the ‘dimensions’, which are seen as the main building blocks of the subject area. The descriptors, formulated in this way, provide structure and transparency: a general way to look at Civil Engineering through which specific programmes can be formulated.

While the general descriptors have the primary purpose of indicating the type and level of learning, in an Assessment Framework these are broken down using ‘sub-descriptors’ or ‘subsets’ which describe the key elements and topics that constitute each descriptor in greater detail. Although the general descriptors are often called learning outcomes, in practice they are much more competence statements. The real, utilizable, learning outcomes of a subject area are the sub-descriptors, because they meet the condition of being measurable, indicating not only a subject, but also context and complexity. The dimensions, sub-dimensions, descriptors and sub-descriptors together make an assessment framework which is complimented by an overview of the most appropriate learning, teaching and assessment strategies and approaches to achieve the intended learning outcomes. These can be formulated per sub dimension but are more often formulated for several related sub descriptors in order to avoid repetition.

According to the Tuning and CALOHEE philosophy, learning, teaching and assessment –
in that order - should be fully aligned. A specific body of learning (knowledge, skills and wider competences), identified by the intended learning outcomes, is split into modules or units spread over the available learning period (e.g. academic years) in such a way that progression routes are established. Appropriate modes of learning, teaching and assessment are linked to each unit or module. These, of course, should fit the level of learning identified.

An Assessment Framework should first and most of all be understood as a source of reference - inspiration and guidance - for modernising, revising and enhancing existing degree programmes and constructing new ones to meet the needs of the learners, preparing them appropriately for their role in society, in terms both of employability and as citizens. For this reason, CALOHEE has developed a model in which the different aspects of the learning process are defined. The ‘knowledge set of descriptors’ is expected not only to cover core knowledge of the subject area but also related theories and methodologies. The ‘skills set of descriptors’ focusses on the skills/competences – generic and subject specific – which are relevant for applying knowledge. With regard to the generic skills /competences one normally thinks of such abilities as critical thinking, analysing and synthesising, creativity and originality and written and oral communication, but it is important to remember also value related competences such as ethical commitment.

4 BACHELOR AND MASTER LEVELS 6 AND 7 OF EQF

The two levels of the European Qualification Framework, 6 and 7, represent the academic qualifications of the majority of civil engineers working as professionals. These two levels are generally known as qualifications denominated bachelor and master. For each one of these levels an example is presented with the indication of the dimension, the learning outcome (knowledge, skill or wider competence), the teaching approach, the learning approach and assessment methods proposed.

The teaching and learning approaches are proposals arising from the consultation among the project partners, targeted surveys and contribution of stakeholders. The proposal of assessment methods was obtained using a web-tool TALOE. This tool is the result of the application of the ALOA model that aligns the assessment methods with the different types of learning outcomes using revised Bloom’s taxonomy and Biggs alignment model [11].

For level 6, first Bologna cycle or bachelor, an example is Analysis and problem solving. In this case for the knowledge dimension one of the learning outcomes is “Demonstrate knowledge and understanding of the process and established methods of analysis of civil engineering issues (products, processes, systems, situations) and of their limitations, of the process and established methods of solving civil engineering problems and of their limitations and demonstrate also awareness of the importance of non-technical, societal, health and safety, environmental, economic and industrial considerations in solving civil engineering problems. The teaching approaches proposed are lectures, seminars, tutorials, flipped classroom, blended teaching and problem-based classes. For the same learning outcome it is proposed in terms of learning attending lectures, attending seminars, attending tutorials, participating in flipped classroom, blended learning and problem-based learning. The assessment methods proposed are short answer questions, multiple choice questions and essays.

For level 7, second Bologna cycle or master, an example is Lifelong Learning. For this dimension the wider competences are defined as Identify the most appropriate learning strategy
and method in independent lifelong learning and to follow developments in science and technology and undertake further studies in new and emerging technologies in civil engineering subject area and within broader or multidisciplinary contexts. For this learning outcome the teaching approaches proposed are problem-based classes, design-based classes, work-based practice and individual supervision. The learning approaches are problem-based learning, design-based learning, practicing professional skills and individual supervision. The assessment methods proposed are problem solving, practical work and reflective practice assignments.

5 CONCLUSIONS

The ultimate ambition of the CALOHEE for Civil Engineering initiative is to develop a transnational multi-dimensional assessment model which allows for actual measuring and comparing of learning, taking into account the specific mission and profile of each degree programme, within its cultural and academic context. This model should offer sets of consistent test formats and items which make it possible the assessment of deep knowledge and understanding as well as high level skills. One could think of, for example, critical awareness, analysing and composition skills.

An Assessment Framework is a key tool in this case because it offers a basis for identifying and developing the items to be tested. Although students’ achievements will be individually assessed, the outcomes of the assessments will be generated at degree programme level (not at the individual student level), because the intention is – in line with traditional quality assurance systems – to diagnose whether the intended learning outcomes are actually achieved. In other words, does the programme offer what it has promised and does it meet the standards which have been agreed by the academic community? The Assessment Framework presented here should be understood as a planning tool, but also as a tool for answering this question.

6 ACKNOWLEDGEMENT

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ENVIEU, THE FIRST JEAN MONNET TEACHING MODULE ABOUT THE ENVIRONMENTAL FRAMEWORK IN EUROPE

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Key words: European studies, Environmental framework, Tailor-made course, Methodology, Learning, Technology.

Abstract.
The Jean Monnet programme co-funded by the Erasmus+ Programme aims to stimulate teaching, research and reflection in the field of European integration studies at the level of higher education institutions. The European integration is the analysis of the origins and evolution of the European Communities and the European Union (EU) in the internal and
external dimensions, including the EU’s role in the dialogue between peoples and cultures and the EU’s role and perception in the world.

The objective of this Jean Monnet module named environmental framework for a sustainable Europe (enviEU) is to make the EU environmental policy known by means of introduction of innovative teaching methodologies based on information and technology tools, raising of critical knowledge leading to analyse how the existing EU policies and regulations in the environmental protection affect technologies design, development and implementation.

The targets of this initiative are students that although they have competences to solve technical problems, they are unconscious about the importance of EU regulatory framework in their works.

EnviEU is based on six topics: i) environmental impact; ii) water; iii) energy; iv) air quality; v) environmental noise and; vi) waste. Each topic has a person in charge, who is an expert in the topic with wide teaching and researching experience in this field.

Throughout the course, each topic will be developed during a complete day. In the morning two teaching activities with a total duration of 2 hours will be carried out by the person in charge and, during the afternoon the project coordination will organize a public event for the audience. To increase the student’s knowledge of some of the selected 6 topics, a summer course with 14 hours of duration will be carried out every summer. At least two events have been planned for each summer course.

1 INTRODUCTION

Jean Monnet Programme, launched in 1989, is the part of Erasmus+ dedicated to promoting excellence in European Union (EU) studies in higher education around the world [1]. These actions tries to create links between academics, researchers and EU policymakers. According to the Programme Guide, there is an emphasis on the study of and research on EU integration and in understanding Europe's place in a globalised world. Specifically, the Jean Monnet programme aims to stimulate teaching, research and reflection in the field of European integration studies at the level of higher education institutions.

European Commission [1] defines European integration as the analysis of the origins and evolution of the European Communities and the EU in all its aspects covering both the internal and external dimension of European integration, including the EU's role in the dialogue between peoples and cultures and the EU's role and perception in the world.

The EU has some of the world's highest environmental standards and probably one of the most restrictive environmental regulations in the world, according to the reports published by the European Environment Agency [2]. The EU environmental policy contributes to make the economy more ecological, protect the nature and safeguard the health and life quality of the inhabitants of the EU. The implementation of this environmental policy in the EU members and more specifically in Spain has become an impulse for the constant update of the existing environmental regulatory models towards an eco-friendly society and further integration of policies that promote a sustainable environmental framework.
In 2016, according to the conducted surveys among the students of Civil Engineering, Chemical Engineering and Environmental Sciences at the University of Granada (UGR), the lack of fundamental specific knowledge about the EU relevant legislations and regulations necessary for the curricula was identified (more than 90% of students demonstrated a considerable knowledge gap in the existing EU Environmental and Chemical legislations). This produces an effect on the appropriateness and quality of the engineering curricula and future performance of young professionals.

In addition, a deeper knowledge about the EU environmental legal framework permits to raise awareness with regard to the objectives of the EU and EU environment policy (especially, the 7th Environment Action Programme). Likewise, the awareness in this topic of different agents of the society (citizens, professionals and politics) facilitates their involvement in decision making according to EU environmental objectives. In this proposal, the fields to be analysed have been organized in six topics: environmental impact assessment, water, energy, air quality, environmental noise and waste. The objective of the proposal is to make the EU environmental policy known by means of introduction of innovative teaching methodologies based on information and technology tools (ICT), raising of critical knowledge leading to analyse how the existing EU policies and regulations in the sphere of environmental protection affect the technologies design, development and implementation.

2 OBJECTIVES OF THE ACTIVITY

The main objective of the enviEU is to provide a tailor-made courses on the EU environmental policy for graduates of the UGR to be useful for their professional life, fostering the introduction of a European Union angle into mainly non-EU related studies. Consequently, the objective is to make the European environmental policy known by means of introduction of innovative teaching methodologies based on ICT, raising of critical knowledge leading to analyse how the existing EU policies and regulations in the sphere of environmental protection affect the technologies design, development and implementation. In this regard, the project actively contributes to the promotion of European Union studies in non-EU related fields, producing a great impact on the Chemical Engineering, Civil Engineering and Environmental sciences at an international level.

Moreover, enviEU will support the coordination and research activities of a young researcher, who has started his academic career and obtained his degree in the last five years. This fosters the development of existing and new teaching and debating activities, including new methodologies, tools and technologies in the academic fields traditionally unbound to the EU studies. The implementation of the programmed seminars, lectures and conferences from the innovative angle of the application of EU regulations to the design and development of technologies will enhance the academic added value of the present initiative. It will actively contribute to the promotion of EU studies at the UGR, providing major visibility to engineering-related academic disciplines at a national level.

Consequently, enviEU complies with the specific objectives of Jean Monnet programme in the following ways:
i) The course provides students and young professionals the applied knowledge about the European directives related with the environment increasing their academic and civic skills and allow the students to improve their future professional lives.

ii) The teaching activities and specifically the events proposed foster the relationship between the students, the private companies and policy-makers. This facilitates an easier dialogue among the future professionals of the environmental technologies to apply and enhance the governance of EU environmental policies.

iii) Though the main target group are the students of Civil Engineering, Chemical Engineering and Environmental Sciences degrees, the course will be open to all the students of the UGR and the general society. Moreover, the resources created by the staff members of the module will be published as open educational license. Both aspects promote the dialogue between the academic world and society.

iv) The implementation of this proposal is a challenge for the staff members and for the
School of Civil Engineering of UGR because it implies to get an innovative teaching tool for their students. Even though most the content is currently given in different subjects by the members of this proposal, the focus of this proposal is radically different. Its aim is to emphasize the importance of the EU policies and how they affect the technologies in a multidisciplinary knowledge area such as the environment, fostering the introduction of environmental studies in Europe.

v) The improvement of the relationship between the academic world and other institutions such as the private companies of the environmental sector and the public institutions is the objective of the events planned.

vi) The quality of professional training of the students on environmental EU subjects improves with this course. For this reason, it would be recognised in the curricula of the students that receive the course. In relation to the assistance of the student to 3 ECTS could be recognized as free optional subject. Moreover, once the project finishes, its incorporation to the study plan will be considered.

vii) The key staff members are members of the UGR with different positions and categories that vary from assistant professor to professor, being the academic coordinator of the module Jaime Martín-Pascual, who is an assistant professor that obtained a PhD degree in 2014. This fact promotes the first teaching experience for a young research practitioner in European Union issues.

Table 1: Work plan of the enviEU autumn course

<table>
<thead>
<tr>
<th>Typology</th>
<th>Title</th>
<th>Duration (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EUROPEAN REGULATIONS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seminar</td>
<td>Regulations, Directives and other European acts</td>
<td>1</td>
</tr>
<tr>
<td><strong>ENVIRONMENTAL IMPACT ASSESSMENT</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecture</td>
<td>Environmental Impact Assessment. Fundamental and applications</td>
<td>2</td>
</tr>
<tr>
<td>Seminar</td>
<td>Landscape restoration</td>
<td>2</td>
</tr>
<tr>
<td>Study visit</td>
<td>Engineering techniques applied to landscape restoration</td>
<td>4</td>
</tr>
<tr>
<td><strong>WATER AND WASTEWATER</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecture</td>
<td>The new EU Water Framework Directive</td>
<td>2</td>
</tr>
<tr>
<td>Seminar</td>
<td>How are European Directives changing the conventional process in water and wastewater treatment?</td>
<td>2</td>
</tr>
<tr>
<td>Study visit</td>
<td>The water and wastewater treatment in Granada.</td>
<td>4</td>
</tr>
<tr>
<td><strong>ENERGY FROM RENEWABLE SOURCES</strong></td>
<td></td>
<td></td>
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<tr>
<td>Lecture</td>
<td>The European Directive on the promotion of the use of energy from renewable sources</td>
<td>2</td>
</tr>
<tr>
<td>Seminar</td>
<td>Plan of renewable energies in Spain motivated by European Directive</td>
<td>2</td>
</tr>
<tr>
<td>Study visit</td>
<td>The renewable photovoltaic and thermal energy generation in Granada</td>
<td>4</td>
</tr>
</tbody>
</table>


3 PROGRAMME ACTIVITIES

enviEU is based on six topics related to the environment: environmental impact assessment, water; energy, air quality, environmental noise and waste. Additionally, a topic 0, related with the European regulation, is included. Each topic has a person of the key staff members in charge, who is an expert in the topic with wide teaching and researching experience in this field.

To achieve adequate follow-up by the students, the different blocks have been structured in 3 annual courses of 25 hours of teaching (1 ECTS) as shown in Figure 1. Annually, during the three years of the project, a course in the first semester (autumn), another one in the second semester (spring) and an intensive course in July (summer course) will be held. The contents of the spring and autumn courses are repeated during the three years. However, the theme of the summer course changes.

Each topic is developed during two middle day (a Thursday in the afternoon and a Friday in the morning per months). In the afternoon two teaching activities of 2 hours each is carried out by the person in charge and, in the afternoon there will be an event organized for the audience (study visit or conference given by an expert from a private or public company followed by a roundtable debate). Table 1 and table 2 show the teaching activities and events of the autumn and spring course respectively.

In order to increase the student’s knowledge of some of the 6 topics, a summer course with 16 hours of duration will be carried out every summer of the three years duration Jean Monnet teaching module. The first summer course will be about water, the second one about waste and the third one will deal with the use of biomass as renewable energy.

<table>
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<tr>
<th>Typology</th>
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<th>Duration (h)</th>
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<tbody>
<tr>
<td>EUROPEAN REGULATIONS</td>
<td>Regulations, Directives and other European acts</td>
<td>1</td>
</tr>
<tr>
<td>AIR POLLUTION</td>
<td>Common noise assessment methods for Europe (CNOSSOS-EU): implementation in the context of EU noise policy developments</td>
<td>2</td>
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<tr>
<td></td>
<td>Management measures of air pollution and engineering technologies</td>
<td>2</td>
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<tr>
<td>Study visit</td>
<td>Air quality and noise control in Granada. Monitoring and control.</td>
<td>6</td>
</tr>
<tr>
<td>ENVIRONMENTAL NOISE</td>
<td>The Environmental Noise Directive</td>
<td>2</td>
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<td></td>
<td>Assessment and management of environmental noise</td>
<td>2</td>
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<tr>
<td>Conference</td>
<td>Effects of the environmental noise directive into the municipal area</td>
<td>3</td>
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<tr>
<td>WASTE</td>
<td>European Waste Framework</td>
<td>2</td>
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<td></td>
<td>European packaging waste.</td>
<td>2</td>
</tr>
<tr>
<td>Conference</td>
<td>Packaging waste management according to the Circular Economy principles</td>
<td>3</td>
</tr>
</tbody>
</table>
4 CONCLUSIONS

- The developed of this teaching module supported by Jean Monnet program will provide a tailor-made course on the EU environmental policy for graduates of the UGR.
- The competencies given in this course are useful for the professional life of the students, encouraging the introduction of an EU angle in principally outside the EU-related studies.
- Knowledge about Europe for a Civil engineering student allows for the development of the future graduate and facilitates their international labor mobility both in and outside Europe.

REFERENCES


USING SIMULATION AND SERIOUS GAMES IN STEM EDUCATION

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Key words: Higher Education, STEM, Simulation, Serious Games.

Abstract. The use of serious games and simulation software in education is continuously increasing due to the availability of new computer software and the universalization of Internet-based learning environments. Such methodological and technological tools contribute the enhancement of the learning experience in the different areas constituting the Science, Technology, Engineering, and Mathematics education. This work reviews the current state-of-the-art in the use of simulation and serious games in higher education and, in particular, in the fields of STEM and Civil Engineering. Among others, the article explores topics such as the benefits and potential drawbacks of teaching practices based on the utilisation of games and simulations, the enrichment of the learning environment provided by simulation-based learning, or the analysis of collaborative interaction throughout digital games and simulation.

1 INTRODUCTION

A distinguishing aspect of the difficulties that students of the Science, Technology, Engineering, and Mathematics (STEM) cope with at present is the increasing complexity of their working environments. This is particularly true in the case of Civil Engineering students. The holistic perspective needed to tackle the new reality requires from these students a certain level of knowledge of many other engineering and social systems, and the understanding of
the deep interrelation among these fields. The present complexity makes the learning process a very challenging one, in which multidisciplinarity, interdisciplinarity, and complex thinking should be achieved. The use of serious games and simulation in learning activities rises as an effective tool to address that challenge [1]. Understanding the potential pedagogical mechanisms of these tools and the associated tradeoffs of their implementation is crucial when developing an adequate roadmap of the educational STEM programs, including those related to Civil Engineering degrees. This paper reviews some existing work from the educational simulation and serious games fields. In particular, the focus is put on identifying best practices and emerging trends of these methodological tools. The learning simulation combines pedagogical, modelling and entertainment elements, presented either in a pure computer-based environment (without the intervention of human actors), or with the participation of drivers, competitors, teammates, and learning communities.

According to the role of entertainment elements, sometimes detrimental to the reality fidelity, the learning simulations can be classified into serious (educational) games and educational simulations. Educational simulations are representations of real phenomena aiming the practice for tasks in the real world, whereas serious games incorporate specific a priori pedagogical approaches, and are designed not only to train tasks but also to teach content. Also, in a simulation, the entertainment is a by-product of the actions and not necessarily the intention of the designers. Usually, motivation to perform any task or job is divided into two facets, intrinsic and extrinsic. Extrinsic motivation consists of behaviors that are performed because of a concrete or perceived consequence or reward, rather than because of the activity itself. On the contrary, intrinsic motivation is characterized by behaviors where people engage in activities that interest them, without the need for an external reward. There has been found to be a strong positive correlation between intrinsic motivation in learning activities and the learning effect of those activities [2]. In the last years, learning practices based on the use of simulation and serious games are attracting a significant attention within the pedagogical environments, as a large number of related publications evidence. Nevertheless, research addressing the topic under the perspective of the STEM and, in particular, Civil Engineering education is scarce. In that regard, this paper presents a focused study that can be used a baseline to design STEM-related programs.

2 GROWING IMPACT OF SIMULATION AND SERIOUS GAMES IN EDUCATION

The inclusion of simulation and serious games in education has received increased attention in recent years. Figure 1 shows a clear increase in Scopus-indexed publications including in its title the terms “education AND (simulation OR serious games)”’. Notice that the use of simulation in education is a topic that has been explored since 1980 (and even much before that date). Nevertheless, it is not until 2017 that the attention of the scientific community experiments a significant and constant growth. Also in the last decade, the use of serious games in education shows a noticeable increment in the number of related papers. Figure 2 illustrates the main areas of application of simulation methods in education. These include, in order of influence: medicine, social sciences, computer science, engineering, nursing, mathematics, and business & management.
Similarly, Figure 3 illustrates the main areas associated with publications focused on the use of serious games in education. Not surprisingly, the main areas are almost the same as before, i.e.: computer science, social sciences, engineering, mathematics, and medicine. The diversity of these areas, ranging from medicine and nursing to social sciences or engineering, shows the outstanding potential of these methodologies when applied in higher education and the fact that a huge variety of professionals can benefit from their inclusion in the university academic programs.
Simulation is an interdisciplinary knowledge area that combines computer science, mathematics, statistics, and business management [3]. The rapid development of computer technology as well as the fast improvement of versatility in programming languages, has made simulation programs become such sophisticated tools that it is possible to reproduce reality with an excellent degree of precision [4]. Simulation games have been utilized as an educational tool in order to complement the traditional teaching methods for many years [5]. As pointed out by Clarke [6], there is not a common agreement on the specific meanings of the terms educational simulation and serious games. Authors such as Bloomer [7] define a game as any contest (play) among adversaries (players) operating under constraints and rules for an objective (e.g., winning the game). Simulation refers to a broad collection of methods and applications that allow the mimicry of the behaviour of real systems, usually on a computer with appropriate software. Simulation has been widely used to analyse systems and to compare proposed scenarios in order to improve the system performance, but it can also be adapted to constitute a game [8]. According to Adelsberger et al. [9], simulation games consist of two components, a description and a simulation model. Other authors define a simulation game as a series of “challenging interactive pedagogical exercises, wherein learners must use their knowledge and skills to attain specific goals, played within an artificial reproduction of a relevant reality” [8]. Simulation games can also be defined as a context or a competition-based problem-solving activity in a virtual reality.

As a learning tool, simulation games attempt to replicate various real world problems in the form of a game for various purposes of training, analysis, or prediction. Such types of learning methods can assist in the development of more effective personal transferable skills, such as teamwork, problem-solving techniques, or oral and written communication [10]. Simulation games indeed help students to learn and have fun simultaneously [11], and they have been applied for training purposes in diverse application fields, including: the military.
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and the aeronautics industry, healthcare services (medicine, nursing, etc.), engineering, management, and several other fields. For example, Stanley and Latimer [12] evaluated the effectiveness and suitability of “The Ward” as a simulation game to promote and support nursing students understanding of decision making, critical thinking, and teamwork in clinical practice situations. Similarly, Deshpande and Huang [13] reviewed the different simulation games that have been applied in the education of science and engineering.

4 USING SERIOUS GAMES TO ENRICH THE LEARNING EXPERIENCE

Traditionally, researchers have artificially separated learning into three areas: affect, behavior, and cognition [14]. Current trends in educational measurement and psychometrics address the artificial disconnect that exists between these. For instance, automatic associative affect results from repeated contact with contexts not consciously under control. Also, within the so-called priming process, there are affective effects that take place prior to cognitive processes, fostering subsequent learning. In serious games the learner is exposed to complex representations, often requiring specific content knowledge and learning progressions to be completed in order to move the game forward toward the objective. Usually, the game adds a story as a means to drive game mechanics. In Lamb [15], the following characteristics of games are described:

(i) emotional attachment to the outcome of the actions taken by the player;
(ii) a uniform set of rules governing the actions players take;
(iii) differential outcomes related to actions taken by players during play;
(iv) differentiation of value for actions taken by players;
(v) consequential actions resulting from actions the players take; and
(vi) agents within the game for the player's characteristics to act upon.

The efficiency of the serious games in the learning process will depend on the understanding of the structure and potential of the game. In that regard, Arnab et al. [16] provide a useful tool to analyse and support some serious games as means for fostering active learning. The tool provides the relation between the learning mechanics based on pedagogical theories and the game mechanics, as depicted in Figure 4. Rows present analogous mechanics from a general perspective. The central columns in each block show the core elements supported by the functional mechanics of the side cells. Colours allow a second classification based on the thinking skills acquired, according to Bloom’s theory [17]. In addition, abstract and concrete elements are indicated by cursive and bold fonts. For instance, the abstract learning objective of participation, which may be supported by concrete learning tasks and demonstrations activities (second row), is connected to the mechanisms of cooperation and collaboration allowed by serious games. The updated state-of-the-art publication by Turner et al. [18] summarises the many reported benefits of the online serious games, such as the increase of the level of motivation, engagement, critical thinking, and content proficiency of the students. As a complementing element of the educational program, they even foster the confidence and satisfaction of the students. It is also highlighted how serious games permit the experiential learning experience, real-life problem solving and training in decision-making processes. The construction of knowledge in a virtual environment is comparable to the construction of knowledge in an analogue environment (i.e., the real world) to take advantage of the engaging nature of video games by stimulation of the areas of the brain associated with attention and arousal. Engagement takes place as a
psychological immersion in the game.

Often, players experience a type of deep engagement known as flow. Flow is a highly energized state of concentration and focus that allows distractions to be excluded [19]. Flow is a concept first introduced by Csiksentmihalyi [20] in the 1990’s, and it is also characterized as a psychological state that a person may enter, while being deeply involved with interactive and immersive learning environments that attract their attention for a period of time. This psychological state strongly fosters retention of contents and self-efficacy. Then, the challenge is to guarantee that serious games keep the student in the flow zone, that is, with a demand level neither too high that causes frustration, nor too low that causes tedium. Hainey
et al. [21] claim that games support constructive, experiential and situated learning; these are all aspects that the modern theories of learning suggest as central for effective learning. However, several drawbacks associated with the use of serious games in education have been identified too. For instance, Rondon et al. [22] note that serious games should be understood as a supportive tool of the contents learned in a lecture-based environment, not a means of replacing the lectures. Bellotti et al. [23] points out that the combination between entertainment and instructional purposes is not immediate, and must not be taken for granted. Integration of both must be designed carefully, avoiding situations where the game itself distracts the student from the learning goals. The learning process within the serious game requires a strong emphasis on guidance to the student. Otherwise, the serious game becomes less effective and may even lead to incomplete or disorganized knowledge. A “scaffolding” approach is needed to gradually build knowledge. It is important to avoid overloading the brain’s working memory, as saturation of short-term memory is known to inhibit learning. In addition, some students might feel anxiety when working in a computer-based environment [24]. However, this issue is becoming less likely within the digital natives that are already used to online learning environments. In fact, educators might find themselves more reluctant to implement serious games than students to use them, because of the generational gap. In either case, time is required by students and instructors to become familiar with the technology. The difficulty of the assessment of the effectiveness of serious games and the estimation of the correlation between game progression and curricular achievements may slow down the embracement of these tools for educational purposes. In that regard, the collaborative action of instructors and game designers during the phases of design and implementation is always recommended. Furthermore, the validation of the game, and refining if necessary, should be addressed based on the observed learning outcomes [25].

5 SIMULATION AND SERIOUS GAMES IN STEM AND CIVIL ENGINEERING

The multiple benefits of the use of simulation tools have been addressed in the literature. Some authors highlight the fact that the use of simulations for teaching and learning is becoming increasingly popular [26]. The value of simulation as supportive of the enhancement in learning that can occur has also been extensively discussed [27]. das Dores Cardoso [28] employ discrete-event simulation as a learning methodology in a course on automatic control systems. According to their tests, the use of such an environment allows students to gain experience in a variety of realistic scenarios. Curland and Fawcett [29] examined the problems with numerical skills applied in operations management and finance. They indicated that business simulations can be of value in overcoming fear of the use of numbers. In Balci et al. [30], the authors discuss the difficulties of teaching modeling and simulation courses in online learning environments, and provide some guidelines on how to develop an online course in this area. All in all, simulation is becoming a frequent pedagogical tool in many STEM courses, both in face-to-face as well as in online environments [31].

Regarding the specific fields of STEM and Civil Engineering, serious games allow the interaction with virtual environments that provide students with the interactive, digital, and
multimedia skill sets required at the workspace. Usually, these skills cannot be learned by the classical lecture-based approach. In Cleophas et al. [32], the authors propose a framework for designing serious games in the area of revenue management. The framework makes use of simulation techniques to evaluate different revenue management strategies. As the authors point out, “simulation systems are well-suited to complement tutoring by allowing players to directly experience the effects of uncertain demand and to interact with realistic representations of complex revenue management systems without the risk and cost associated to real-world experiments.” According to Ritterfeld [33], serious games is an important field of scholarship and practices focusing on the use of digital gaming platforms and technologies for purposes beyond pure entertainment. Examples of serious games actually being used, Schäfer et al. [34] show a collaborative-competitive serious game for learning mathematical logic in Computer Science at Aachen University (Germany). Rozkhova [35] uses a serious game for learning first-year Vector Algebra and Analytic Geometry, at the Elite Technical Education department of the National Research Tomsk Polytechnic University. Assessment can also be included in games. Students usually prefer questions that are included in games instead of traditional questions on paper. There are also interesting examples of serious games applied to the Civil Engineering field. For instance, the use of specific modules of the Sparksville 25 game program, which allow the operative learning of applications such as the management of natural resources and the control of energy systems [18]. Online games on virtual truss bridge have been also applied. The aim is to learn and practise the engineering mechanics, such as the estimation of the angles and spans of the bridge segments [36]. In most of the cases, students using this serious games obtained better grades than those who did not use them.

6 CONCLUSIONS AND FUTURE WORK

It is expected that graduate Civil Engineers are able to conceptualise engineering models based on a wide range of fundamentals on engineering, physics, and mathematics. Additionally, they should be able to identify the most appropriate techniques and tools, when facing the present complex engineering problems, with awareness of the available resources and existing limitations. These specific skills are sometimes barely acquired by the passive learning process provided in a lecture-based environment. For that reason, traditionally site training and secondments in engineering companies have been considered as an important part of the educational program. In that context, the learning simulation tools, that is, educational simulation and serious games, provide the students with a more holistic learning experience, allowing them to learn from mistakes and failures in a safe lab environment.

These learning simulation tools offer a number of clear advantages over traditional learning experiences, especially when properly combined with an online-learning environment in which students (even from different universities and countries) can interact among them as well as with instructors and industrial experts. Thus, simulation and serious games open new possibilities yet to be fully explored not only in Civil Engineering but also in the broader area of Science, Technology, Engineering, and Mathematics.

In future works, we expect to be able to extend this paper in different ways: (i) by
discussing how the integration of learning simulation tools can be effectively and efficiently integrated with online learning environments; (ii) by completing a more exhaustive literature review on both successful and unsuccessful case studies regarding the implementation of these tools in real-life higher education; and (iii) by deploying our own case studies in different universities and measuring the effect of the introduction of these educational resources in different STEM-related degrees.

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BUILDING FREEFORM: A WORKSHOP EXPERIMENT FROM DESIGN TO FABRICATION

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Key words: Workshop, structural design, Design/build.

Abstract. In the following of an already old tradition of design/build workshops in architecture, the works presented here illustrate an attempt of introducing design/build teaching experiments in structural engineering education. This one-week experiment was conducted yearly during the last nine years at the Ecole des Ponts ParisTech, France. The workshop, called “Building free-form”, is organised by founding members of the thin[k]shell project, an academic initiative for mixing advanced research, teaching and practical realisations with industrial partners. This project will be first detailed, because it is essential to the framework and objectives of the workshop. Then the evolution throughout the years of the pedagogy and of the supporting objects (first textile structures, then elastic gridshells) will be detailed. Finally, last year experiment centred on the use of robotic fabrication and its impact on the whole design process will be presented. Main aspects of workshop programs, teaching material and financial issues will be given for each type of structures, as well as some feedback on the various editions.

1 THE THIN[K]SHELL PROJECT

In the following of an already old tradition of design/build workshops in architecture (see for example the experiments of M. Vrontissi [1] in Volos Greece, those of J. Ramon in Talca Chile [2], M. Kawaguchi in Tokyo-Japan [3]), we present here feedback on an attempt of introducing design/build teaching experiments in structural engineering education at the Ecole des Ponts. We focus on a one-week workshop called “Building freeform”, held yearly during the last nine years.

This workshop is a typical illustration of initiatives held in the framework of the thin[k]shell project at the Ecole des Ponts. Or, to be more accurate, the educational principles of the thin[k]shell project are a direct emanation of the experience gained in the teaching of the “building freeform” workshop. The spectrum of the project is however wider and extends to expeditions in the field of structural engineering beyond education. It promotes an integrated vision of research, education and fabrication which embraces the whole design process from the very first sketches to the construction of full scale buildings, from material/assembly testing to the development of original numerical tools. The team (about 15 persons) gathered around the development of the first prototypes of elastic gridshells in composite materials [4].
Nowadays, it combines expertise in the field of architecture, material science, structural engineering, historical buildings, architectural geometry and numerical fabrication.

The thin[k]shell project was initiated by members of the laboratoire Navier, but is now developing with fruitful collaborations with partner laboratories (the Geometry and Curvature group of LAMA, the IMAGINE group from Laboratoire d’Informatique Gaspard Monge (LIGM), or the laboratoire Géométrie et Structures pour l’Architecture (GSA) from the School of Architecture Paris-Malaquais) and many industrial partners.

This integrated vision of research, education and fabrication is promoted throughout the courses taught by the members of the project at the Ecole des Ponts (especially the “Structural design” and “Advanced structural design” courses, the “Design by Data” postgraduate program, and the workshops “Crossing my bridge”, “Fold me a shelter” or “Building an arch”, see figure 1) and in other higher education programs in the schools of Architecture of Grenoble, Paris-Malaquais, Marne-la-vallée.

![Figure 1: Design built workshop at Ecole des Ponts: crossing my bridge (left) and fold me a shelter (right), photo by courtesy C.Douthe (left) and A. Lebee (right)](image)

About eight PhD candidates are currently concerned by the design of structures and provide regularly small scale projects related to their research to master students for exploration, experimentation or numerical development. This is beneficial to the candidates who can hence test ideas, process, tools or methodologies before they might be introduced in a larger scale workshop or prototype (this, of course, helps also improving the academic productivity of the team and academic publications). This is also beneficial to the master students who get initiated with up-to-date research, digital fabrication processes or metrological advances and who may then apply for PhD funding.

The concepts with the highest potential get then further developed and come out with full scale realizations associating clients and/or industrial partners. The 3 days’ temporary pavilion of the Solidays festival 2011 (see figure 2 left) was led by a group of 8 final year students (a two-semesters adventure with “officially” a half day per week dedicated to the project) and the design office T/E/S/S [4]. The temporary cathedral of Créteil had to hold for two years and therefore required deeper investigation and was thus designed by T/E/S/S and the laboratoire Navier [5]. Last realization is an exploration of the possibilities offered by developable surfaces for the construction of freeform without formwork or scaffolding (see figure 2 right).
2 THE “BUILDING FREEFORM” WORKSHOP: PAST RECORDS

2.1 Pedagogical objectives

The “Building freeform” workshop was thus initiated by a group of academics working in the field of structural design and pretty much influenced by the thoughts of the structural morphology group of the International Association of Shell and Spatial Structures, especially by R. Motro [6]. In this founder paper, R. Motro explains that structural design is at the frontier of: form (geometry), forces (static), structure (topology and relations between elements), material (mechanical behaviour) and technology (fabrication process). The general idea of the workshop was thus to get the students initiated with the constant compromise that exists in structural design between those five fields and how much it has become necessary to embrace those five fields to succeed in the design of contemporary freeform architecture.

Indeed, this branch of architecture which denotes fascinating doubly curved structures and envelop, seems to be within easy reach thanks to contemporary digital fabrication tools. However, they remain enigmatic and hard to comprehend by the designers, who are often extremely dependent on a technological process in comparison with “classic” buildings where they can really explore various design alternatives. The workshop organization has evolved throughout the years, but it always started with an overview of the possibilities offered by doubly curved structures, both from technological and conceptual perspectives. The major part of the week being then devoted to the design and fabrication of medium to full scale pavilions, with various typologies: tensile structures, then elastic gridshells and finally rigid gridshells.

2.2 The tensile structure years

During the first years, the workshop focused hence on the construction of a tensile pavilion with a 10 m² to 30 m² covered surface (see figure 3). Tensile structures were chosen for their didactic aspect because they are very hierarchic structures that allow to address every steps of the design process and every fields of structural design, as well as their interactions:

1. Definition of a form in equilibrium under self-stress (form-force interaction),
2. Definition of the supporting members (force-structure interaction),
3. Dimensioning of members (introduction of material parameters),
4. Definition of the cutting pattern (form-material-technology interaction),
5. Design of details (forces-material-technology interaction),

Especially, tensile structures offer the possibility to address all these issues at real scale, to work with the real materials, with realistic details (although knocked up) and with structures larger than human. The physical experiment is thus not biased by any scaling and students encounter all problems linked with structural design from design to fabrication, including control of geometry, management of tolerances and the necessity of tuning.

Practically, the week was organized as shown in table 1. After some introductory conferences, the students start working in groups of three and to prepare pavilion proposals based on physical models and drawings on scale. They defend then their proposal and make critics on the other proposals in order to choose collegially the prize-winners that will be built at full scale. This collective evaluation of proposals was very effective and forced them to stand back to assess the feasibility of the structures that they will all have to build together, based on what they have just learnt about the design of free-form structures. By orienting some questions and explaining clearly the learning objectives of the workshop, democracy always brought an acceptable solution, except once where authority was necessary to rebut a proposal which would have directed all the design effort toward a post design instead of toward tensile architecture… Then, in the second part of the week, the students work all together on one or two structures and experience the necessity for tasks separation, coordination and interoperability of tools or procedures, which is really key in free-form architecture.

The workshop started with 15 students in 2009 and ended with 32 in 2015, all final year students (one third from architecture school, the rest from the Civil Engineering department). Supports included experimental facilities, one full time academic per 10 students and about 1000 € consumable: the PVC textile was kindly offered by Serge Ferrari textile. The form-finding and cutting pattern were done with dedicated codes, for Sketch-up and Autocad respectively, provided by the teaching staff.
### Table 1: Typical organisation of the one-week workshop during the first years

<table>
<thead>
<tr>
<th>Day</th>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mon.</td>
<td>8h30–10h30</td>
<td>Overview of double curved structures (conf. by C. Douthe).</td>
</tr>
<tr>
<td></td>
<td>11h00–12h</td>
<td>Form-finding (conf. by C. Douthe).</td>
</tr>
<tr>
<td></td>
<td>14h–16h</td>
<td>Design of textile structures, technology, details and standards… (conf. by M. Bagnéris)</td>
</tr>
<tr>
<td>Wed.</td>
<td>8h30–10h30</td>
<td>Design of doubly curved shapes (conf. by M. Bagnéris).</td>
</tr>
<tr>
<td></td>
<td>10h30–12h</td>
<td>Team work by group of 3 students.</td>
</tr>
<tr>
<td></td>
<td>16h–18h</td>
<td>Presentation of the project and team work by group of 3 students.</td>
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<tr>
<td></td>
<td>18h</td>
<td>Proposal outlines for the pavilion competition (lycra models and drawing on scale 1/20)</td>
</tr>
<tr>
<td>Wed.</td>
<td>8h30–10h30</td>
<td>Collective evaluation of proposals by students and staff.</td>
</tr>
<tr>
<td></td>
<td>10h30–12h</td>
<td>Team work by group of 10 students: organisation and separation of tasks (geometry, details, dimensioning, construction process)</td>
</tr>
<tr>
<td></td>
<td>13h30–18h30</td>
<td>Experiments and fabrication of prototype details, Definition of the cutting pattern and full scale printing of laise, setting up of anchorage, etc.</td>
</tr>
<tr>
<td></td>
<td>13h30–18h</td>
<td>Fabrication</td>
</tr>
<tr>
<td>Thurs.</td>
<td>8h30–12h</td>
<td>Finalisation of shop drawing: Definition of the cutting pattern and full scale printing of laise</td>
</tr>
<tr>
<td>Fri.</td>
<td>8h30–12h</td>
<td>Assembly</td>
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<tr>
<td></td>
<td>13h–14h</td>
<td>Tuning of the structure</td>
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<tr>
<td></td>
<td>14h–15h</td>
<td>Collective evaluation of the built object and feedback on the workshop</td>
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<tr>
<td></td>
<td>15h–17h</td>
<td>Tidying, gathering of production (photo, sketches, prototypes, shop drawing, reports of team work)</td>
</tr>
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</table>

### 2.3 Extension to elastic gridshells

Considering the success of the tensile structures formula, the authors attempted to apply it to the realization of an elastic gridshell, a structural typology closely linked with their research expertise [4-5]. The goal was to investigate ways of direct transmission from laboratory to the next generation of engineers. For financial reasons, the experimentations started at reduced scale: first 2x2 m grids made of 5 mm circular GFRP profiles, then 4x4 m made of 20 mm bamboo stems and finally a 6x8 m grid made of 10 mm circular GFRP profiles (thanks to the offer of Solution Composites for the composite materials). The themes addressed were very close to those of the textile pavilion:

1. Form-finding, mapping of the grid on the desired surface,
2. Definition of supports (free edge, opening, anchorage…),
3. Sizing of members and structural analysis,
4. Construction process.

However, concerning detailing, especially grid connections, the main choices had to be made
before the workshop, so that the consumables could be supplied on time. In comparison with
the tensile pavilion, an essential part of structural design could not be investigated by the
students. This is why the size of the prototype was progressively increased, trying to find a size
at which one will shift from mock-up to realistic detailing, with little success (the small size of
the grid members did not allow for knocked up details and most of the time pluming pipe
connectors were used) until 2016. It is worth mentioning here the “SheltAir pavilion” built by
G. Quinn et al in Berlin 2018 where very convincing details with similar circular composite
profiles were designed and will certainly inspire future editions of the workshops.

![Image](photo by courtesy C. Douthe left and S. Lenne right)

**Figure 4**: 2015 edition with mock-up like grid (left) and 2016 edition with its full scale wooden grid (right)

2016 represents indeed a turning year in the workshop organization and pedagogy. Guided
by this desire of working at real scale, with real material like for the tensile pavilion, we took
the chance to work with two sponsors: Würth France who supplied all the hardware and the
Association Filière bois Haut Languedoc Sud Massif Central who provided the premium
quality wood for the structure. Thanks to this financial support, it was possible to get over the
gridshell size limit and to build a representative structure (50 m² on the ground), with realistic
cross-sections (12x48mm), realistic details and a realistic construction process. This size
change was not harmless to the pedagogy of the workshop:

- materials and consumable still had to be supplied in advanced,
- industrial sponsors had expectations on the quality of the results,
- working at such scale implies additional workload for fabrication and assembling.

Therefore, we decided to reorganize the week and to tell the students a story: the school,
owner of the yard, wanted a small pavilion for demonstrating the lab know-how on elastic
gridshells, the academic staff had conducted concept design studies and they, the students, had
now been selected for conducting the developed and technical designs as well as the fabrication
of the pavilion. After the introductory conferences, the results of the preliminary studies that
had been conducted during the summer were presented and a notebook with preliminary
sketches of all the details was given them. The competition phase of previous editions of the
workshop was hence skipped, depriving them of the trial and error experimental way of learning
and the associated self-criticism and step back. However, doing so, they were allowed to go
deeper into the design and their understanding of the structure and all aspects linked with
construction methods. On Tuesday, the 30 students were thus separated into five sub-groups
(each supervised by an academic) which had all the charge of some aspect of the final design and had to experiment fabrication to be able then to systematize it:
- form and structure (definition of the final form and structural analysis)
- bracing (distribution over the structure and design of the tensioning system),
- foundation (design of anchorage, including slab characterization and setting-up),
- wooden grid (material characterization, framing, connection verification),
- covering (design and fabrication of covering casket system in PEHD)

Then on Wednesday, a general coordination meeting was organized before producing shop drawings and launching fabrication. Thursday was dedicated to the assembling of the grid, then Friday to the forming, bracing and covering.

To face the production requirements, it was also decided to introduce into the workshop some initiation to digital fabrication: robotized milling for the grid (cutting at length and opening of slotted holes), 3-axes milling cutter for the covering, laser cutter for the tensioning system of the bracing. The goal was not to learn them to master those tools but to understand how they can be used for the standard production of unique pieces and how to calibrate the necessary tolerances and to verify the accuracy of the produced pieces. However, due to the unforeseen high humidity of wood, the pieces got stacked in the conveyer of the milling robot and part of the fabrication at to be done last minute with hand tools: a good introduction to the necessity of redundancy in systems!

The 2016 edition was a real success, enthusiastic for all: students, organizers, industrial partners and administration of the school and laboratory who had gained a full scale prototype illustrating the most recent works on elastic gridshells covered with planar quads [7]. The students enjoyed being part of a large team work, even if the initial design was not their own. Preparation time was however about four times higher (around 6 months in cumulative) and therefore required the mobilization of additional persons for the supervision. This turn out to be very federative for the thin[k]shell group, also very time-consuming.

3 THE 2017 EDITION

3.1 Scientific context and relation with industrial partners

Strengthened by the 2016 experience, we decided to pursue the idea that the workshop could be a way to link closely research and education: while the students learn about structural design,
they can also take part in the thoughts of the laboratory on the possibilities offered by digital fabrication to the design of curved envelopes. Indeed, in the last three years, considerable effort has been made by the members of the thin[k]shell group to re-appropriate geometry and to integrate the most recent developments of the new born field called “architectural geometry” into practical tools for designers. The close collaboration with Prof. L. Hauswirth from the UPEM helped a lot and has still extremely promising prospects, including the organization of workshops for the mathematic students around applications to structural engineering. In parallel to these theoretical developments, the Ecole des Ponts ParisTech invested in two robotic cells for building a Co-Innovation Lab around digital fabrication applied to civil engineering. And hence came naturally the idea that the workshop should illustrate the knowledge of the members on advanced discrete geometry, structural design and robotic fabrication.

The 2017 pavilion is thus based on an original structural system, called shell-nexorade hybrid, which derives from a surface initially meshed by planar quads which is transformed so that members are only connected by pairs [8] (see figure 6). The pavilion hence tackles main fabrication constraints of free form architecture: covering with quadrilateral panels, straight members, simple T-joints for connection. To achieve this, an intricate game of eccentricities between members (beam-beam and beam-panel) is necessary and realised by the machining by collaborative 6-axes robots of the extremities and the top surfaces of the members.

Industrial partners are really key to the project and were associated upstream of the design. As a matter in fact, the authors believe that successful realisations of freeform structures require a collaboration of all actors of the construction process: owner, designer and contractor, from the beginning. All roles are here endorsed by the academic staff of the week, especially that of the contractor which relies on a tailor made production process, but precisely this is where industrial partners were indispensable:

- Simonin SAS, supplied the wood and served as consultant for wood machining,
- HAL Robotics, developed the software linking geometry to machine control command,
- ABB, set the robotic cell, helped calibrating the robots, guarantying process accuracy,
- Würth France, supplied hardware and served as consultant for connection design.

All partners attended the workshop and could explain their contribution to the pavilion design and more generally their role into the design process of complex structures. For example, for connections, a screw that goes beyond Eurocode 5 was used because it allows to transmit normal forces along the grain of the wooden member. It was hence an opportunity to introduce in the teaching the procedure of European Technical Agreement and the method for bringing innovation in structural engineering practice.
3.2 Pedagogical objectives

Pedagogically, the principle remains the same: the academic staff (2 professors, 5 PhD students and 3 technicians) does the concept and development designs while the students are in charge of the technical design and fabrication/assembly of the pavilion. The week starts with one day conferences about double curved structures, digital fabrication and the concept design of the pavilion. On Tuesday and Wednesday, the students separate in sub-groups:

- geometry and structural analysis (interaction between form and forces)
- connection (experimental characterization of material and connection capacity, verification of each connection),
- construction process and geometric control (3d photogrammetric reconstruction, plumblines as well as triangulation with double decametres) design of anchorage plates, including concrete slab characterization and setting-up),
- robotized manufacturing applied to wood machining (analysis of the production process and fabrication of the last members and panels).

Each group is co-supervised by an academic and an external partner, which again allows for experience sharing between students, researchers and private industries. Thursday and Friday are then devoted to the assembly of the pavilion.

Contrary to the 2016 edition, no notebook with connection drawings is given to the students, because the 2017 workflow is fully integrated numerically into the 3d modelling environment of Rhinoceros/grasshopper. No shop drawings are produced or printed: the geometry being completely three dimensional, it is directly transformed into machine commands for the robots who mill the beams and bore inclined predrilling holes for screws (see figure 7). This disappearing of drawing is not obvious, and we insisted all the week on the necessity to introduce geometric control procedure and on the difficulty linked with the interoperability of all the numerical developments, which is another key issue for the successful realization of freeform architecture.

Figure 7: [right] Workflow in the robotic cell: fixed feeder (1), stationary circular saw (2), milling (3-7), fixed wood rooter (8). [left] First row: tool collision detection and second row: toolpath and robot simulation.

It must be noticed here that the ambition of building in one week a pavilion that should last for one year and illustrate actual research developments goes beyond a one-week workshop. Time spent for the pavilion was evaluated to approximately 18 months of a full time person, without counting the time of the 32 students during the week. This is a fantastic adventure that truly united the research group and helped progressing technically all the involved PhD
students. Students were immersed in an enthusiastic framework and never complained being only a wheel of a complex organization. As a matter in fact, one month after the completion of the workshop, the school celebrated the 20 years of its settlement on the campus and the students of the workshop were the only ones who had the chance to present their work in pecha-kucha plenary session, which they have done brilliantly.

4 CONCLUSIONS

We presented here a feedback on a design/build workshop lead over the last nine years. This workshop is about structural design with application to doubly curved structures. It aims at experimenting the necessary compromise between form, forces, structure, material and technology in the design process. We insisted on the interest of working at full scale, with the real material (or at least realistic material) for the relevance of the work on detailing and construction process. We explored various situation scenarios to make the students familiar with the various phases from design to fabrication.

Figure 7: Photo of participants (staff, partners on side, students in the middle) in front of the 2017 pavilion.

REFERENCES

ELECTRONIC EDUCATIONAL RESOURCES AS INNOVATIVE TECHNOLOGIES OF ENGINEERING EDUCATION

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Key words: Education, Electronic resources, Resource structure, Thermal protection.

Abstract. The development of electronic educational resources is an important direction in the education system. This article details the sequence of electronic educational resources creation using an example of the discipline "Building Thermophysics" included in the module "Fundamentals of building microclimate".

The project development begins with the developing of an application for the electronic educational resources, which includes the following sections: General information and goals for the electronic educational resources creation, terms of electronic educational resources creation, and the characteristics of electronic educational resources".

The section of general information and goals for the electronic educational resources creation includes information about the head and members of the creative team, a resource type and working language, a target group, the mode of study and expected educational outcomes.

Terms of electronic educational resources creation sector comprises information about materials availability and the ability to perform and implement the project at stipulated time.

In the section of characteristics of electronic educational resources contains the concept of the electronic educational resource. The authors should provide a list of electronic materials for the development of electronic educational resource such as teaching aids, guidelines for design and calculation, the number of slides, illustrations and examples of problem solving.

On agreeing and introducing the needed changes and corrections, the electronic educational resource is integrated into a single shell, reviewed by an expert commission and uploaded on the university’s website. The learning outcomes include the following skills: to collect, process, analyze information for drafting of technical specifications on heat and gas supply and ventilation system design; to develop project and working documentation; to perform calculations of elements and equipment of heat and gas supply and ventilation systems.
1 INTRODUCTION

Nowadays, the information and telecommunication technologies intensively develop and widely apply not only in science, technology, but also in education. Today we are faced with a rapid transition from physical reality to virtual one. Therefore the task of the university is to teach students to live at the level of the most progressive ideas, to master the ways of continuous acquisition of new knowledge and the ability to learn independently; master the skills of working with any information, with heterogeneous, contradictory data, form the skills of an independent type of thinking [1].

Modern universities need a new educational process organization, it is necessary to transform the role and functions of the department and the teacher, change the ways of creating and updating the educational and methodological complex for each discipline. Electronic technologies are a means of creating the most adequate conditions for the realization of the student and teacher abilities in the educational process, individualizing and improving the learning process [2,3].

In 2011 Russia adopted the bologna process for the creation of a common space in the field of higher education in Europe [4]. The development of new teaching technologies using electronic educational resources (EER) is important for the successful implementation of new educational programs. The modern electronic educational resource is not simply static materials. EER today becomes the environment for the interaction of its users where new knowledge concentrates and born.

2 THE DEVELOPMENT OF ELECTRONIC EDUCATIONAL RESOURSE

The center for new educational technologies (CNTS) of the Ural federal university (UrFU) creates electronic products, for example the creation of the EER for the discipline of building which was included in the module of fundamentals of microclimate of buildings. This creation marks a successful cooperation between the department of heat and gas Supply and ventilation of the institute of civil engineering and architecture, UrFU and CNTS [5].

The course "Building Thermophysics" is designed to provide knowledge about the thermal, humidity and air conditions of the building that is necessary for the rational designing of external enclosing structures of buildings. New thermal insulation, facing and structural materials with different physical properties are used for the building construction. In addition, the discipline "Building Thermophysics" gives information about physical principles and methods of calculating the processes existing in external enclosing structures of buildings [6].

The creation of the resource begins with the drawing up an application, which includes the following sections: "General information and goals for the EER creation", "Terms of EER development", "Characteristics of EER".

The section of general information and goals for the EER creations includes the members and the head of the creative team, the resource type and language, and the target group (bachelors, masters, specialty, and supplementary education programs). In addition, the mode of study, the profile and name of the module and discipline are also indicated. The expected educational outcomes should also equally be presented. The aims for the creation of EER for the discipline of building thermophysics are presented as thus:
- To provide the educational process with main and additional methodic materials in electronic form;
- To motivate, involve in the creative process and intensification of student activities;
- To improve the materials renewability and modernity;
- To intensify the interaction between participants of educational process through the Internet;
- To enhance team work;
- To develop communication with employers and to participate in technological processes;
- To develop educational content mobility (availability at any time, and on any device);
- To improve information visibility;
- To solve professionally-oriented tasks.

The "Terms of EER development" section demonstrates the material availability and the ability to perform and implement the project on time. The status of the project is proposed to be evaluated according to the following options:
- The resource is planned to be developed;
- The author's materials are ready;
- The resource is ready for expert evaluation.

During development of EER the authors materials such as methodic and educational editions were presented in [6, 7] and recourse was ready for expert evaluation.

The section "Characteristics of EER" contains the concept of EER. The concept for the discipline "Building Thermophysics" is presented as an example:

The electronic educational course on the discipline "Building Thermophysics" has a modular structure and includes:
1) Lecture demonstrations (72 slides, 100 illustrations);
2) Methodical recommendations on the calculation of thermal protection and thermal conditions of buildings and structures.
3) Questions for exam, term glossary, examples of problem solving

The main tasks are to increase the effectiveness of educational process; provide visible demonstration materials; possibility of usage modern regulatory documents and recommendations on energy saving, including these for the student’s independent work.

The structure of EER is presented in the Table 1.

<table>
<thead>
<tr>
<th>Section</th>
<th>Content</th>
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</table>
| 1. Thermal protection problems | Aim: to be able to analyze the factors affecting the heat protection of buildings.  
Information material (4 illustrations):  
- basic terms  
- schemes of internal and external influences (fig. 1)  
- schemes for developing the building thermal regime (fig. 2)  
- List of literature for the study of discipline. |
| 2. Stationary heat transfer. Types of heat transfer | Aim: to be able to draw conclusions of the basic design dependencies for the basic methods of heat transfer.  
Information material (3 illustrations):  
- basic terms |
| 3. Heat transfer through external enclosing structures | Aim: to be able to analyze the ways of heat transfer from the internal air to the outside, to determine heat flows through external enclosing structures. Information material (5 illustrations):  
- basic terms  
- resistance to heat transfer  
- thermal resistance of heterogeneous structures  
- thermal resistance of air interlayers  
- the basic design dependencies.  
Practice: to calculate the heat flux through enclosing structures. |
|-------------------------------------------------|-------------------------------------------------------------------------------------------------|
| 4. Normalization of heat protection               | Aim: to be able to calculate the resistance to the heat transfer of external enclosing structures based on regulatory, economic requirements and condition of energy saving. Information material (6 illustrations):  
- basic terms (2 illustrations)  
- the scheme of human heat exchange with the environment  
- normative materials (2 illustrations)  
- the basic design dependencies.  
Practice: to calculate the resistance to heat transfer based on sanitary and hygienic requirements, economic requirements and energy saving conditions; to determine the insulation layer thickness. |
| 5. Nonstationary heat transfer. Heat absorption. | Aim: to be able to analyze the factors determining regimes of non-stationary heat transfer. Information material (4 illustrations):  
- basic terms  
- temperature change along the enclosing structure thickness  
- thermal inertia  
- the main design dependencies.  
Practice: to calculate the heat absorption and evaluate the heat resistance of the room. |
| 6. Humidity conditions                            | Aim: to be able to assess the humidity conditions influence on the burning characteristics of enclosing structures. Information material (4 illustrations):  
- the basic design dependencies  
- phase transition diagram  
- humidity conditions in the thickness of enclosing structures  
- technique of calculation.  
Practice: to calculate the temperatures in the thickness of enclosing structures, to plot the partial pressures, to analyze the room humidity conditions. |
7. Air permeability

<table>
<thead>
<tr>
<th>Aim: to be able to calculate the enclosing structures for air permeability.</th>
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<tbody>
<tr>
<td>Information material (5 illustrations):</td>
</tr>
<tr>
<td>- scheme for thermal pressure determining</td>
</tr>
<tr>
<td>- scheme of flow around the building</td>
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<tr>
<td>- technique of calculation air permeability</td>
</tr>
<tr>
<td>- the basic design dependencies</td>
</tr>
<tr>
<td>- technique of calculation of enclosing structures for infiltration.</td>
</tr>
<tr>
<td>Practice: to calculate the external enclosing structures resistance to air permeability, to determine the heat consumption for outside air heating.</td>
</tr>
</tbody>
</table>

The educational outcomes include the following skills: to collect, process and analyze information to draft technical specifications for heat and gas supply and ventilation system designing; to develop project and working documentation; to perform thermo-technical calculation of external enclosing structures of buildings, analyzing thermal, humidity and air conditions.

In addition, a course project plan and practical exercises, including the individual task selection, the calculation of thermal protection, heat, humidity and air conditions and the typical tasks solution according to the discipline sections was created.

Thus, a student receives a possibility to obtain independently all necessary information via EER. The educational outcomes are achieved with the help of:
- availability of theoretical material, visibility of demonstration materials;
- availability of normative and reference information used in the design process (all Union State Standards, questions for exam preparation, glossary of terms);
- simplicity of searching information with the help of references;
- availability of lecture demonstrations, both in the University and during the independent work of students;
- possibilities of discussion by means of network interaction and the choice of a constructive solution.

After agreeing and introducing changes and corrections, the EER was integrated into a single shell, downloaded to the website and adopted by the expert commission of the University.

3 CONCLUSION

Electronic educational resources contribute to more effectively organization of the educational process and creating new directions in professional development, distance and additional education.

The electronic educational resource is constantly being updated, not only by the authors, but also in the process of students' work. The resource is based on cloud services; it is integrated with social networks, services for collaboration and users communication. Any activity of the trainee within the framework of the resource can be fixed as a result of training, the storage of which is an obligatory function of the systems providing the learning process.

The electronic multimedia educational resource "Building Thermophysics" has received approval in distance education, specialty construction, and in the professional
development specialty termed “Energy Saving”. The EER "Building Thermophysics" user group is up to 100 people per year.

Figure 1. Scheme of internal and external influences

Figure 2. Scheme for developing the building thermal regime
REFERENCES

SEISMOCODE: A LIFELONG E-LEARNING PLATFORM TO HELP CIVIL ENGINEERS KEEP PACE WITH BUILDING CODES EVOLUTION

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Key words: E-Learning, Building Design, Seismic Code, Lifelong Learning

Abstract. The harmonization of the Romanian legal framework with its European counterpart, carried out within the preparation of the 2007 accession of the country to the European Union, included, among others, the entire set of national building codes and regulations. This radical change, performed in a rather short interval, had a strong impact on the capacity of civil engineering professionals to assimilate the new norms. The national code for the seismic design of buildings, P100, was completely rewritten and restructured. Its present edition follows closely the structure and content of Eurocode 8, Part I, implementing at the same time, via the Nationally Determined Parameters, results from recent earthquake engineering research performed in Romania. Even though various initiatives were taken for the assimilation of this new code, many of its provisions were still regarded by structural engineers as difficult to understand. This represented a critical situation for a seismic country like Romania. The development of SEISMOCODE, an online lifelong learning platform facilitating the assimilation of the new provisions, came out as an efficient solution. The platform, focused on the seismic design of concrete structures, is built around a body of knowledge that provides basic information on the most relevant parts of the code, as well as on related codes and standards. The platform also includes a Wiki system, several interactive e-learning modules for (self-)evaluation, a multimedia collection and a user’s forum. The platform is created in support to lifelong learning programs in civil engineering, as well as an auxiliary tool for graduate and postgraduate university courses.
1 INTRODUCTION

In preparation to the 2007 accession of Romania to the EU, a thorough and extensive process of harmonization of the national legal framework with its European counterpart was carried out. The process included, among others, the entire set of Romanian building codes and regulations, which were revised, prior to the accession, over the span of more than one decade. In addition, a large number of European standards, among which the Eurocodes, were adopted as national standards. This radical change, performed in a relatively short interval, had a strong impact on the capacity of the civil engineering community to assimilate the new norms and to implement them in everyday practice. The case of the national code for the seismic design of buildings, P100, is illustrative. Issued in 2006 [1] and revised in 2013 [2], the code underwent substantial changes, being completely rewritten and restructured and following closely, in its new form, the structure and content of Eurocode 8, Part I [3]. The code also implemented results from earthquake engineering research performed in Romania in recent years. Even though various initiatives were taken for the assimilation of this new code, many of its provisions were still regarded by structural engineers as difficult to understand. This represented a critical situation for a seismic country like Romania. The development of SEISMOCODE [4], an online lifelong learning system facilitating the assimilation of the new provisions, came out as an efficient solution.

2 PLATFORM STRUCTURE AND IMPLEMENTATION

The SEISMOCODE platform, created in Romania within a recent nationally-funded R&D project, is built around a body of knowledge providing basic information on the seismic design of concrete structures according to the new norms. The platform also includes a Wiki system, several interactive e-learning modules for (self-)evaluation, a multimedia collection and a user forum (Fig. 1).

Figure 1: Platform components
SEISMOCODE is implemented on the Moodle platform [5], a rich-featured open-source learning management system, largely used worldwide to create online educational environments. Detailed presentations of Moodle features and of their use in higher education can be found in [6] and [7].

2.1 The Body of Knowledge

The central part of SEISMOCODE – the Body of Knowledge (BK) – is structured according to the logical steps of building design. This type of organization was considered more practical for platform users than the one that would strictly follow the code structure. Implemented by using the Courses feature of Moodle, the BK contains 14 sections (courses), as follows (Fig. 2):

1. Main steps of the seismic design of reinforced concrete structures
2. Establishment of performance demands for building structures subjected to seismic loads
3. Selection of the structural system and establishment of the structural configuration
4. Selection of the energy dissipation mechanism and of the ductility level
5. Assessment of non-seismic loads and of masses
6. Assessment of seismic design loads
7. Pre-dimensioning of structural members
8. Structural modelling and analysis
9. Dimensioning and verification of structural members and of the entire structure
10. Design of frame structures
11. Design of shear wall structures
12. Analysis and detailing of floor slabs as horizontal diaphragms
13. Dimensioning of the infrastructure
14. Nonlinear static analysis and nonlinear dynamic analysis

Besides P100 code provisions, the BK also includes references to related norms ([8], [9] etc.) and to commentaries concerning the background of these provisions and their practical use.

2.2 The Wiki System

The *Wiki System* (WS) is aimed to bring additional explanations to the topics dealt with in the Body of Knowledge (Fig. 3). The WS, implemented using the *Wiki* feature of the Moodle platform, provides a convenient way to clarify specific aspects without interrupting the basic presentation. In addition, glossaries are provided to specific sections of BK, in order to give short definitions of various notions mentioned in the course. The *Label* feature in Moodle is used as well, in order to create short highlighted notes in the text.

![Figure 3: A section of the Body of Knowledge, with a Wiki page and a glossary](image)

2.2 The Interactive E-Learning Modules

The *Interactive E-Learning Modules* (IELM) include various tools for learning assessment and self-assessment. These are implemented by using the *Questionnaire* and *Quiz* features of the Moodle platform, which allow configuring various types of questions and ways of answering them (Fig. 4). In addition, a COLLES survey [10] was implemented (Fig. 5).
Figure 4: Questionnaire on seismic loads assessment

Figure 5: COLLES preliminary survey to assess users’ opinions
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Ionuţ Damian, Andrei Papurcu and Cristian Ruşanu

The COLLES survey, part of the users’ feedback collection system, focuses on aspects as: relevance, reflection, interactivity, tutor support, peer support and reciprocal interpretation of communications [10]. This type of survey is applicable especially when the platform is used in blended learning environments.

2.3 The Multimedia Collection

The SEISMOCODE platform includes a collection of multimedia resources, consisting of a series of presentations focused on relevant topics of seismic design. These are recorded by the members of the project teams, being available either as embedded videos (Fig. 6) or as YouTube videos (Fig. 7). The videos are available in the corresponding sections of the Body of Knowledge and on the platform start page as well.

2.4 Other features

A professional discussion forum was also implemented, to allow interaction with users and to provide a more direct way to collect their opinions and potential suggestions concerning the future improvement of platform content and functionality.

The platform can be easily accessed from mobile devices, such as smartphones or tablets, by using the Moodle Mobile application.

More detailed descriptions of particular features and components of the SEISMOCODE platform can be found in [11]…[14].

![Figure 6](image-url): Multimedia resources available in the section “Assessment of seismic design loads”
3 CONCLUSIONS

The SEISMOCODE platform was developed in response to the need of facilitating the assimilation of the new European harmonized Romanian seismic code by practicing engineers. In the context of the country’s seismicity, the existence of a competent civil engineering community, capable to apply modern seismic design methods, is essential.

The platform was conceived mainly for use in lifelong learning programs, but can represent as well an auxiliary tool for graduate and postgraduate university courses.

ACKNOWLEDGEMENTS

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MAKING EASIER THE TEACHING - LEARNING PROCESS OF OPENSEES AND ITS USE IN PRACTICE AND RESEARCH
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Key words: OpenSees, StruBIM, BIM, Teaching, Learning, Practice.

Abstract. This article shows the links between teaching, research and practice by means of a calculation engine called OpenSees. OpenSees is a well-known framework to perform linear or non-linear analysis, developed at University of California, Berkeley. Its use is widespread all over the world and allows users to simulate efficiently the response of structural and geotechnical systems subjected to earthquakes and other hazards. Initially, OpenSees was difficult to learn because of the lack of user-friendly and guided environment (script input) and, for this reason, it was little used in practice and in research, despite it is a powerful tool. Cype S.A. integrated OpenSees as calculation engine in its new suite for analyzing and designing structures: StruBIM. This suite integrated OpenSees in a user-friendly interface, interactive view of the model, guided calculation process and post-processor of results after performing the analysis. The results of this integration are that it is much easier to teach and learn how to use OpenSees, its scope of application, its functionality and the resolution of educational practical cases with it. Bearing in mind the current requirements of the European society, a practical approach using a powerful and widespread tool valid for practical and research work is needed for learners’ studies. Besides, another result, which is related to the previous one, is that OpenSees is currently an attractive tool for civil engineers and architects to use in practice and to solve complex actual cases. Analogously, Cype is currently working on extending StruBIM to make use of all functionality of OpenSees to be used in research world. Therefore, the teaching - research - practice cycle is closed again, this time with a teaching-learning process so much easier to achieve and a practice and research part able to use the functionality and the high performance of OpenSees. This is fruit of the detecting that the former teaching - research - practice cycle had serious deficiencies.

1 INTRODUCTION
Software has become very important for engineering practice. The size of the engineering problems is enough to be almost indispensable the use of engineering software. For this reason, it is a key aspect that students become familiar with the philosophy behind the computer tools. It is necessary to remember that Spain took part, together with other member states, in the elaboration of the European educative reform regarding university that completely changed the organisation of the teaching plans, the curriculum and the teaching-learning approach. After
embracing all the required changes in the structure of the educative system, that were stated by the Bologna's plan [1], students’ title is a European one which is valid to work in all the state members since it is obtained in a country that is part of the European Higher Education Area. This possibility has brought about more chances for the learners but also a huge responsibility for the countries in the achievement of qualified engineers.

The students’ training needs to be eclectic in order to deal with the different skills that are valuable to become a good engineer. A more real-life direction and a pragmatist approach of teaching-learning process is important as the Council of Europe [2] stated in its educative recommendations. Bearing in mind all this information, university studies should provide learners with an actual practice and a real insight about their future jobs such as the use of engineering software.

In this context, OpenSees [3] is a powerful engineering software tool developed at University of California, Berkeley. It let users simulate efficiently the response of structural and geotechnical systems subjected to earthquakes and other hazards in a linear or non-linear way. Besides it is free to use in teaching and research purposes. However it is very hard for students to learn to use OpenSees because of the lack of user interface (script input) and guided environment. CYPE Company is trying to avoid this problem by integrating OpenSees as calculation engine in its new program to analyze structures: StruBIM Analysis [4].

StruBIM Analysis [4] forms part of StruBIM suite, which is a group of structural programs, each one related to one stage of structural design integrated in a BIM workflow. StruBIM Design is responsible of designing and checking columns, beams, slabs and walls. It imports the analytical model results from StruBIM Analysis [4] or from a file with a specific format. Besides, it is able to manage a local analytical model of each floor to design tendons, slabs and beams. It uses OpenSees as calculation engine. Analogously to StruBIM Design, Cype has created StruBIM Foundations to design foundation elements.

As a consequence of integrating OpenSees as a calculation engine of StruBIM Analysis [4], it is much easier to teach and learn how to use OpenSees, its scope of application, its functionality and the resolution of educational practical cases with it. Besides, OpenSees is integrated in a BIM workflow since StruBIM is integrated too. This fact causes that students can learn OpenSees taking advantage of BIM philosophy, which makes easier the student focuses just in learning OpenSees and not in the modeling phase.

2 TEACHING-LEARNING PROCESS OF OPENSEES: BEFORE AND AFTER

Before integrating OpenSees in a user-friendly and guided environment, OpenSees was used mainly in research. Both experienced researchers and PhD candidates must learn how to use OpenSees by resorting to the help on the Internet. This process was slow because the programming language that uses OpenSees to insert the data had to be learned. Consequently, neither engineering students nor engineering companies used OpenSees. This situation has changed since OpenSees was integrated in StruBIM because of two main reasons: (1) OpenSees is provided with a user-friendly and guided interface. Therefore, researchers, students and professional engineers can use OpenSees in their everyday life, (2) OpenSees is integrated within a BIM workflow which is displayed in Section 4.
A program like OpenSees, which was created to use it in the research world is now attractive to be used by anybody. First, research sector created and used OpenSees. Then, professional sector (CYPE S.A.) realized OpenSees could be widely used. Last, engineering students have an opportunity to learn a powerful tool within and user-friendly, didactic and motivating environment. Of course, engineering professionals and researcher can take advantage of OpenSees much easily. In turn, students and professionals can improve OpenSees because it is an open source software where user community can contribute with their code. Therefore, the three sectors (researchers, professionals and students) feed each other to make OpenSees better and more widespread.

3 EXTENSIONS PERFORMED TO OPENSEES TO ITS INTEGRATION IN STRUBIM

Several extensions have been carried out to integrate OpenSees inside StruBIM. Two new elements have been developed for Opensees: A one-dimensional elastic 2 node bar and a 6-node triangular shell element. Both support a wide kind of loads, local eccentricities, and stiffness multipliers. One-dimensional element calculates sectional forces and deflections at any inner points of the element without adding new nodes. Shell element supports thick sections and it works for non-linear analysis. Besides, we have implemented a new solver of system of called MUMPS (Multifrontal Massively Parallel Sparse Direct Solver) [5], which was developed in several European universities. It speeds up the calculation process. Other extensions were the capability of calculating several load cases in parallel and a new system of relating degrees of freedom. Figure 1 shows how to run the analysis in StruBIM Analysis [4] selecting OpenSees as calculation engine. Currently, all non-linear performance of OpenSees is being implemented in StruBIM Analysis [4] to make use of it.

4 BENEFITS FOR STUDENTS OF USING OPENSEES INSIDE A BIM WORKFLOW

The integration of OpenSees in StruBIM not only means a user-friendly interface but also the integration in a BIM workflow. OpenSees, as all structural computer programs, models analytical elements such as one-dimensional elements, shells elements, the relation between degrees of freedom, etc. In order to perform the structural analysis, it is necessary to gather some initial information from the architectural model. This flow implies that the structural analysis tool is able to read the structural model (beams, columns, slabs…) and create the analytical model adding the information that cannot be described in the modeling tool (if it is necessary). This is carried out by StruBIM Analysis [4]. The procedure from creating the architectural model to having the drawings is illustrated in Figure 2.
The main benefits that users can take from the workflow of the Figure 2 is that they will be able to use all the functionality of OpenSees just importing the structural model into StruBIM. The structural model which derives from the architectural model can be made with any modelling commercial tool available on the market. User will be able to perform a complex non-linear analysis of an actual structure with OpenSees with a minimum effort. This is unthinkable by coding the data input as OpenSees itself demands.

Another advantage of integrating OpenSees in a BIM workflow is that OpenSees could be part of an integrated teaching-learning strategy of university. Universities have based their organisation on both the current legal framework established by the Royal Decree 1393/2007 October 29th [6] which states the structure of the official university studies and the ECTS user guide (2015) [7] published by the Education Ministry. Both documents gather the new implementations in terms of high studies required by the European Union. The following sentences have been extracted from the Royal Decree 1393/2007 October 29th [6]: “the competence is understood as the capacity to transfer knowledge into practice”, “prepare students for the practical and professional life”. The following sentences have been extracted from the ECTS user guide (2015) [7]: “the curriculum should be designed to get necessary competences to be a professional”, “students must be able to apply their knowledge to their job”, “students must be able to transmit information and solutions to an specialized or non-specialized public”, “students must be able to apply their knowledge in multidisciplinary contexts.”.
Figure 2: Structural analysis and design integrated in a BIM workflow

StruBIM Analysis generates the analytical model from the structural

The powerful calculation engine OpenSees confers StruBIM high processing performance

Architectural model

Structural model

Feedback of architectural model

Design, check, drawings and reports

Analytical model

Calculation of analytical model

OpenSees
Therefore, curriculum of universities must teach students to be able to apply their knowledge on a multidisciplinary and professional context. To achieve it, a new approach based on BIM philosophy is being carried out in some masters. It consists of creating a professional actual project which will be developed in several subjects of the degree or of the master. For instance, a project of a building covers many knowledge areas such as modelling, structure, water supply, wastewater evacuation, illumination, heating, ventilating and air conditioning (HVAC), acoustics, telecommunications, etc. Each discipline would be treated in a subject with a specific software. In this way, each subject will contribute to the main global project. In order to integrate efficiently the results of every discipline, a BIM workflow is used. BIMserver.center [8] offers a bunch of programs integrated in an workflow to cover every discipline of a project. StruBIM is among these programs. For this reason, OpenSees could be used to cover the structural analysis discipline of the global project inside a multidisciplinary and multi-subject context.

6 CONCLUSIONS

- OpenSees has been equipped with a user-friendly and guided interface by integrating it as a calculation engine of StruBIM Analysis [4]. Consequently, the functionality of OpenSees is much easier to teach and learn.
- Before integrating OpenSees in a user-friendly and guided environment, OpenSees was used mainly in research with a great effort. Now, it is easy to use for students and professionals.
- Several extensions have been carried out to integrate OpenSees inside StruBIM. Two new complete finite elements, a new solver of system of equations (MUMPS) [5], the capability of calculating several load cases in parallel and a new system of relating degrees of freedom.
- A way with which universities could teach professional-oriented practical skills in a multidisciplinary context, as the Royal Decree 1393/2007 October 29th [6] and the “ECTS user guide” (2015) [7] states, is to create a professional global project which involves several subjects of the degree or of the master. Each subject would treat a discipline with a specific software. In order to integrate efficiently the results of every discipline of each subject, a BIM workflow is employed. In this context, OpenSees could be taught inside a professional and multidisciplinary project because it is integrated in StruBIM which is also integrated in a BIM workflow.

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NEW CAPABILITIES IN ROAD TUNNEL OPERATION EDUCATION

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Abstract. Faculty of Civil Engineering at University of Žilina, especially the staff of the Department of Construction Management, has recently dealt with a project focused on applied research on new technologies to improve the safety of road tunnel operation. One of the results is Tunnel Traffic & Operation Simulator (Simulator), a unique device for simulation traffic in two-tube road tunnel with possibility of interrupting the traffic flow by various emergency events. It is also possible to simulate the failures of different technological equipment. A new study subject “Tunnels” was created in the last re-accreditation of the second degree study program in 2015. Within the laboratory exercises, the students are taking practical lessons on Simulator in order to learn the principles of road tunnel safety operation. In our paper, the Simulator will be described in detail followed by the opportunities for student education and vocational training of real road tunnel operators in terms of accredited educational program “Management of Tunnel Operation” of lifelong continuing education.

1 INTRODUCTION

Simulator is a unique feature and new opportunity for education at the field of university and training of real road tunnel operators of Slovak tunnel administrator. Simulator was created as a result of a research project “Centre of Transport Research”.

On the basis of simulator existence a new study subject “Tunnels” was created in the last re-accreditation of the second degree study program called “Technology and building management”. This study program deals with the operation and maintenance of road tunnels, designing individual technological equipment. Within a laboratory exercises, the students as virtual road tunnel operators are taught how to control the tunnel during emergency events, standard and nonstandard situations, breakdowns and failures of tunnel equipment. Safety of
Another advantage with regard to the existence of the simulator was the possibility to set up a new accredited educational program of lifelong continuing education. This program was prepared in cooperation of National Motorway Company (NMC) that is administrator of all road tunnels in Slovakia.

Nowadays we have a road tunnel „construction boom“ in Slovakia. Eight road tunnels are operated under the NMC’s administration. Four of them are two-tube tunnels with strictly unidirectional traffic and rest of them are single-tube tunnels operated bi-directionally:

- Branisko (4975 m, 2003), bi-directional, semi-transversal ventilation system, the longest tunnel in Slovakia;
- Horelica (605 m, 2004), bi-directional, frequent traffic jams due to the near city junction, 4% of longitudinal slope in tunnel;
- Sitina (1440 m, 2007), uni-directional, highway capital city tunnel with high traffic volume, tunnel closure causes a traffic collapse in Bratislava;
- Bôrik (999 m, 2009), uni-directional, located under the High Tatras at high altitude;
- Šibenik (588 m, 2013), uni-directional, the newest road tunnel opened last year;
- Poľana (898 m, 2017), bi-directional, low traffic volume;
- Svěřínovec (420 m, 2017), bi-directional, low traffic volume;
- Považský Chlmec (2249 m, 2017), uni-directional, the newest tunnel in Slovakia

Other 4 tunnels are in construction process, including the longest tunnel of Slovakia, tunnel Višňové (7500 m, 2020). For all real road tunnel operators is this educational program mandatory in its specific modules. In regard to European Directive 2004/54/EC of the European Parliament and of the Council of 29 April 2004 on minimum safety requirements for tunnels in the trans-European road network, the administrative authority of road tunnel shall ensure regular training of operational staff. The personnel involved in the operation as well as the emergency services shall receive appropriate initial and continuing training [1,2]. The person responsible for the training is a safety officer, main person involved in all modules of educational program.

2 SIMULATOR

Training of real Slovak road tunnel operators is generally performed within the competence of tunnel safety officer of Slovakia inter alia at the Simulator (Fig. 1 and Fig. 2) regularly every year from 2013. Simulator was created as the result of research project in 2013, so the technology equipment of virtual tunnel, visualization of Central control system (CCS) and way of operation/control is in accordance with Slovak legislation valid at that time. It allows simulate incidents which are rare in the real tunnel traffic with the aim of verification of correctness and philosophy of the tunnel operation. The correct choice of traffic-operation state and consistent the optimal managing of emergency event are a key element to achieve successful solution of any emergency event. Visualizations of the tunnel traffic and technology management are the same as on the real operator workplace of a two-tube tunnel. It is possible to control a virtual tunnel by two independent operators (for traffic and technology) and their work is changeable, so it means that single operator can control entire tunnel from his/her workstation. In contrast to real traffic, simulation of video surveillance shows a virtual traffic in the tunnel tubes and in front of them. The simulator will...
be complemented next year by the results of applied research of “Models of formation and spread of fire to increase safety of road tunnels”, namely of 2D and 3D visualizations of the spread and stratification of smoke from the fire in road tunnel [3].

![Scheme of Simulator](image1)

**Figure 1**: Scheme of Simulator

![Real photo of Simulator](image2)

**Figure 2**: Real photo of Simulator

### 2.1 Simulation of emergency events

There are a lot of possibilities to simulate various emergency events from position of coordinator, e.g. (Fig. 3):

- slowly moving vehicle forming tailback of cars in tunnel tube,
- breakdown of vehicle (stopped vehicle) and possibility to make an accident,
- animal in tunnel and possibility of collision,
- pedestrian in tunnel and possibility of collision,
stopped heavy good vehicle (HGV) with dangerous goods (DG) and possibility of leakage or fire,
lost cargo and possibility of collision or fire,
leakage of chemical substance,
demonstration of people in tunnel,
threat of terrorist attack,
vehicle in bad direction,
oversized vehicle stopped in front of the tunnel portal,
stopped bus and a lot of people moving in the tunnel,
accident of two cars and possibility of fire.

Figure 3: Simulation of emergency events (examples)

2.2 Simulation of warnings and alarms

There are also a lot of possibilities to simulate different standard and non-standard situations, technology equipment faults, all in combination with emergency events mentioned in the previous chapter:

- changes of physical values (opacity/visibility, level of carbon monoxide, luminosity, temperature, speed of airflow) due to actual conditions,
- changes of traffic flow (sporadic, normal, tailbacks, stop and go),
- faults and breakdowns of tunnel technologic equipment (cameras, various detectors, traffic signs, power supply, local connections, etc.),
- changes of operational parameters (day, night, fog, smog),
- emergency calls (from SOS cabin, with tunnel specialists, integrated emergency rescue system, rescuers, fireman and many other responsible persons).
3 ACCREDITED EDUCATIONAL PROGRAM

The regular education (training) of operators is ensured by University of Žilina through an accredited educational program called “Management of tunnel operation”. It consists of five training modules:

- Basics of operations management (BOM), within the range of 100 h,
- Management of technology (MT), 30 h,
- Operation of technological devices (OTD), 30 h,
- Tunnel management (TM), 10 h,
- Operation and management processes (OMP), 10 h.

After successful passing the course participant obtains a certificate of professional competence, which provides evidence to meet the qualification prerequisites for the profession. First two modules are very important and are described in the next subchapters.

3.1 Basics of operations management

This training module is basic (access) course designated for all staff of NMC within the work with tunnels, e.g. operators, tunnel technicians, tunnel specialists and management staff (head of the tunnel, director of center of highway’s and tunnel’s maintenance). This basic module is continued by other modules. The range of module of combined form (distance and attendance form) is 70 h of teaching (53 h of lectures and 17 h of practical exercises), 10 h of self-study and 20 h technical excursion. The goal of course is to acquire knowledge and skills required to manage the operation of the tunnel in all operating states and possible emergency situations. The graduate should know the basic principles of tunnel operation, construction technology of tunnel tubes, technological devices used to control tunnel. Should acquire skills from measurements in the laboratory, have necessary knowledge and understanding of the central control system (CCS) and technological equipment: lighting, ventilation, fire protection, tunnel inspections and maintenance, status evaluation of tunnel, technological devices and sensors of technical parameters needed for rational management of the tunnel. Complete the foundations of rhetoric, communication skills and psychology. Because of three new tunnels put in the operation last year, this module was performed in autumn 2017 (Fig. 4).

Figure 4: Lectures of basic educational module for 61 participants (09/2017)
12 CONCLUSIONS

In this paper some activities of Faculty of Civil Engineering at University of Žilina, mainly of Centre of Transport Research and Department of Construction Management are illustrated. One of the primary objectives of each tunnel is to advance the high level of traffic and users safety. Changes of the traffic-operation states and other equipment are reflecting at the simulated traffic, as well as simulations of various emergency events in traffic initiate changes in tunnel detecting and measuring devices. Training of tunnel operators by simulator and possibility to try different situations and to verify the correctness of their solutions repeatedly is never-enough-to-be-regretted.

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DIGITAL TWINS IN CIVIL AND ENVIRONMENTAL ENGINEERING CLASSROOMS

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Key words: IoT, Education, Civil Engineering, Experimental Methodology, Fabrication.

Abstract. Digital twins are understood as digital replica of physical models whose behavior can be observed simultaneously (digitally and physically) in real time. These tools are increasingly used in advanced industries for several purposes. The digital representation provides both the elements and the dynamics of how an Internet of Things (IoT) device operates and lives throughout its life cycle. Despite its complexity, the materialization of these digital artifacts in their simplest form imply the use of a threefold technology: sensors, data acquisition systems (DAS) and graphical user interfaces (GUI). This paper describes several educational exploratory tasks performed at the School of Civil Engineering in Barcelona (UPC) aimed at developing meaningful yet simple digital twins for civil engineering classrooms. The project encompasses the use of simple GUs that show in real time physical systems from several disciplines such as structural engineering, soils mechanics, hydraulics, environmental
Engineering, coastal engineering or structural dynamics. The project has shown potential for civil engineering classrooms at two levels: i) these portable tools can be used pedagogically for demonstrating key concepts with a high degree of interactivity, ii) the development of these artifacts (from sensors to GUls) may provide a key understanding of several concepts associated with IoT mechanics for civil engineering students. It is noteworthy that nowadays, average students are seldom acquainted with sensors, electronics and virtualization of physical magnitudes at Bachelor and Master level. IoT technologies will be needed in civil engineering classrooms in the following years due to the increasing trends related to automation, monitoring and digitalization that the construction industry will undertake. Experimental and numerical pedagogical activities may be enriched with this concept since they allow navigating from physical to virtual realms and vice versa. The paper includes several examples with real applications as well as some recommendations for its potential application.

1 INTRODUCTION

One of the greatest challenges in civil engineering education in the years to come is to provide an adequate perspective to students at Bachelor and Master levels when it comes to all changes the professional sector will experience. Digital technologies disrupt industries as can be testified by the photography and the musical sectors, just to cite a few. The relentless trend of sophistication in automation, sensor deployment and control in construction is providing a huge potential for IoT applications in the sector [1]. The mechanics of automation and the use of sensors have been largely investigated for robotic construction and massive deployment of sensors [2][3] but their systematic application in civil engineering schools as part of the curricula is still in its infancy [4].

One the other hand, students are increasingly acquainted with the vast array of possibilities that are provided by digital technologies. The use and development of Software is natural for them in all subjects and fields. Programming, CAD or Simulation applications erect a vast framework of tools that are routinely used in civil engineering classrooms at various levels [5] [6] [7]. Laboratory activities are also one of the greatest experiences that students gather during their higher education journey [8] [9] [10].

Moreover, the educational sector has been increasingly infused with a vast array of pedagogical tools that make adequate use of both physical and digital realms separately. Project-based learning PBL [11], constructivist hands-on experiences [12], learning through making [13] or massive open online courses [14] are only a fraction of new educational experiences that are enriching civil engineering classrooms. However, few educational frameworks related to the blend of both physical and digital realms within civil engineering subjects are available [15] [16].

This paper presents some efforts undertaken at the School of Civil Engineering at UPC, Barcelona, Spain aimed at blending digital technologies and physical civil engineering problems by means of the concept of digital twin. The effort has been performed by educators from several core disciplines of civil engineering such as structural engineering, geotechnical engineering, coastal engineering, environmental engineering and hydraulic engineering.
Several examples have been built from scratch by students with varying level of achievement and success. The main idea for all cases has been to analyze the potential use of digital twins from a twofold perspective:

- As portable artifacts to be brought to the classrooms for illustration and demonstration of particular phenomena.
- As potential tools to be developed by students as a PBL, constructivist way of encompassing theory, fabrication, programming and physical-to-digital connection by means of electronics.

The project has been under development during the 2017-2018 academic year. Some of the findings are pinpointed as well as some recommendations related to the methodology that may be implemented in civil engineering classrooms.

2 DESCRIPTION OF THE PROJECT

The School of Civil Engineering has facilitated the development of an academic project aimed at studying the potential of digital twins as a pedagogical vehicle for civil engineering classrooms. The project belongs to the series of "Ajuts de millora a la docència" or AMD grants (Learning enhancement scholarships) in which students develop weekly tasks intended to improve teaching within the school. In the AMD grants given to the group in the 2017-2018 edition, these tasks are provided and supervised by educators within four different fields:

- Steel Structures Design
- Geotechnical engineering
- Coastal Engineering
- Environmental Engineering

The origin of the project can be found in similar experiences developed in the educational space "Camins Makers" at the School in other subjects:


In past editions of the yearly AMD grants, students have been developing a vast array of artifacts for civil engineering purposes. The use of 3D printing, open-source hardware and software as well as fabrication has provided an interesting learning environment in which lectures, workshops and educational research are performed and constantly evolving. Different tools such as electronic prototyping boards and computers (Arduino, Raspberry Pi), 3D printers, Web-based or desktop-based graphical user interfaces (GUI) and physical tools are brought together with a constructivist approach. Students involved in these lectures, workshops or grants can use the space quite freely as well as the available tools with the help of technicians. The space has limited access to these students so far.

Digital twins are understood as digital replica of physical models whose behavior can be
observed simultaneously (digitally and physically) in real time. The digital representation provides both the elements and the dynamics of how an Internet of Things (IoT) device operates and lives throughout its life cycle. Despite its complexity at various levels (scale reduction, multi-physics, multivariable, sensor embedness or other issues), the materialization of these digital artifacts in their simplest form imply the use of a threefold technology:

- Sensors
- Data acquisition systems (DAS)
- Graphical user interfaces (GUI)

The educational experience was deployed with the aim of understanding several features of the concept "Digital Twin" from an educational perspective. The aforementioned twofold perspective (portable artifacts for the classroom or project to be developed by students) has been under scrutiny at various levels:

- Individual projects undertaken by AMD students with a weekly work load of five hours during three months (either Bachelor or Master Levels).
- Collective projects undertaken by Master students in the form of simple digital twins that have been developed within the frame of the course Structural Dynamics.

The development of such projects require hands-on activities: Physically, the construction of artifacts whose level of complexity may vary depending on the field. Digitally, the development and coding of Software. The physical-to-digital conversion (or ADC in electronic jargon) is provided by sensors and microcontrollers. Civil engineering students are often acquainted with fabrication and programming but not necessarily with electronics. One of the greatest challenges of the projects is to assess the latter lack of background. In either case, a set of common tools/resources were provided and established as standard equipment:

- A civil engineering problem with routine application in lectures.
- Open-source, low-cost hardware (sensors and microcontrollers).
- Open programming software platforms.

3 TOOLS

The Arduino platform [17] and Processing [18] have been systematically used as the Hardware-Software combination for the development of the educational experience due to their availability at the school, their open-source nature of both and their increasing popularity worldwide. A brief description of both tools is addressed succinctly.
3.1 The Arduino platform

Arduino is an open hardware-prototyping platform. A set of up to 6 analog and 13 digital pins are available in this board. Connection to computers is performed via USB (for uploading programs or providing power). Any program following the Arduino syntax can be uploaded/modified as needed within the Arduino IDE (or alternatively, from other platforms). The board can be programmed to sense the environment by receiving analog inputs from many sensors, and/or to affect its surroundings by controlling lights, motors, and other actuators or digital devices. Add-in peripheral bluetooth shields can be added easily (other more sophisticated boards have BT capabilities embedded) as well as other modules for connectivity such as WiFi module, Xbee protocols or similar. A more powerful tool (Arduino DUE) provides a superior performance. The typical structure of Arduino programs is fairly simple can be divided in three main parts: structure, values (variables and constants), and functions. These functions require at least two parts, or blocks of statements. The setup() function is called when a sketch starts. It is used to initialize variables, pin modes, start using libraries, define communication protocols etc. The setup function will only run once, after each power up or reset of the Arduino board. After creating a setup() function, the loop() function which is repeated consecutively. Programming with the Arduino environment provides capabilities related to the Serial Port Communication and/or to the BT connections if needed. Analog signals from sensors and microcontrollers can be sent to the computer or to BT receivers.

3.2 Processing

Processing is a visual language and development environment built on top of the Java programming language. It allows generating computer simulations and visual graphics from scratch. In this context, Processing is used for developing graphical user interfaces. Processing follows a syntaxes that is very similar to the one used in the Arduino IDE. This may facilitate the structure of the project to students that need to learn from scratch both syntaxes. The platform allows developing object-oriented programs. Classes depict the behaviour of objects. Processing includes widely depicted in-built classes defining the behaviour of vectors or images (PVector, PImage). In addition, the Serial port connection is fairly straightforward and results measured by sensors can be derived to Processing in real time with a great ease.

3.3 Fabrication

Physical or digital fabrication tools (such as 3D printers, laser cutting or classical tools) have been used in the development of the project. The construction of the physical counterparts represents a very important aspect of the twin, in which creativity and constructivism is present all the time.
4 EXAMPLES

The project has been under development during the 2017-2018 academic year. For some examples, only preliminary results can be included in this document due to submission constraints. In the following, digital twins related to several fields are described. For all cases, the structure of the artifact follow a similar pattern which is illustrated in figure 1.

![Diagram of digital twin components]

Fig. 1 The pattern in all digital twins

4.1 Steel structures

Digital twins in the design of steel structures have been built for various purposes. As an example, basic digital twins aimed at showing both physically and digitally the planar behavior of steel frames subjected to both vertical and horizontal loads. Pressure and distance sensors controlled by the user provide data in real time that is visualized in the form of typical bending or shear force diagrams and stresses distributions, that follow adequate mathematical formulations. Figure 2 shows an example of the physical artifact as well as its digital twin. A scale-reduced frame provided with sensors and microcontrollers is used as a portable example for teaching. In this case, the frame is built for several load directions at variable positions (vertical, horizontal)
4.2 Geotechnical Engineering

Digital twins in geotechnical engineering have been initially built for the reproduction of the permeability test in sands and lines. This test requires the design of a soil column through which water passes during a certain amount of time. After percolating, the liquid is stored in a tank, whose height is measured with distance sensors and subsequently shown in real time digitally. The supporting structures have been designed with impervious 3D printed materials. Figure 3 shows schematics of the designed twin.

4.3 Coastal Engineering

Digital twins in coastal engineering have been initially conceived for the reproduction of a wave maker. This construction requires the design of a channel in which waves are generated cyclically by means of a servomotor. The height of the waves is measured in real time and visualized digitally. Creative forms for visualizing waves in real time can be obtained in Processing by using object-oriented programming. Figure 4 shows a conceptual design of the wave generator. It has been found that the construction of a portable object is quite complex.
4.4 Environmental Engineering

Digital twins in environmental engineering were initially built up for the monitoring of a microbial fuel cell. The microcontroller monitors the voltage decrease during the oxidation of organic matter in wastewater treatment systems. The process lasts several hours. Visual applications must account for this fact in order to present results in a meaningful way. Physical and digital objects can be seen in figure 5.

4.5 Hydraulics

Digital twins in hydraulics have been built for the reproduction of an existing hydraulic channel. The channel is provided with sensors (distance) that generate data related to the water flow and its speed. With these results, real-time, object-oriented particles systems are developed in Processing. As a result, one can see in real time how particles are accelerated similarly to the flow (figure 6). This digital twin is not portable but allows showing simple graphical user interfaces to students during laboratory experiences.
4 PRELIMINARY RESULTS AND FINDINGS

The on-going project digital twins consists of a constructivist hands-on set of examples built by students in which interfaces between data coming from sensors are visually displayed by applications developed by them. In this visualization, these simple yet meaningful artifacts including sensors, microcontrollers and development are encompassed to the classical needs associated with civil engineering problems. For the twofold perspective that is discussed throughout the paper (portable objects and hands-on PBL project), preliminary results related to the experience show that digital twins can be a very useful tool for the understanding of physical phenomena in their portable or in the laboratory forms. Their use as a PBL project for civil engineering students has not yet been fully assessed though. Questions related to the needed educational methodology for the application of such methodology need to be addressed and applied in the classroom in order to provide a vaster educational insight.

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INTERNATIONALIZATION OF HIGHER EDUCATION STUDIES – CASE STUDIES FROM POLISH TECHNICAL UNIVERSITIES

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Abstract. Internationalization of study is one of the most important processes which development can be observed in higher education in the first decade of the 21st century. International exchange, of course, existed all over the world for years, and it always was one of the engines stimulating the development of research and education. Poland entered the wide international market of the university education just about 30 years ago when started to be a member of many European projects but especially after joining EU in 2004 and taking part in the creation of EHEA and ERA. However, despite many activities and programmes performed, the level of internationalization of Polish university education is still very low in comparison to other OECD countries. For this reason internationalization of Polish higher education institutions is currently one of the most important goals defined in The Strategy for the Development of Higher Education: 2010–2020, commissioned in 2009 and 2014 by the Conference of Rectors of Academic Schools in Poland (KRASP) and the Polish Rectors Foundation (FRP). Among operational goals this report indicates the following needs: increasing attractiveness of Polish universities as partners in international educational and research area; giving international character for educational and research activities carried out at Polish universities; improving the image of Polish higher education in the world. The paper presents the general information concerning the activities currently proposed to improve internationalization of Polish universities by the organizations related to the higher education societies as well as the by Polish Ministry of Science and Higher Education (MNiSW) in the programme for the development of higher education and science in the period 2015-2030. Some activities as Erasmus programmes, summer schools, double diploma and T.I.M.E., English language studies and courses, different internship funds as well as the international accreditations were discussed on the example of two selected Polish technical universities of different size and regional situation: Wroclaw University of Science and Technology (WUST) and Bialystok University of Technology (BUT). Especially, some works made by the Faculty of Civil Engineering of WUST and the Faculty of Civil and Environmental Engineering of BUT, at which civil engineering is the main field-of-study, are presented.
1 INTRODUCTION

Internationalization of research and education processes is one of the most important strategic goals for Polish universities since the beginning of the 21st century [1-4]. Poland entered the international market of higher education just about 30 years ago when started to take part in many European projects (TEMPUS is worth mentioning) but especially after joining EU in 2004 and taking part in the creation of EHEA and ERA. However, Polish universities still have to face a very large distance to overcome in this field, both to European and world universities [2, 5, 6].

For this reason internationalization of Polish higher education institutions is currently wide discussed by different governmental and societal institutions and many interesting programmes have been developed and they are implemented into action [1-8]. For example, in The Strategy for the Development of Higher Education: 2010–2020, commissioned in 2009 and 2014 by the Conference of Rectors of Academic Schools in Poland and the Polish Rectors Foundation [1] as the operational goals, the following needs were indicated: increasing attractiveness of Polish universities as partners in international educational and research area; giving international character for educational and research activities carried out at Polish universities; improving the image of Polish higher education in the world. Among other it resulted in creation of the Study in Poland project of international promotion of Polish higher education and study opportunities in Poland (see: chapter 2). Meanwhile, under the auspices of the Polish Ministry of Science and Higher Education, strategic programmes for development of Polish higher education and research institutions, including process of internationalization, have also been developed and launched [2, 3].

The goals for the activities in this field are defined as [2]:

- the development of activities that will allow the best universities to advance in international rankings what may influence on the decisions of foreigners to study or to perform the academic work in Poland;
- launching a programme supporting universities in obtaining international accreditations;
- stimulation of the creation of courses and whole study programmes given in English;
- expanding scholarship programmes financing mobility and establishing cooperation with the best foreign institutions and scientists;
- active policy to promote studying in Poland and facilitating the adaptation of foreign students in Poland.

More detailed goals for universities were defined as [3]:

- acquisition of international accreditations for higher education institutions or individual education programmes;
- increasing the number of first and second cycle programmes in foreign languages and joint educational projects;
- building up doctoral programmes on international scale and developing career paths for post-doctoral candidates;
- increasing the number of foreign scientists involved in didactic and scientific work in Poland as well as foreign reviewers;
- increasing the offer of study conducted in the form of e-learning, including massive online open courses (MOOCs);
- developing mechanisms for better servicing of foreign students, developing competencies
of administrative employees, including their language competences;
- supporting students and academic staff travelling abroad and returning to Poland;
- (ex. increasing the recognition of foreign visits in the frame of educational programmes);
- participation of the university in the implementation of the Ready, Study, Go! action;
- use of state promotion support (see: chapter 3).

Some performed and developed activities as, among others, Erasmus programmes, summer schools, double diploma and T.I.M.E. programmes, English language studies and courses, different internship funds as well as international accreditations for study programmes were discussed in the paper on the example of the activities of two Polish technical universities: Wrocław University of Science and Technology (WUST) and Białystok University of Technology (BUT) (see: chapter 4).

2 PROGRAMME STUDY IN POLAND

The Study in Poland (www.studyinpoland.pl) project was created on the initiative of the Conference of Rectors of the Academic Schools in Poland and the Perspektywy Educational Foundation in the form of an integrated marketing platform for Polish universities. It is a long-term project of promoting Polish higher education and study opportunities in Poland. It assumes the complexity and long-term nature of conducting, as well as flexibility in launching its modules, such as information and promotion activities or implementation of projects aimed at increasing the number of study programmes in English. One of the very important activities is also awareness of foreigners about the possibilities and conditions of studying in Poland. The programme offers also analysis of the process of internationalization of studies in Poland in a statistical way (Figs 1 and 2).

![Figure 1: Number of foreign students in Poland 2010-2016 (source: www.studyinpoland.pl)](image)

The Study in Poland project strives to significantly improve the internationalization of Polish universities. Since 2005 Polish universities have consistently increased the number of foreign students who currently constitute 4.88% of all students in Poland (eight years ago there were only 0.61% and in the academic year 2015/16 - 4.07%). However, the growth in percentage is also due to decrease in the total number of students in Poland (Fig. 3).
Despite the increase in total number of foreign students that choose Poland to study, there are still fewer percentage of foreign students studying in Poland in comparison to the most developed European countries or China, but also in comparison to the neighbouring states as Czech Republic, Hungary, Slovakia or Lithuania.

3 POLISH NATIONAL AGENCY FOR ACADEMIC EXCHANGE NAWA

Polish National Agency for Academic Exchange (NAWA) was set up in 2017 with the aim to coordinate all state activities determining the process of internationalization of Polish academic and research institutions by:

- supporting international mobility of students, academics and researchers;
- supporting the process of internationalization of Polish HEIs and research institutions;
- promoting Polish science and higher education worldwide;
- promoting and popularize teaching of Polish language.

The Agency’s mission is to support academic exchange and international cooperation in order to strengthen the potential of Polish science and higher education. The Agency’s task is
to conduct a long-term policy to support academic mobility and pro-quality internationalization of the Polish universities offer, among others through the implementation of programmes addressed to students and academic staff both from Poland and from abroad. 

NAWA (https://nawa.gov.pl/en/) offers programmes for outgoing Polish students and for incoming foreigners. At present, foreign students are offered scholarship programmes as part of development assistance and a scholarship programme for persons of Polish origin. Polish students have the opportunity to go abroad under the Central European University Exchange Programme (CEEPUS), which is the second largest academic exchange programme after the Erasmus + programme - and on the basis of bilateral agreements with third part countries.

4 SELECTED FORMS OF INTERNATIONAL COOPERATION IN THE EDUCATION AREA – EXPERIENCE OF WUST AND BUT

4.1 Description of the faculties offering civil engineering major

Wroclaw University of Science and Technology (WUST) is the largest technical university in the Lower Silesia. It offers 51 fields of studies in more than 130 specializations (also within the individual course of study), including 31 programmes taught in foreign languages. Wroclaw University of Science and Technology currently educates approximately 28,000 students and 854 PhD students. The academic staff consists of 2,165 research and teaching academicians. All faculties of WUST have been participating in the Erasmus programme since it began functioning at universities in Poland. Within the Erasmus Programme, Wroclaw University of Science and Technology cooperates with 270 foreign universities, and its faculties have signed more than 390 bilateral agreements.

The Faculty of Civil Engineering (FCE) provides of civil engineering study in general academic profile, at both the first (BSc) and the second (MSc) cycles and in full- and part-time forms. The curriculum is fully based on NQF and for the first time it was introduced in the academic year 2012/2013. At the BSc level students can choose from three diploma specializations: Building Engineering, Geo-engineering and Hydro-engineering, and Civil Engineering (all given in Polish). At the MSc level students can elect one of 9 specializations: Building Structures, Building Technology, Hydro-engineering and Special Structures, Underground and Urban Infrastructure, Roads and Airports, Railway Engineering, Bridge Engineering, Theory of Structures (all given in Polish), and Civil Engineering, given in English. After completing any of these BSc or MSc specializations graduates can apply for recognition of the Polish Chamber of Civil Engineers. Currently, FCE educates 2,300 students and 50 PhD students and the faculty employs nearly 160 of academic staff.

The WUST has 826 foreign full-time students while there are 42 students from abroad (in 2016 there were 26 students) at the FCE. The development of the total number of foreign students at WUST is presented in Fig. 4. It can be seen that currently full-time foreign students constitute only about 2.87% of total number of WUST students. This number is even less at the FCE reaching only 1.81%.

Bialystok University of Technology (BUT) is the largest technical university in the northeast of Poland. Bialystok Technical University currently offers 26 fields of studies and numerous specializations at full-time and part-time studies. The university educates about 8,500 students and the teaching staff consists of nearly 660 academics.
All faculties of BUT have been participating in the Erasmus programme since 1998. Within the framework of bilateral contracts, the university actively cooperates with 130 foreign institutions. BUT offers 10 full educational programmes in foreign languages (including two doctoral programmes), and for students of the Erasmus programme it also offers a selection of courses from all conducted fields of studies.

The Faculty of Civil and Environmental Engineering (FC&EE) offers five graduate programmes at full-time and part-time studies: Civil Engineering, Spatial Planning, Landscape Architecture, Environmental Engineering and Environmental Protection. Studies are organized in three-cycle structure recommended by the European Union (Bologna Declaration) with PhD course as the highest cycle. The majority of course units at the FC&EE is taught in Polish. Although, there is a number of courses offered in English. English taught studies are offered in the following study programmes: Environmental Engineering, Construction and Building Systems Engineering, Landscape Architecture and Civil Engineering. Currently, more than 2,400 students and about 50 PhD students study at the FC&EE. The Faculty employs nearly 160 academics.

In addition to offering the full cycle study in English, Faculty of Civil and Environmental Engineering of BUT focuses on short-term stays of foreign students (one or two semesters) as part of exchange programs, internships, double degree programmes and freemovers. The development of number of foreign students at FC&EE is presented in Table 1. Civil engineering has been the most popular field of study for many years.

Table 1. Foreign students at FC&EE of BUT (source: BUT IROffice)

<table>
<thead>
<tr>
<th>Academic year</th>
<th>Erasmus+ KA103/KA107</th>
<th>Freemovers</th>
<th>Internship</th>
<th>Full time</th>
<th>Double degree</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014/2015</td>
<td>75</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>92</td>
</tr>
<tr>
<td>2015/2016</td>
<td>86</td>
<td>16</td>
<td>0</td>
<td>1</td>
<td>36</td>
<td>139</td>
</tr>
<tr>
<td>2016/2017</td>
<td>84</td>
<td>8</td>
<td>1</td>
<td>5</td>
<td>34</td>
<td>132</td>
</tr>
<tr>
<td>2017/2018</td>
<td>64</td>
<td>3</td>
<td>1</td>
<td>37</td>
<td>36</td>
<td>141</td>
</tr>
</tbody>
</table>
4.2 ERASMUS+ programme

The ERASMUS+ Programme has been carried out in Poland since 1987. Despite its scope and objectives being broadened over almost 30 years, the main idea remains the same-developement of international co-operation among universities. It supports international cooperation of universities, enables students to go abroad for part of their studies and internship, promotes the mobility of university staff and creates numerous opportunities for universities to participate in projects with foreign partners.

![Figure 5: Total number of outgoing and incoming students at WUST and FCE within Erasmus+ programmes (source: WUST IROffice)](image1)

![Figure 6: Total number of outgoing and incoming students at BUT and FC&EE within the Erasmus+ programmes (source: BUT IROffice)](image2)

ERASMUS is the most popular programme for international exchange of students and academic and administrative staff. Currently, the following types of ERASMUS activities are conducted at WUST and BUT: Erasmus+ - studies abroad and student and graduate internships (KA103) in programme countries, Erasmus+ with partner countries (KA107) and Erasmus Mundus. The total number of students participating in Erasmus+ programme and
number of students of considered faculties are presented in Figs 5 and 6. Both universities are very active participants of Erasmus+ programme, but the trends in the numbers of outgoing and incoming students are totally different.

4.3 Double diploma and T.I.M.E. programmes

The T.I.M.E. programme is implemented by the elite of European universities with a recognized teaching and scientific reputation, based on trust, reciprocity and equivalence of the partners' benefits. The study is awarded with two diplomas that increase the employment opportunities of graduates on the European labour market. Thanks to agreed programmes, students, by completing a part of the study programme at a partner university, obtain a double diploma: a home university and a partner university. The programme assumes extending standard studies by one year (4 years at the home university and 2 at a partner one), studying in the partner's language and treating foreign students equally with their own students.

The WUST conducts, in cooperation with selected partner universities, education programmes within the framework of double diploma agreements, the so-called double degree. A significant part of these agreements was signed thanks to the WUST affiliation to T.I.M.E. Association as the first Polish technical university in 2004. The FCE of WUST is currently a partner in the T.I.M.E. programme with: Ecole Centrale de Lille, Politecnico di Milano, and Ecole des PontsParistech.

The FC&EE offers cooperation within double diploma programme with Lviv Polytechnic National University, Poltava National Technical University, Moscow State University of Civil Engineering, Tianjin Chengjian University (for incoming students), Hebei Normal University for Nationalities, Polytechnic Institute of Bragança, Polytechnic School of Belmez, University of Cordoba, University of Beira Interior, Universite de Valenciennes et du Hainaut-Cambresis.

4.4 Study programmes in foreign languages

From 2010 the FCE of WUST offers the MSc specialization in Civil Engineering [9] given in English and dedicated to foreign students (both the full-time and Erasmus ones) as well as for Polish students keen on study in English. The CE specialisation enables a graduate to gain extended knowledge and skills in the area of design and construction of different building objects such as composite reinforced concrete and steel structures, building structures, urban engineering objects, roads and highways, bridges, railway engineering objects. Moreover the graduate possesses extended knowledge of hydraulics and computer aided engineering. In the year 2017-2018 the total number of students studying this specialization was 62, including 14 participants from abroad.

The FC&EE of BUT offer for study in English consists of the following full-time studies: Civil Engineering, Environmental Engineering, Construction and Building Systems Engineering, and Landscape Architecture. Graduates of the CE course will acquire comprehensive knowledge of: erecting apartment buildings, transportation and industrial infrastructure, designing engineering structures. They will also have knowledge of building technology, organization and management as well as building development using modern technologies and computing techniques in civil engineering practice. On completing the course of EE graduates will have extensive knowledge how to solve technical, technological
and organizational problems related to the protection, utilization and conversion of environmental resources both in rural as well as urban environment. The graduate of CBSE is prepared to perform construction as well as building systems installation manager duties and responsibilities. They are also prepared to design civil-engineering objects of small volume, including their basic building systems. Graduates of LE will attain all the necessary abilities to carry out design, documentation and stock taking work in the field of planning green areas (parks and gardens) in urban open spaces. Currently, the number of participants in these courses is 40, including 33 students from abroad.

4.5 Summer schools

One of the best ways to acquire foreign students to study at the universities are summer schools [10]. Summer schools in recent years experienced a huge development at European universities - this is very often the result of the need to search for foreign candidates for studies, especially from countries such as India and China, in the face of shrinking number of national candidates. In addition, summer schools, very often narrowly profiled, allow for the fetching of the most talented students, promising the opportunity to carry out later scientific work. Of course, the undeniable advantage of these schools is cooperation between students coming from many different countries and continents.

At WUST there are organized the following summer schools: TECHSummer2018 (dedicated to students from India); Energy, Excellence, Excitement 3E+; Summer School of Architecture; GUT Summer School (dedicated for students from Guilin University of Technology). In the two first schools FCE of WUST is one of the leading faculties. For example, TECHSummer started with 15 students in 2014 and there was 53 Indian young people in 2017.

BUT organized the following summer schools: Polish-German-Belarusian Summer School for students from BUT, Belarusian National Technical University in Minsk, and Eberswalde University for Sustainable Development (3 editions of international summer school in Poland, Germany and Belarus); Polish-Chinese Summer School (2016, 2017) for students from BUT, School of Management of Zhejiang University Ningbo Institute of Technology (ZJUNIT) from China; Summer Schools VIPSKILLS (Virtual and Intensive Course Developing Practical Skills of Future Engineers) dedicated for civil and environmental engineering students form BUT, University of Cordoba and Vilnius Gediminas Technical University.

5 INTERNATIONAL ACCREDITATION OF STUDY PROGRAMMES

The Polish Accreditation Committee (PKA) - an independent institution working with the aim of education quality improvement has been working in Poland since 2002. The primary objective of the PKA is to support Polish public and non-public higher education institutions in the development of educational standards matching the best models adopted in the European and global academic area. Another institution dedicated exclusively to assessment of technical fields of studies is the Accreditation Commission of Universities of Technology (KAUT). It is authorized by the European Network for Accreditation of Engineering Education (ENAEE) to award also the European EUR-ACE® Label certificate.

Currently, the Polish Ministry of Higher Education and Science, opened a project dedicated to support Polish higher education institution in obtaining international
accreditations. In case of civil engineering filed-of-study the ABET Accreditation and ENAEE (EUR-ACE® Label) are the most desired.

6 CONCLUSIONS

In the paper, based on the data on international exchange of two selected Polish technical universities (WUST and BUT) and their faculties educating in the civil engineering field-of-study, respectively: Faculty of Civil Engineering and Faculty of Civil and Environmental Engineering, as well as on presentation of selected forms of implemented activities (international exchange programmes, foreign language education programmes, double diploma programmes, summer schools etc.) the current condition of the internationalization process at these institutions was discussed.

Due to the length of existence, the largest student exchange is organized as a part of the Erasmus+ programme activities, although it is limited by the granted funds. Three other forms of action are becoming increasingly important: study in foreign languages, double diploma agreements and summer schools. The latter one constitutes a very good way of presenting the universities and faculties to potential candidates, especially from such countries as India, Turkey, China or Vietnam, in the case of the universities considered. Together with the BSc and MSc programmes, offered in foreign languages, and obtained international accreditations, they seem to be the best solution for increasing the internationalization level of Polish HEIs.

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IMPACT OF COOPERATION BETWEEN UNIVERSITIES AND INDUSTRY ON CIVIL ENGINEERING CURRICULUM OF STUDY – EXPERIENCE OF POLISH TECHNICAL UNIVERSITIES

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Key words: University, Industry, Cooperation, Education.

Abstract. The development of a knowledge-based economy requires stronger and continuous cooperation between the spheres of education, science and industry. The universities create their surroundings through transfer of technology and scientific staff, and through graduates preparation. Benefits of scientific institutions, including higher education ones, in this type of cooperation consist mainly of increasing their recognition among employers and candidates for study, improving the quality of education and research, receiving financial benefits and fulfilling legal obligations. As the other main partner, the industry can achieve, among others, the following benefits: improving the quality of human capital, using the university as a source of ideas, promoting the company's image as an attractive partner, creating a network of contacts with the academic environment. Because of the benefits mentioned the relationships between universities and the socio-economic environment are becoming more and more intensive. Research conducted at technical universities always had influence on what and how students were taught. Good and valuable education process cannot exist without the scientific research in the field of study represented. From the other side, there must exist synergy between research and industry, and what is nowadays extremely important, the learning outcomes such as knowledge and competences of graduates, have to fulfill the needs of industry. Some general experiences regarding cooperation between science and industry with its impact on forming the curriculum of civil engineering are presented on basis of bachelor and master degrees studies at the technical universities in Białystok and Wrocław (Poland).

1 INTRODUCTION

In the relation "university - industry", cooperation takes place mainly on two main levels:

- scientific and research cooperation in the following forms:
  - conducting research and development projects, applied by industry in the form of technology,
  - joint implementation of research projects along with raising funds for their financing,
- performance of technical expertise by university professionals;
- cooperation in the field of education in the following forms:
  - creation of curriculum of study consistent with the needs of business (e.g. by creating desired courses of study, especially of practical profile),
  - participation in launching dual studies, included in the strategy of modernization the higher education (students will be educated both at the university and by the employer, gaining knowledge on the one hand and practical skills on the other one),
  - individual support of the education process (e.g. in the form of providing materials and data for diploma thesis, involvement of practitioners into the teaching process, enabling students to complete traineeships and internships),
  - choosing the best graduates for possible employment in companies.

The enterprises are becoming increasingly active, and they offer universities various forms of cooperation in order to prepare graduates to enter the labour market. The main proposals of cooperation in the field of education are indicated in Fig. 1.

![Figure 1: Main forms of cooperation between technical universities and employers in the education area](image)

Some aspects of cooperation between university and industry and its impact on forming curriculum of study in the field of civil engineering are presented on the basis of the bachelor degree (BSc) and master degree (MSc) studies at the technical universities in Białystok and Wrocław (Poland).

2 COOPERATION BETWEEN TECHNICAL UNIVERSITIES AND INDUSTRY IN THE R&D AREA

The development of innovative technologies and the introduction of new products as a result of R&D conducted by the company requires large expenditures on scientific and research infrastructure as well as building specialized competences in a selected area of science and research. Big industrial companies usually have their own excellent research centers in which they employ outstanding scientists. However, in the case of smaller companies, one of the options for the operation of enterprise is to cooperate with scientific and research organizations in order to carry out joint research work or to use already developed research results in practice. On the other hand, scientific and research organizations want the results of their investigation to be applied in industry.
In the area of research, the six main categories of cooperation between universities and enterprises are mentioned most frequently [1]: research sponsorship, joint research, formation of consortia, licensing (technology transfer), creation of start-up enterprises, data exchange. It is worth noting, however, that only the first three forms assume co-operation at the level of conducting research, the others assume sharing of ready-made solutions developed in the course of research. As pointed out by representatives of the largest international corporations, cooperation in the field of research is worth taking even when each partner has the knowledge and resources which enable the project to be carried out independently, because it allows to improve the quality of research, increase their scope, and to reduce of costs. This solution is also supported by the growing demand for interdisciplinary research [2].

For scientific and research organizations, such as universities, scientific and research activity is one of the two basic goals of operating. The other one is education of students. It is obvious that education of students (engineers in the case of technical universities) consistent with the requirements and needs of broadly understood industry, cannot function without the conducting and implementing the research of universities in the areas of education they provide. Only when there is a link between the results of research activity (performed by the university itself or conducted in cooperation with the industry) with the education process, this education can be effective and guarantee the promotion of graduates able to meet the requirements of the labour market.

3 COOPERATION BETWEEN TECHNICAL UNIVERSITIES AND INDUSTRY IN THE AREA OF EDUCATION

3.1 Employers’ requirements for graduates of the technical studies

The employers indicate a lot of gaps in the education programme or inadequacy of programme to their specific needs as well to the expectation of the labour market. They underline not enough practical classes and practice acquired in university, the lack of opportunities to acquire the professional certificates during study period, inefficient division of education process into first and second degree, insufficient share of courses typical or fundamental for civil engineering in the whole curriculum of study.

The employers expect graduates to have a high level of competence which is a synthesis of theoretical knowledge, practical skills and personal features [3-5]. In their opinion, the role of the education system is to prepare graduates practically for the profession and to provide them with a wide range of professional skills. The most frequently mentioned weakness of university graduates is the lack of experience and practical skills as well as lack of the ability of analytical thinking, ability to establish contacts, to create a harmonious cooperation, a sense of responsibility etc. Education in the field of civil engineering enables the acquisition of the majority of competencies considered important and useful at work, except for professional experience. The lack of these abilities of graduates creates for the employers the necessity to conduct the adaptation process of a new employee to work in an enterprise which can last from one month to up to three years [5, 6].

A detailed list of the most important competences for employers and those whose graduates are missing the most is given in Table 1.
Table 1: Graduates competencies according to employers

<table>
<thead>
<tr>
<th>The most important competences for employers</th>
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</thead>
<tbody>
<tr>
<td>Effective communication</td>
</tr>
<tr>
<td>Knowledge of foreign languages</td>
</tr>
<tr>
<td>Openness to learning and permanent development</td>
</tr>
<tr>
<td>Involvement in work</td>
</tr>
<tr>
<td>Ability to group work</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Competences with the largest gap in relation to the expectations of employers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to define and justify priorities</td>
</tr>
<tr>
<td>Ability to organize work and effective time management</td>
</tr>
<tr>
<td>Correct self-esteem; understanding personal strengths and limitations</td>
</tr>
<tr>
<td>Ability to project management</td>
</tr>
</tbody>
</table>

3.2 Curriculum design

The idea of curriculum based on learning outcomes should facilitate cooperation of universities with external stakeholders in the process of educational offer development. According to current rules, every curriculum, regardless of profile, has to be assessed and accepted by the representatives of employers and professional organizations [7]. However, the cooperation with employers is the most significant matter in case of practical profile of study.

The legislation [7] clearly differentiates the requirements for practical and academic profiles of education, among others, obliging universities to increase, within the framework of practical profile studies, the period of student internships or closer cooperation with experienced practitioners.

Practical profile includes the modules for acquiring the practical skills and social competences. It is implemented with the assumption that more than a half of the study programme as defined in ECTS credits consists of practical classes forming these skills, including those obtained during workshops conducted by practitioners with professional experience gained outside the university.

Academic profile includes modules related to research conducted in the university, carried out with the assumption that more than a half of the study programme as defined in ECTS credits consists of classes for in-depth knowledge acquisition. The solutions should limit the popular fields of study with many graduates whose qualifications do not meet the needs of the labour market, in universities that do not guarantee a high level of education resulting from the lack of specialized academic staff. In addition, following the suggestions of employers in the current rules, the organizational units conducting the studies of practical profile are required to include at least three months of professional internship in the curriculum [3].

In case of universities considered: Faculty of Civil and Environmental Engineering (FC&EE) of Bialystok University of Technology (BUT) and Faculty of Civil Engineering (FCE) of Wroclaw University of Science and Technology (WUST) the current curricula of two-level civil engineering studies of general academic profile are mainly based on the knowledge and experience of university staff. However, the guidelines and recommendations from the construction industry and professional organizations were also taken into account. Graduates of the 1st level studies are mostly directed to work in building sites, whereas the
2nd level studies develops the most advanced knowledge and competences, thus the graduates are also predisposed to creative design work and scientific research.

### 3.2.1 Civil engineering BSc graduate profile and employability

After completing the first level studies in the field of *civil engineering*, a graduate, according to their acquired knowledge, skills and competences, is prepared to be able to: make decisions concerning the design of elements and simple objects of housing and public service buildings, as well as simple industrial and transportation infrastructure. He knows how to implement proper building materials and apply construction technologies. A graduate knows the principles of the strength of materials and structural mechanics and is able to formulate, construct and apply simple engineering structural calculation models. A graduate is able to create and read technical drawings and to recognize cartographic and geodesic elaborations. He knows and applies current building codes. A graduate takes advantage of the latest computer technology supporting the modelling and design of structures, construction processes and also construction works management. He knows the latest design techniques, as well as trends in construction work development and is able to administer a construction site. He knows the performance analysis principles and also the costs and scheduling of construction works. He is able to critically select arguments that support collective decisions concerning task performance in civil engineering. A graduate is able to work in a team and has knowledge and skills in the area of occupational safety and health. He is responsible for his own and other employees safety at a workplace. He is able to complete a report on the course of performed tasks and designs. He is aware of the necessity of continuous job and personal competence development and follows a code of ethics. A graduate of *civil engineering* is prepared to be able to supervise construction sites of all types of structures; to participate in the design of housing and public service buildings, simple industrial constructions and transportation infrastructure and to organize the production of construction elements. A graduate is prepared for work in: construction companies; supervision of civil engineering works; concrete, steel, timber and building element plants; the building materials industry and also governmental and local government administration units connected with civil engineering and architecture. A graduate is able to use a foreign language to at least B2 level according to the Common European Framework of Reference for Languages (CEFRL) and is able to use a specialized language within his profession. He is also prepared to undertake the second level studies in the field of civil engineering.

### 3.2.2 Civil engineering MSc graduate profile and employability

After completing the second level studies in the field of *civil engineering*, graduates, according to their acquired knowledge, skills and competences, are able to make decisions concerning the proper selection of building materials to be used, the design of building objects and also construction procedure. Graduates in today's age know the trends in the designing and preparing the construction projects. They are able to design the complicated building objects, they know advanced structural mechanics, and are able to formulate, create and then apply the appropriate calculation models of complex engineering structures. They are able to make and read technical drawings, to recognize cartographic and geodesic elaborations and also to lead construction works. They are able to formulate and solve new,
innovative engineering, technical and organizational problems related to civil engineering. Graduates can use of computer technologies that support design processes, as well as construction projects. They are able to critically choose arguments supporting collective decisions regarding the execution of civil engineering tasks. They are able to elaborate and publish reports regarding the development of works. Graduates are aware of the necessity of developing professional and personal competences. They follow the code of ethics and know and apply building law regulations. They possess language skills in the area of the scientific disciplines and fields of study adequate to the studied discipline according to CEFR requirements to at least B2+ level. Graduates are prepared to solve complex project, organizational and technological problems; to elaborate and realize research programmes; to undertake actions on an international scale; to participate in the marketing and promotion of building products; to continue their education and participate in research and activities directly related to civil engineering and building materials manufacturing. They are ready to increase their qualifications continuously and to complement their knowledge and also to manage big teams. Graduates have the possibility to start work in design offices, construction companies, research institutes and research and development centres, and also institutions dealing with advisory and knowledge promotion in the area of civil engineering. The second level civil engineering graduates are also prepared to continue their education and undertake the third level studies.

3.3 Dual study

One of the most effective forms of employers' participation in creation a curriculum and in education of graduates for their needs is a dual study. The dual study is an innovative system of study, assuming the acquisition of academic knowledge and practical experience at the same time. The study programme includes the necessary theoretical knowledge acquired during lectures, classes and laboratories/workshops at the university, interconnected with periods of work in various positions in the company, within the frame of a contracted internship. Dual study is characterized by closely linking education with practical activity in the workplace. In this way the theoretical knowledge is immediately put into practice. In order to determine the course of study and professional practice the programme council is appointed in agreement with the professional organizations, which include representatives of the companies and institutions employing students. As a result of extensive discussions the best form of the course is determined. During studies the student learns about the structure and expectations of employers towards their employees. Student working at the plant also prepares interim papers thematically related to his work, and at the end of education he solves a specific problem associated with the plant, in the form of a thesis. The supervisors of the thesis are an employee of the university and a professional representative designated by the employer (with the title of at least MA/MSc). At the end of studies the graduate automatically becomes a potential full-fledged company employee, whose employment does not require any additional training or implementing to the corporate structure. However, the creation of such studies is associated with overcoming multiple organizational and financial barriers by all participants of the project.
3.4 Post-graduate studies

The easier form of preparing graduates for the needs of labour market is conducting joint post-graduate studies by the university and the only particular employer, or employers of a similar profile. The implementation of post-graduate studies is independent of the course of studies leading to the professional title (MA). Classes in the course of post-graduate studies are targeted at the specific needs of the labour market to supplement the knowledge and skills of graduates. The teachers are partially the university staff and partially - practitioners (employees of enterprise). The studies are designed for graduates of first-degree study and can be implemented during the second cycle of study.

3.5 Seminars and trainings organized by the professional associations and employers

The valuable complement to the teaching process is presenting the practical side of the issues discussed. The subjects of conferences and seminars organized by professional associations, and often also by individual employers are beyond the scope of typical curriculum of study. The topics often fill the gap in the typical university education regarding the latest trends in the civil engineering, as well as the specific needs reported by employers, that should be incorporated into educational process for engineers. Particularly valuable element of such training is the presentation of specific case studies, or preparing a lecture based on the own experience of company. Usually trainings and lectures are conducted free of charge.

3.6 Cooperation agreements

In the frame of bilateral agreement the university and enterprise declare their willingness to cooperate in the areas covered by their statutory activities, in all legally permissible forms. Usually the agreement concerns the cooperation for implementation of joint projects in a selected faculty of civil engineering, such as:

- optional (extra) courses for students and teaching staff of faculty,
- outdoor activities - technical trips to building sites ("meeting with reality"),
- scientific cooperation (joint projects, publications, conferences, etc.),
- implementation of practical PhD thesis,
- implementation of BSc and MSc theses suggested by enterprise with the participation of two supervisors (one from university, other from enterprise),
- 6-month internships according to the curriculum of study particularly important for study curricula with practical profile),
- optional internships for gaining practical skills,
- industrial internships for teaching staff of faculty (according to individual applications),
- competitions announced by enterprise for thesis in the specified topic (subject indicated by the company),
- cooperation with the students' scientific teams,

as well as in other areas established during mutual cooperation. Particular activities under the agreement usually depend on the needs of the enterprise.
4 CONCLUSIONS

The development of a knowledge-based economy will require stronger and stronger cooperation between the spheres of education, science and business. The activity of the university should be aimed at the full use of the scientific potential in cooperation with the industry, but also at improving the quality of education and effective preparation of graduates - future employees and employers. As a result, an increase in the competitiveness of the university and its graduates in the domestic and international labor market is expected.

In the case of BUT and WUST, as well as on the example faculties of these universities educating in the field of civil engineering, the process of building the relationship and cooperation with entrepreneurs and business is one of the main elements of the development strategies they implemented.

The benefits of higher education institutions from this type of cooperation include mainly: increasing their recognition among employers and candidates, improving the quality of education (by creating study curricula with participation of employers) and research. The benefits of students are as follows: better chances for their employment, obtaining payment from the company for their research work, as well as passing internships and building an important network of professional contacts. The benefits of enterprises have their source in reducing costs and risks, improving the human capital quality, using the university as a source of ideas, promoting the company's image as an attractive and responsible employer, creating a future-oriented, innovative network of contacts, developing new products and services, and helping apprentices.

REFERENCES

THE BENEFITS OF COOPERATION WITH STAKEHOLDERS IN IMPLEMENTATION OF MASTER PROGRAMME “BUILDING DESIGN FOR SUSTAINABLE DEVELOPMENT”

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Key words: Interdisciplinary Master Programme, Practice-oriented Approach, Business, Olympiads, Competitions.

Abstract. The article provides an opportunity to learn about the success factors of strategic partnerships between universities and business. It describes the experience of creating a unique interdisciplinary practical-oriented Master Programme "Building Design for Sustainable Development", developed according to the most modern educational standards within the international project "Master Degree in Innovative Technologies in Energy Efficient Buildings for Russian and Armenian Universities and Stakeholders". The Programme was developed in cooperation with the members of the consortium, which includes four Russian, two Armenian and five EU universities, European Civil Engineering Education and Training (EUCEET - Association). Work on the educational programme was conducted in close cooperation with employers - leading enterprises in the field of construction and energy in Russia, Armenia and Italy. The educational process should be modern and effective, taking into account the Bologna Process, which introduced the concept of a practice-oriented approach to the development of educational programmes. In this context, the role of employers is of fundamental importance, since they will establish links with the labor market.

Another effective way to achieve these results are international student olympiads and competitions organized by world business leaders in the production of building materials, construction and architecture. Experience has shown that this is an important step in the interaction of the students of the master's degree programmes and the stakeholders. Motivation of students: the acquisition of practical design skills, taking into account the latest achievements in the field of construction and architecture. Motivation of the organizers of international competitions and competitions: acquaintance of the younger generation of
builders and architects with materials and developments of a specific corporation or manufacturer; attraction of the most talented students and trainees at operating enterprises; intensive coverage in the press, the internet and other media. Summing up, international student olympiads and competitions are an active and mutually beneficial partnership in education and business.

1 INTRODUCTION

The tasks of ensuring innovative development of the economy and the formation of a knowledge-based society require studying the interaction between different institutions in the spheres of education and production. Integrative interaction of such institutions gives a multiplier effect, such as, in particular, the experience of China, Israel and Finland [1]. The level of development of any state is directly determined by the effectiveness of its economic sphere. Every developed economy is formed under the influence of a number of factors: successful business, high level of citizens' education, well-formed and well-functioning educational system. The interaction of the identified factors is also important. So, cooperation (partner interaction) of professional education and business has been and remains one of the main factors of the development of Russia's human resources.

The main driving force for the development of cooperation is the mutual interest of the state, vocational education and business in the training of professional staff whose knowledge, skills and professional competencies meet the requirements of modern innovative economy. Training of qualified employees for such a huge and diverse country like Russia can’t be provided by the efforts of only education or only business. Effective and responsible cooperation of all stakeholders from education and business is necessary. The growing openness of the national economy, the growing mobility of financial resources and labor potential are forcing radical measures to be taken to ensure the reproduction of labor resources and their compliance with the requirements of competitive enterprises [2,3].

In conditions of increasing the requirements of the society to the effectiveness of education in terms of the effectiveness of total costs, the need to meet the expectations of students for decent employment, most often the initiator are technical universities with traditions in the field of applied scientific researches and their implementation [4]. One of the most common forms of integration in this case is the development of practice-oriented master programs. Thanks to this form, the synergistic effect is achieved through the use of the capabilities of industrial and laboratory equipment in the educational process, targeted research in master's thesis and the exchange of knowledge between teachers, undergraduates and industrial workers.

2 MASTER’S DEGREE PROGRAM

The Institute of Civil Engineering and Architecture of the Ural Federal University named after the first President of Russia B.N. Yeltsin implements the unique interdisciplinary Master’s Degree Programme «Building Design for Sustainable Development». The educational programme is developed according to the most modern educational standards within the framework of the international project ERASMUS + "Master Degree in Innovative Technologies in Energy Efficient Buildings for Russian and Armenian Universities and Stakeholders" (MARUEEB).
The Programme corresponds to the trends and requirements of the 2030 Agenda for Sustainable Development, adopted in September 2015 by the leaders of 170 countries at the UN General Assembly in New York [5,6]. The UN Programme contains 17 integrated, interrelated and indivisible goals of sustainable development, which include a universal, flexible and comprehensive plan of action for the world community.

The concept of sustainable development has emerged in the process of combining the three main points of view: economic, social and environmental. It implies the adoption of measures aimed at the optimal use of limited resources and the use of environmentally-friendly, energy- and material-saving technologies, the preservation of the stability of social and cultural systems, and the integrity of biological and physical systems [7].

Although all 17 Global Sustainable Development Goals are interrelated and important, we distinguish among them two especially important. SDG 7: Ensure access to affordable, reliable, sustainable and modern energy for all and SDG 12: Ensure sustainable consumption and production patterns [8].

Currently, the effective use of energy is a worldwide concept. Many countries, even those with large reserves of natural resources such as natural gas, oil and coal, have realized the importance of preserving their resources so that they can be used for a longer period [9,10]. In order to develop and implement steps to improve energy efficiency, special attention should be paid to the education sector, to train a new generation of engineers "equipped" with specific technical knowledge and management skills in the field of energy efficiency.

Current climatic conditions of Russia are characterized by cold winters and hot summers. According to this, an integrated approach is required to solve the problems of reducing energy consumption for heating and air conditioning therefore future specialists should have high-quality modern knowledge related to activities and methods for improving the energy efficiency of buildings and structures. The MARUEEB project aims to develop and implement innovative master's educational programmes to train a new generation of civil engineers and architects with in-depth knowledge of energy efficiency and energy saving. The Programme "Building Design for Sustainable Development" was developed jointly with the members of the consortium (Table 1), which includes four Russian, two Armenian and five European universities, European Civil Engineering Education and Training (EUCEET - Association).

On the other hand, the educational process should be developed in a modern and effective way, taking into account the Bologna Process, which introduced the concept of student-centered approach to the development of educational programmes. In this context, close interaction with business and the labor market is mandatory, because they represent future employers (employers – Stakeholders) of students enrolled in a magistracy [11]. Employers' participation is considered significant when formulating the specific content of educational programmes in order to ensure students' interest in employers' companies and the ability of graduates to find work as close to the profile of training as possible. The student-centered approach requires a change in the consciousness of the faculty staff responsible for developing and implementing curricula, in terms of learning outcomes that must be achieved in accordance with the level of education (for example, bachelor's, master's).
Table 1: Members of the MARUEEB Project Consortium

<table>
<thead>
<tr>
<th>Russian and Armenian members</th>
<th>EU members</th>
<th>Employers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ural Federal University (Russia)</td>
<td>University of Genoa (Italy)</td>
<td>Engineering Academy of Armenia (Armenia)</td>
</tr>
<tr>
<td>Peter the Great St. Petersburg State Polytechnic University (Russia)</td>
<td>Second University of Naples (Italy)</td>
<td>Ministry of Education and Science of Armenia (Armenia)</td>
</tr>
<tr>
<td>Tambov State Technical University (Russia)</td>
<td>Slovak Technical University (Slovakia)</td>
<td>TICASS Consortium (Italy)</td>
</tr>
<tr>
<td>Voronezh State University of Architecture and Construction (Russia)</td>
<td>Technical University of Iasi (Romania)</td>
<td>European Association for Building Education and Retraining EUCET (Belgium)</td>
</tr>
<tr>
<td>National Polytechnic University of Armenia (Armenia)</td>
<td>Kaunas University of Technology (Lithuania)</td>
<td>AE Consulting (Armenia)</td>
</tr>
<tr>
<td>American University of Armenia (Armenia)</td>
<td>Non-profit partnership “Atomstroykompleks” (Russia)</td>
<td>Center for Building Expertise of R&amp;D (Russia)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Full cycle project company “Uralproektubrava” (Russia)</td>
</tr>
</tbody>
</table>

Employers’ participation is considered significant when formulating the specific content of educational programmes in order to ensure students’ interest in employers' companies and the ability of graduates to find work as close to the profile of training as possible. The student-centered approach requires a change in the consciousness of the faculty staff responsible for developing and implementing curricula, in terms of learning outcomes that must be achieved in accordance with the level of education (for example, bachelor’s, master’s) [11].

At present, many educational programmes are developed on the basis of traditions, available resources and interests of the teaching staff, therefore they can be considered as "based on the existing base" and "focused on the teaching staff." In other words, they are more focused on the structure than on the students. The transition to a student-centered approach is a process that is currently taking place all over the world, and the goal of this transition is the introduction of an innovative process of developing educational programmes. In particular, the emphasis is on the fact that the results of the training should be in accordance with the objectives of the programme, meet the needs and expectations of students and society, aimed at ensuring their employment after graduation, development of personality and citizenship [11].

All this underscores the importance and necessity of organizing positive cooperation and creating solid relations between higher education institutions and employers, which become central figures in the process of developing educational programs, because they will be the ultimate beneficiaries of the educational process. The importance of the relationship between universities and employers is emphasized in the MARUEEB international project, since the first stage of the project is represented by a survey of about 100 enterprises and organizations in Russia and Armenia in order to perform an analysis of labor market needs and understand what are the demands from business and society in the regions of implementation of the developed educational programmes. The interest of business also lies in the fact that within
Thus, the educational Programme "Building Design for Sustainable Development" was formed in an optimal way, based on the needs of the local business community.

3 OLYMPIADS AND COMPETITIONS

An effective way to achieve these results are International Student Olympiads and Competitions organized by world business leaders in the production of building materials, construction and architecture. Experience has shown that this is an important step in the interaction of the students of the master's degree programme and the stakeholders. For example, in 2017, PERI first launched the "Universities" project, within the framework of which it held the PERI Championship among construction universities. During the preparation for the Championship, engineers and project managers read 150 lectures for students across the country [12]. The aim of the Championship is to give students a real opportunity to expand theoretical knowledge, gain invaluable practical experience and make useful acquaintances with professionals in the construction industry. For the Company it is an opportunity from the very beginning to be close and participate in the formation of future specialists. Today, students learn the basics of the profession, and in the future they will become employees of construction and industrial companies. And perhaps they will become part of the PERI team.

Another example is the International Contest "Designing a Multicomfort House", organized by the Saint-Gobain Company. Saint-Gobain is a world leader in creating a comfortable space for living, working and resting. The student competition has been held since 2005 on many countries of the world as part of the implementation of a global strategy to reduce emissions of carbon dioxide into the atmosphere. Russia joined the project in 2011, and over that time, it was attended by more than a thousand students from different regions of the country, each of which had the opportunity to manifest itself in the field of modern architecture [13]. Every year, students develop new projects of modern facilities and infrastructures on the territory of different cities of the world, with contrasting climatic conditions, for example Astana in Kazakhstan or Dubai in the UAE. When designing, they take into account not only the features of climate and territory, but also how to intelligently integrate the object into the concept of a complex of knowledge about the cultural and historical heritage of the city. And there are a lot of such examples.

Participation in Contests and Olympiads forms the following competencies for students:
- stable career growth;
- managerial and leadership skills;
- motivation to actively participate in a difficult and interesting program;
- interpersonal and communication skills;
- a clear vision of own professional development;
- ambitiousness and commitment.

Motivation of students: the acquisition of practical design skills, taking into account the latest achievements in the field of construction and architecture; the possibility of further cooperation in the scientific and research field on the basis of enterprises and design organizations and even employment; international cooperation with young scientists and
students from different countries, etc. An important quality that a student acquires in participating in Contests and Olympiads is the ability to work in a team, which at the present stage is considered as the basic competence of a person, since it affects the quality of the joint work and at the same time determines its results and success [14, 15].

Motivation of the organizers of International Olympiads, Championships and Competitions includes:
- acquaintance of the younger generation of builders and architects with materials and developments of a specific corporation or manufacturer;
- attraction of the most talented students and trainees at operating enterprises;
- intensive coverage in the press, the internet and other media.

Summing up, International Student Olympiads, Championships and Competitions are an active and mutually beneficial partnership in education and business.

Thus, the cooperation between education and business is beneficial to both parties, and this implies the main goal of pedagogy - to determine the methods that help students to see, know, develop and find their place in the future profession.

4 Conclusion

The high importance and lack of the interaction between education and business determine the novelty of futtick development of the proposed forms of cooperation. The main result is an integrated approach to the formation of the relationship between the subjects under consideration. Education and business should function in a constant mutual influence and mutual support, thus setting the pace of development of the economy and the state as a whole. The proposed forms of interaction allow us to reconcile the spheres of social life that are divergent at first glance into a single direction, and also to eliminate the most important labor market problems: supply and demand discrepancy, and unemployment.

References


ASSESSMENT OF CIVIL ENGINEERING EDUCATIONAL SYSTEM IN IRAN: PROBLEMS AND SOLUTIONS

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Key words: Engineering Education, Curriculum, Civil Engineering, Iran Universities, Educational Program.
Abstract. Engineering education is a mighty driver of society growth and is one of the most effective instruments for eradicating the poverty and essential task for improving economy and social facilities in each country. A good educational system in university that ensures learning for all students provides them with necessary skills for success in both academic job and industry. This paper has comprehensively evaluated civil engineering educational program in universities of Iran. One of the weaknesses of education system in Iran is that the society is suffering from educational inflation and paper qualification which lead to a painful situation to the economy of this country. For instance, in the year 2001, two millions and two hundred thousand people attended the university entrance exam, which has fallen to 800,000 in 2015. Evidently, it has reached to less than half in a decay. Therefore, by reduction of applicants’ population in the recent years, many of the capacities and created costs for educational system are becoming useless.
1. INTRODUCTION.

Civil engineering may be divided into a wide spectrum of sub disciplines: Construction of buildings, bridges, dams and tunnels are the first duties of a civil engineer that comes to mind, as they are their most impressive creations. However, the basic fields of civil engineering in most of the countries are categorized in construction engineering, structural engineering, geotechnical engineering, transportation engineering, surveying, water resource engineering and environmental engineering. Construction engineering deals with planning, building and maintenance of structures [1]. Construction engineers turn analysis and design into reality, which is the tangible part of each project. In the structural branch, engineers are focusing on analysis and design of structures. Geotechnical engineers analyze the behavior of the rock and soil, which affect the response of underground and above structures [2]. Transportation system of each country builds the economic infrastructure of that country [3]. Transportation engineering deals with analysis, design, construction and maintenance of all types of transportation facilities. The surveying branch is related to surveying and levelling of lands using different engineering facilities and mapping. Water resource engineers are responsible for physical control of water, which leads to design and construction of hydraulic structures such as pumping stations, dams and water distribution systems. Environmental engineering have become increasingly common since it deals with sewage management, purification of water/air systems and treatment of chemical wastes.
2. A BRIEF HISTORY OF HIGHER EDUCATION AND CIVIL ENGINEERING IN IRAN.

The first civil engineering institution in England was established in 1818 in United Kingdom-London and the dominant engineer Thomas Telford became its president in 1820. Throughout the history, Persia (Iran) always has been a cradle of science. Shapur 1 of the Sasanian Empire in 240 A.D. built the oldest university of the world with the name of Jundishapur. This university was one of the most important medical research center of that time. Jundishapur University has played an important role in the fields of Alchemy (Chemistry) [3], Biology and medical sciences. Iranian, Greek, Indian and Romanian scholars carried out their scientific investigations there. The history of civil engineering in Iran backs to the year 1934, when Tehran University (UT) was founded. UT is the oldest modern university of Iran, which was established by the court minister of the Pahlavi dynasty Abdolhossein Teymourtash and is known as the mother University of Iran [5]. Natural science and Mathematics, Theology, Literature (Philosophy and educational sciences), Medicine, Law (Political science and economic) and Engineering were the first faculties of UT. Presently, UT contains 16 faculties, over 500 fields of study, 260000 alumni and more than 2000 assistant professor/associated professor/full professor [6]. Civil engineering department of UT offers 10 fields of study, leading to the degree of Bachelor of Science (B.Sc.), Master of Science (M.Sc.) and Doctorate of Philosophy (Ph.D.) that were authorized by Ministry of Science Research and Technology (MSRT) in Iran [7, 8].
3. AN OVERALL REVIEW ON CIVIL ENGINEERING IN IRAN.

Since education in civil engineering is a decisive component for development of every society and its economy, all countries all around the world have created various types of educational system to help their people and society to grow up. In Iran, civil engineering at graduate level is divided into three groups: civil-civil, civil-survey and civil-water. Students of civil-civil deal with the problems of structures and earthquake, geotechnics, hydraulic and transportation [9]. When the location of the structures is determined, surveyors identify the boundaries and features of the property to determine the site circumstances since during their education they acquire the profession of determining three-dimensional positions of points, distances and angles between them. Civil-water engineering in Iran at graduate level is concerned with quality and quantity of water resources, which are located in both underground and above ground. This branch of civil engineering is intimately connected to the analysis and design of pipelines, water supply networks and hydraulic structures. In Iran full time Bachelor, master and doctorate students in civil engineering will be anticipated to perform their degree in 4, 2 and 4 years respectively. The aim of bachelor degree in civil engineering is to educate generalist engineers who have solid foundation in this field of engineering [10]. Therefore, the B.Sc. program’s student in Iran should pass 142 credits, which contain 22 credit of general courses, 25 credit of core courses, 14 credits for elective courses, and 81 credits for specialized courses. Master program in Iran normally involve 30 credit units and has a duration of one academic year for passing the courses and in the following year, candidate should perform 6-credit thesis. There are not huge differences between different
academic degrees in UT and other universities in Iran since, all of them are regulated by Ministry of Science, Research and Technology (MSRT). However, according to the major fields of department’s professors, the elective courses may be changed in different universities. Ph.D. program, as the highest academic degree in the world, might be pursued by two different ways: course-based and research-based [11]. The most classical-form of Ph.D. is course-based. In this type of doctorate program, students are obliged to attend the classes and pass the defined courses. After taking part in these classes, in the fourth semester they have to take a general exam, which is a combination of all presented courses in the past semesters and so called comprehensive exam. This is the most difficult part of doctorate program in Iran since usually questions are posed as challenges and it is expected that deep and thoughtful answers will be given to these questions. Essentially the main purpose of comprehensive exam is that the student who participated in different classes, shows his/her knowledge in various educational fields. In other words, student must be able to prove his/her mastery of the subject. The most anxious thing about the comprehensive exam is that, you can only fail once in the exam and if you fail that for the second time, you will be expelled from the university.

4. CHALLENGES OF CIVIL ENGINEERING IN IRAN.

Evaluation of the differences among engineering educational systems among different countries may leads to create a better Iranian educational system by incorporating the positive aspects of different assessed systems. One of the weaknesses of civil engineering educational system in Iran is that engineering education is not considered as an investment for industrial system
growth since, the education system emphasizes on increasing the knowledge and neglect the growth of skills. There are many different things that could cause the mentioned problem. For instance, lack of engineering activities and laboratory equipment have an adverse effect on increase of skill, growth in achievement and performance of civil engineering students. Therefore, In the current system, there is a tendency toward education of engineers who are ready to have academic or theoretical jobs but not operative ones such as the ones increasing and improving national production or fulfilling the technical needs of the country. One strategy that can be used in this context is having long term planning for civil engineering students, which includes increasing the budget for establishment of equipped laboratories and at the same time enhancing professional job opportunities. Other strategies that may be used are presenting practical courses, making students familiar with real projects and preparing them for getting inside the industry. Paper qualification in Iran leads to a painful situation to its economy. In table 1, statistics of students and universities in different countries are provided. According to the last announcement of Ministry of Science, Research and Technology (MSRT), Iran with 80.28 Million population has 2640 universities which is 5 times more than developed countries, among which the share of public universities from the student population is 68% and 32% is the share of private ones. China and India with 1.415 and 1.342 Billion population have 2481 and 1620 universities respectively. In Iran in the year 2001, two millions and two hundred thousand people attended the university entrance exam, which has fallen to 800,000 in 2015. Evidently, it has reached to less than half in a decay. Therefore, many of the capacities and human resources for the Iranian educational system are becoming useless by reduction of applicants’ population in recent years. Since
Globalization is a process of interaction and alliance between different people, societies, universities and organizations, one of the most effective solution for the above mentioned problem is enhancing international collaboration of universities in Iran with the first level universities of developed countries, which leads to have foreign exchange programs, balanced quality and quantity of educational services with applicants’ quantity and an increase in the number of professional organizations. Moreover, following novel educational methods such as virtual learning or e-learning lead to flourish students’ creativities and increase collaboration between students and professors of different universities.

Table 1. Statistics of students and universities in different countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Population (Million)</th>
<th>No. of University</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>1415.05</td>
<td>2481</td>
</tr>
<tr>
<td>India</td>
<td>1342.5</td>
<td>1342</td>
</tr>
<tr>
<td>Germany</td>
<td>82.30</td>
<td>412</td>
</tr>
<tr>
<td>Iran</td>
<td>80.28</td>
<td>2640</td>
</tr>
<tr>
<td>England</td>
<td>66.57</td>
<td>291</td>
</tr>
<tr>
<td>Italy</td>
<td>59.29</td>
<td>236</td>
</tr>
<tr>
<td>Canada</td>
<td>36.89</td>
<td>329</td>
</tr>
</tbody>
</table>

5. CONCLUSION.

There are some major problems in today’s civil engineering education system of Iran, which should be addressed and solved, if the future of the country has to be secured. In the current system, tendencies of graduates are more toward education of engineers who are ready to have academic jobs but not operative
jobs such as increasing and improving national production or meeting technical needs of country. One strategy that can be used in this context is having long term planning for civil engineering students, which includes increasing the budget for establishment of equipped laboratories and at the same time enhancing professional job opportunities. Other strategies that may be used are presenting practical courses, making students familiar with real project and preparing them for getting inside the industry. Paper qualification in Iran leads to a painful situation to the economy of Iran. Moreover, many of the capacities and human resources for the Iranian educational system are becoming useless by reduction of applicants’ population in recent years. One of the most effective solution for this problem is enhancing international collaboration of universities in Iran with the first level universities of developed countries, which leads to have foreign exchange programs, balanced quality and quantity of educational services with applicants’ quantity and an increase in the number of professional organizations.

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CIVIL ENGINEERING EDUCATION PROGRAM IN RESPONSE TO THE INFRASTRUCTURE DEVELOPMENT IN RECENT YEARS IN VIET NAM

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Key words: AASTHO LRFD, SNIP 02, INFRASTRUCTURE, VIET NAM, EDUCATION PROGRAM

Abstract. The development of infrastructure systems including long-span bridges, highways, high buildings, large dams, etc… requires graduates to acquire certain knowledge to meet the demands of working positions in many foreign consultancy companies and entrepreneurs. At traditional thought on the work of civil engineering, there is a concern on the balance between the design philosophy of Soviet-Union standards and the new design philosophy under ASSHTO’s standard systems. This study’s contribution is to clarify the advantages and disadvantages of the new civil engineering education program, developed for undergraduates at University of Transport and Communications (UTC), to adapt to job requirements of foreign companies in the designing and construction of infrastructures in Viet Nam based on ASSHTO’s standard system.
1 INTRODUCTION

In current years, along with renovations in state policies, Vietnamese Government has made considerable socio-economic achievements. These achievements are represented through impressive indices of the economic growth which one of all is GDP (Gross Domestic Product) with an increase of 6.68% in 2015, and 6.81% in 2017. Along with economic development and adaptation, motivation of economy, culture, education and national security, infrastructure has been ceaselessly improved in Viet Nam. It was showed off through representative constructions as high buildings, which more and more pop up to replace tenement houses being degraded in inner city and to meet housing of city dwellers in belt areas or outskirts, as well as commercial demand. Typically, some skyscraper such as AON Landmark 72 Building, Bitexco Financial Tower, or Lotte Center Ha Noi Building, can be mentioned. Along with that, infrastructure systems of transport have been also enlarged and constructed progressively. In Viet Nam, highways, large bridges, tunnels, metropolitan railways of transportation infrastructure have been invested and constructed intensively. Some outstanding constructions could be mentioned: Hai Van tunnel, Thu Thiem tunnel, Deo Ca tunnel, Can Tho Bridge, Bai Chay Bridge, Metropolitan railways in both Hanoi and Ho Chi Minh City.

![Dragon bridge](image1.png) ![Ha Noi - Hai Phong expressway](image2.png)

**Figure 1:** Some typical projects in Viet Nam

Particularly in road transport, according to statistics [1] in 2010, the total length of roads in Vietnam is 258,200km with national road and highway accounting for 18,744km of length. By 2014, the total length of roads had extended to 300,000km and national road systems lengthened to 19,457km. This shows the significant development of infrastructure in Viet Nam in current years. However, in order to ensure the rapid, quality and stable development, skillful and high quality human resource are needed. These resources could be supplied by engaging experts from developed countries like Japan, South Korea, France, and Australia in short-term… However, in long-term, to sustainably develop by domestic resource and to suit Vietnam’s economic conditions, engineers and human resources should be proactively educated and trained in Vietnam. This is appropriate although it would cope with a great deal of difficulty in recent circumstances in Viet Nam. In spite of impressive records of developments, Vietnam is still a developing country with a starting point as an agricultural
country. Nevertheless, along with the integration in economy, education and culture, difficulties have been overcome to train human resources corresponding with demands.

With difficulties enlisted above, to meet the need of human resources for roads and bridges infrastructure developments, UTC has properly innovated and improved its curricular. Specifically, in order to catch up tendency of deep and large integration and collaboration of Viet Nam with developed countries, the university has established the proper syllabus which is upgraded with educational system of developed countries for road and bridge engineers. Using to train alumnus, apart from old knowledgeable systems which are still needed in the courses, the university has added more major documents, learning resources and standard from developed countries. To be more detailed, the new standards of road-bridge engineering [2, 3, 4, 5] have been integrated into syllabus apart from the older standard [6, 7, 8, 9]. Besides amendments in systems of documents, UTC has also changed its educational approach for students by adapting to new knowledge supplemented. Thanks to such changes, graduates from UTC have met working assignments in infrastructure development.

2 THE LIMITATIONS OF THE PHILOSOPHY AND DESIGNED METHODS BASED ON BRIDGE AND CULVERT STANDARDS OF THE SOVIET UNION (BASED ON SNIP 02) ARE TAUGHT TO ENGINEERS OF UNIVERSITY OF TRANSPORT AND COMMUNICATIONS

Design standards of bridge and culvert of the Soviet Union, which is a basement of Snip 02 and Design standards of bridge and culvert 22TCN 18-79 of Viet Nam, is one of the first generations of its system based on the limited state methods. The working state of structures is divided into two ranges: one range maintaining working capacity and the other one having no working capacity. Two ranges are separated by a set of limited state. Checking formula according to this standard is:

\[ N \leq F \cdot R \]  

Of which:

- \( N \): is calculating force.
- \( F \): characteristics of section.
- \( R \): corresponding calculated strength.

By 2001, all bridge and culvert constructions in Vietnam calculated and designed are based on standard system which is built according to design standards of bridge and culvert of the Soviet Union. In order to synchronize with the system of designing standards, those regarding exploitation appraisal are built on Russian system. Over times, these standards have proven their effectiveness, efficiency and convenience in practice. Formula system of standards based on fundamental principle of mechanics, elastic theory, so generations of engineers and students educated by university of transport and communication absorb, apply creatively all knowledge learnt in practice.

In spite of positive side, this system of standards also shows its shortcomings. Steel structure only considered capacity of materials in elastic stage. For concrete structure, working of concrete beyond its elastic limitation was considered but all calculations still were based on elastic theory. It is the drawback of the standard system. Therefore, it can be see that mechanical properties of material in structure could not be maximized. Meanwhile, the value of the representative resistance, given for comparison with the multiple effects, is not the real
resistance of the structure due to the stability impact considered in a separate state. In addition, prestressed concrete structure did not take into account the tensile strength of concrete, leading to an overly safe design of the structure. This may lead to waste of materials forming up the structure. Especially as the quality characteristics of the material has been greatly improved nowadays. This was reflected in the size of large bridges when applying this standard design system.

3 USING AASHTO STANDARD SYSTEM IN DESIGN OF TRANSPORTATION CONSTRUCTION.

With a demand for innovation and integration, standard systems from developed countries have been introduced to students in the bridge and road sector in Vietnam. Typically, the standard generation system of the AASHTO LRFD has been gradually applied to substitute the standard of the Soviet Union for calculation and design of road bridges.

The AASHTO LRFD standard system is a new generation of standards in the world based on advances in bridge construction. With complete principles and logical approach, using this standard system in designing and calculating bridges, would ensure the safety of the work from the construction to the exploitation stage and aesthetics. Ideology, design philosophy in line with other major design standards have been approved and have been developing in both Asia and Europe and in the field of structural engineering in general. There are advantages from the familiarity of the limited state method like design standards of bridge and culvert of the Soviet Union but the AASHTO LRFD system applies theories of probability to guarantee reliability and safety of the works at a certain level. The checking formula for this standard is [2]:

$$\Sigma \eta \gamma Q_i \leq \phi R_n$$

(2)

In which:

$Q_i$: force effect.
$R_n$: nominal resistance.
$\gamma$: load factor.
$\eta$: load modifier.
$\phi$: Resistance factor.

Throughout the study, application of the AASHTO LRFD standard system has shown the advantages that have overcome the disadvantages of the Snip 02 previously applied in Vietnam in designing bridges. The application of this standard system in design and calculation of structures allows to exploit the characteristics of steel outside the elastic range. In calculation, the interaction between the stability and the working properties of steel would be considered together, thus the calculated resistance is the real resistance. This allows a better exploitation of working ability of the material, so the structure designed could be slender, aesthetic and would be more economical in using materials. Besides, on the basis of statistical probability theory, the statistic of impact loads was taken into calculating model in accordance with the real load. This ensures the sustainable exploitation without the overload in service stage.

As well as any standard system, although it is advanced, the usage and application of the
standard would still meet hidden difficulties. Based on the theory of reliability and statistical probability, calculating coefficients taking the checking formula into account would only ensure engineers to be able to use in design but would understand the root of these coefficients. It implies that engineers and user have to read the instructions carefully and to remember the formulas in the standard mechanically.

4 EVALUATING OPPORTUNITIES AND DIFFICULTIES WHEN IMPLEMENTING TRANSFORMATIONS, UPDATING STANDARDISED SYSTEMS AND CHANGES IN TEACHING SYLLABUS

Unlike some developed countries in the world, young generations in Vietnam get great financial support from families even during adulthood, which has been profoundly brought by long-standing cultures in education. This has an impact on teaching methods in education. Influenced by the out-of-date methods of educating as well, young generations in Vietnam lack, in their daily life, quite a number of aptitudes such as: social skills, living skills and self-study skills, self-reliant skills which to larger or lesser extent, it impedes the creativity and the ability of study on their own. Students in the major of civil engineering are no exception, therefore the methodology and syllabus must solve these issues in a way that keeps abreast of innovations and integrations, but well suits the characteristics of Vietnamese young generations as well.

In recent years, knowledge and information that UTC taught and instructed for students have been upgraded and innovated based on the development of achievements obtained. In civil engineering discipline, there is a difference between Vietnamese students and students of developed and other countries: foreign students are provided with foundational knowledge, followed by attaining considerable expertise in a specific area after graduating, while in Vietnam, almost all colleges tend to educate student following specific fields right from the start. This approach basically causes two main issues for learners: firstly, some learners could not make the decision of choosing a major shortly after finishing high school; secondly, students tend to face more hurdles in switching to other areas, though areas are in the same field.

From these points, University of Transport and Communications has established a syllabus that is suitable for students in the civil engineering discipline. As regards the difficulties mentioned above, namely low independence and low self-contained competence, the syllabus has been set up to tackle these weaknesses in order to, although curriculum innovated and applied advanced methods from developed countries, still suit the characteristics of Vietnamese students. Besides that, the syllabus helps to improve active learning ability among students: simultaneously the study will concern the interactions between lecturers and students, and between students together. Students attend classes not only to gain knowledge but also equip themselves with self-study and boost enthusiasm in learning. This approach enables students to be actively engaged in scientific research activities which intend to be systematic studying right when at university [10]. This would be truly beneficial for learners when they have intentions to switch to other areas in the same field. Self-study meets the demands of work to learners and sometimes it would meet the need of knowledge and innovation for the world [11], which is the key to success in career and life.

More specifically, there has been the innovation of syllabus in the civil engineering
discipline at University of Transport and Communications, Vietnam in recent years. Specific major in the transport construction field are trained thoroughly to students. The module has been changed from yearly based system to course credits. This module enables competent students to graduate earlier and also to gives those more choices to accomplish the required credits. Besides that, materials and standards have been updated from developed countries, however the key contents have also been retained to be suitable for the situation of Vietnam.

It is clear that along with design standards of bridge and culvert of the Soviet Union and Snip 02 of Russia [6, 7, 8, 9] that was previously included in teaching lessons, new criteria and materials of AASHTO LRFD [2, 3, 4, 5] have also updated into the syllabus. However, there were significant differences between these standards, thus if all knowledge and contents are taught and instructed for students, then volume of knowledge would be excessive, and students would be passive in the way that they absorb knowledge. Therefore, contents of the knowledge and standard system have been comprehensively summarized by experts and premium lecturers to deliver to students. Specialized knowledge of majors are taught to students in the final year after they gain a grasp of foundational subjects in the previous years as in some foreign countries. Teaching methodology has been transformed to stimulate independence in learning. There used to be one-side interaction from lecturers in almost all subjects, which lessons have divided into 2 sections: theory and discussion. During discussion time, students are supposed to prepare for the topics to interchange with lecturers. This profoundly increase self-study and interactions between students together, between lecturers and students as well. Furthermore, students have built for themselves methods of self-study not only while studying in university but also they do the real work.

5 CONCLUSION

- Thanks to improvements in college syllabus to keep up with latest trends in all fields at global level, there have been significant achievements in upgrading syllabus for students in the major of civil engineering. The robust evidence lies in high proportions of students getting a job related to the major when graduated from universities. In addition, graduates in civil engineering at University of Transport and Communications have taken part in foreign invested projects and met the criteria set in the field. They have been also engaged in tasks of other majors such as civil constructing, irrigating. It can be seen from their positions in the jobs that they took part in and master of technology in large and complex constructions. This indicates the result of self-study which is consequence of innovating syllabus.

- System of latest standards has been updated into teaching and quickly comprehended by learners. Especially, graduates in civil engineering discipline have a good command of criteria system of Russia and AASHTO. They are well-adjusted and complete the assigned duties pretty well. Standards of AASHTO LRFD are widely used in designing new bridges in Vietnam. Standard of Russia are still flexibly used in appraising old bridges and designing railway bridges. At the same time, system of criteria of EURO CODE, BS, CEB-FIP, and SETRA… are studied by Vietnamese engineers to meet the needs of their jobs or related projects.
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DOCTORAL COURSES (IN GEOTECHNICAL ENGINEERING):
WHAT HAS BEEN CHANGING IN ITALY IN THE LAST 30 YEARS

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Key words: Education, Civil Engineering, Doctoral Schools in Italy.

Abstract. Doctoral schools in Italy began on middle 80s. Since that the objectives and fundamental rules for the third level of Higher Education in Italy changed several times. The paper shows the legislative evolution and reports, in a narrative way, the experience of 5 Ph. D. in Geotechnical Engineering over a period of 30 years (from 1987 to 2017). The narration focuses on general rules, availability of grants, tutorage and evaluation board, pointing out positive and negative aspects of the many changes occurred over 30 years. Ph. D. Courses in Italy are regulated by National Laws approved by the Parliament. The main conclusions can be summarized as follows: a) the recently introduced requirement of educational credits acquisition did not change the spirit of Doctoral studies that are mainly oriented to strength the students’ research skills; b) based on the Authors’ experiences it is strongly advised to promote Doctoral Schools restricted to specific subject areas in which the teaching staff and the members of the Council belong from different institutions (Consortia); c) Bilateral Agreements for double or multiple degrees are really encouraged.
1 INTRODUCTION

The Decree 382 (November 11th, 1980) of the President of the Italian Republic established the Doctorate in Italy. The main objective was offering to “future” researchers the possibility of carrying out original and innovative researches under the supervision of an expert or a Council of experts. The candidate was asked to produce a Ph. D. Thesis. He was also asked to defend the Thesis, firstly in front of an internal Jury, and thereafter in front of an external Jury. At that time, and somewhat also today, academia was the only occupation perspective of Ph. D graduates. People, not attending the Doctoral Courses, could be admitted to defend their Ph. D. Thesis. Public employees (Law 476 of August 13th, 1984) were encouraged to enter the Doctorate. Indeed, their position in the Public Administration was guaranteed during the Doctorate period. This type of doctorate appears very similar to those available in USA Universities.

The first fundamental change of Doctorate in Italy occurred on July 3rd, 1998 (Law No. 210 and subsequent Decree No. 224 of the Italian Ministry of Education, April 30th, 1999). These modifications reflected the addresses of the so-called Bologna Process. Doctorates became university study - courses with study programs and ECTS. Therefore, the possibility of defending the own Ph. D. thesis without admission and participation to the study-course programs was canceled. The production of a Ph. D Thesis remained but the emphasis was put on the education and training process of new Researchers (innovation and originality of the Thesis was no longer explicitly mentioned). The aim was also to enlarge the graduate employability in Public and Private Research Institution and Companies. Therefore, the Ph. D. degree is no more a pure academic title and the Ministerial Decree No. 224 strongly fosters the International cooperation and that between Academia and Industry.

Several steps were done until the Decree No. 45 of the Italian Ministry of Education (February 8th, 2013) that completed the transformation of the Doctoral Schools. This process put strong emphasis on the following aspects:

- multi-disciplinary study programs
- quality of the teaching staff
- degree of internationalization
- degree of cooperation with industry and socio-economical system;
- attractiveness
- facilities and resources

A National Agency was entrusted of evaluating, according to the above-mentioned criteria, the quality of Doctoral Courses. It is worth mentioning the impressive increase of the number of doctoral students. In the period 2000-2007 the number of students increased from 21290 to 39829. In the same period the Ph. D. graduates increased from 2919 to 10099.

2 EVOLUTION OF DOCTORATE IN ITALY

This chapter shows, in a narrative way, the progressive changes of Doctorate in Italy. In particular, the Authors illustrate their own experience focusing on the following aspects: admission rules, requested activities, composition of the Teacher Council, available research grants, experience at international level, assessment, recognition and post-doc perspective.
2.1 Doctorate in Geotechnical Engineering (Consortia of Northern Universities and Southern Universities)

Lo Presti graduated Ph. D. in Geotechnical Engineering in 1987. The Doctoral School of Geotechnical Engineering was a Consortium of four Universities: Technical University of Milan, Technical University of Turin, University of Genoa and University of Padua. The Council of the Doctoral School included the Professors of Geotechnical Engineering of the Consortium Partners. A National competition, with 5 granted positions, was announced for the admission to the Doctorate. The admission test consisted of a written and oral examination. The examination board admitted 5 students. The only requested requirements were the Italian citizenship and a M. Sc degree.

He had the honor to have Prof. M. Jamiolkowski as tutor and to be involved, since the first day, in the ongoing research activities at ENEL CRIS Milan and Ismes Bergamo [1,2]. Lo Presti was encouraged to attend various lectures, but he was not requested to obtain educational credits. The progress of his research activity, as well as of the other students, was periodically examined by the teacher board. The final written version of his Ph. D. Thesis [3] was examined by international expert before the official defense in front of an independent National Jury in Rome. Over five Ph. D. students of his cohort, three became professors of Geotechnical Engineering.

Squeglia graduated Ph. D. in Geotechnical Engineering in 1998. The Doctoral School of Geotechnical Engineering was a Consortium of two Universities: University of Rome “La Sapienza” and University of Naples “Federico II”. The Council of the Doctoral School included the Professors of Geotechnical Engineering of the Consortium Partners. A National competition, with three granted positions, was announced for the admission to the Doctorate. The admission test consisted of a written and an oral examination. The examination board admitted three students. The only requested requirements were the Italian citizenship and a M. Sc degree.

Squeglia’s tutors were Prof. Viggiani, Prof. Evangelista – from University of Naples – and Prof. Calabresi – from University of Rome. The topic of his thesis, “Electrokinetic properties of fine grained soils” [4], originated from a field experience carried out in Pisa to verify the possibility to use electroosmosis as means to stabilize the leaning tower [5,6]. During doctorate Squeglia voluntarily attended various lectures, to complete his preparation in disciplines useful for his studies such as electrochemistry, but he was not requested to obtain educational credits. The progress of his research activity, as well as of the other students, was yearly examined by the teacher board. The final written version of his Ph. D. Thesis was examined by teacher board before the official defense in front of an independent National Jury in Rome. Over three Ph. D. students of his cohort, two became professors of Geotechnical Engineering.

2.2 The Leonardo da Vinci Doctoral School (University of Pisa)

The Faculty of Engineering of the University of Pisa offered until 2012 Doctoral Courses in the framework of the Leonardo da Vinci Engineering Doctoral School. In the framework of such a School, the Civil Engineering area offered four different curricula (namely: Structural, Building, Hydraulic and Infrastructures/Transportation Engineering). Unfortunately, a curriculum in Geotechnical Engineering was not considered. The admission test consisted of a
written and oral examination, focused on a specific Ph. D. project proposed by the candidate. The only requested requirement was a M. Sc degree. There were a limited number of scholarships per year.

Ph. D. students were requested to attend a minimum number of classes i.e. a minimum number of lecture-hours such as 20-30 per year. A short non-comprehensive list of subjects includes the following topics: Tensor computation, English for writing papers, FEM and Numerical Methods, Advanced Continuum Mechanics. Students were also encouraged to attend/participate various Seminars/Workshops/Conferences/Courses organized by the Doctoral School as well as by other proponents. Participation to these events was intended to exchange information, present/illustrate the results and receive suggestions about the current research activities. In any case, the progress of the research activity was periodically (twice a year) examined by the School Council (Civil Engineering Area). Final examination was done by an ad-hoc Jury composed of external experts and members of the Council of the Doctoral School (i.e. a local Jury).

In between 2011 and 2012 the Doctoral School Leonardo da Vinci changed a lot, because of the new rules established by the Law N. 240 of December 30th, 2010 [7]. Indeed, according to the so-called Gelmini Law the Faculties were canceled and Doctoral Schools were mainly established at Department Level. It is important to remark that the Ministry granted only one Doctoral Schools for each Department. Moreover, according to the new rules, Departments with less than 50 Professors could not survive. Therefore, the Departmental reorganization of Universities created culturally heterogeneous structures in many cases. As for the University of Pisa, most of the Civil Engineering staff joined the International Doctoral School of Civil and Environmental Engineering (see next chapter). The Department of Energy, System, Territory and Construction Engineering, originated after the Gelmini reform, offered a curriculum named “Sciences and Techniques for Smart European Cities and Territories”. The Council of this Curriculum was very heterogeneous (Real estate, Urban Planning, Geotechnical Engineering, Transportation Engineering) and included a limited number of professors.

Cosanti was one of the last Ph. D graduates of the Civil Engineering Curriculum of the Leonardo da Vinci Doctoral School [8]. Based on the research results obtained during the doctoral studies Cosanti published 4 research articles in the Italian Geotechnical Journal [9-12] and 3 book chapters [13-15].

Pierotti obtained a scholarship that was granted by USL1 of Massa Carrara (a public body of the Italian Sanitary System for the control of safety conditions in underground mines). Pierotti graduated Ph. D. by discussing a Thesis [16] of Geotechnical Engineering in 2016 (Doctoral School Leonardo da Vinci, Curriculum “Sciences and Techniques for Smart European Cities and Territories”). Pierotti had three tutors: a) from the University, b) from the financing institution and c) from industry. Unfortunately, the objectives of the financing Partner diverged from the scientific objectives that have been initially established. Publishing of the output of her Ph. D. Thesis is underway.

2.3 International Ph. D. Course in Civil and Environmental Engineering (University of Florence, University of Pisa, University of Perugia and TU Braunschweig)

The International Ph. D. Course in Civil and Environmental Engineering is a Doctoral
Exchange Program established by a Consortium of one German University (Technical University of Braunschweig) and three Italian Universities (University of Florence, University of Pisa and University of Perugia).

This International Ph. D. Program was born in the early 2000s based on a Joint Declaration by the Hochschulrektorenkonferenz (HRK) and the Conferenza dei Rettori delle Università Italiane (CRUI) on Bi-nationally Supervised Doctoral Theses (‘co-tutelle de thèse’).

This Joint Declaration was developed taking into consideration the Sorbonne Declaration of May 1998 and the Bologna Declaration of June 1999, with the awareness that bi-nationally supervised doctoral theses will play an important role in the development of intra-European mobility of university researchers and in fostering the institutional co-operation between Italy and Germany.

In the first years, this Ph. D. Course was characterized by a real doctoral students’ exchange. Approximately the 40% of the enrolled students came from Germany and the other 60% from Italy. In the last years practically all the students came from Italy.

During the last ten years this Ph. D. Course changed its name at least three times. At the beginning the name was ‘Risk Management on the Built Environment’, then ‘Mitigation of Risk due to Natural Hazards on Structures and Infrastructures’, in 2011 (XXVII Cycle) became ‘Processes, Materials and Constructions in Civil and Environmental Engineering and for the Protection of the Historic-Monumental Heritage’ and finally in 2012 (XXVIII Cycle) the name assumed the current form.

In the same year (2012), the Agreement on a Joint Doctoral Program between the Technical University of Braunschweig and the University of Florence was signed. In this document the two universities stated to:

- recognize the result of the jointly supervised doctoral procedure and the validity of the doctoral degree awarded and
- jointly award the doctoral degree and issue a joint doctoral diploma.

Starting from 2012 (XXVIII Cycle) and up to now, the International Ph. D. Course in Civil and Environmental Engineering was structured in three different curricula:

- Solid, fluid and materials mechanics;
- Constructions design, verification and control;
- Environment, resources and security.

The overall teaching staff and the members of the Council of the Doctoral School are heterogeneous and composed by Italian and German Professors belonging to all the main areas of Civil and Environmental Engineering and Architecture. The number of Geotechnical Engineering Professors is substantially covered by the Italian teaching staff. In fact, from the German side there is only one Associate Professor in Geotechnical Engineering.

The admission to the Doctoral School takes place after a national/international and public competitive examination. The call for the students’ selection offered scholarships every year, funded by Universities and public or private institutions.

The admission procedure consists of two steps:
The requirement to attend the examination is the MSc degree (or an equivalent degree). According to the Ph. D. Course regulations (XXIX Cycle), was mandatory to spend at least 9 months abroad in one or more international Universities and as minimum 4 months at the Technical University of Braunschweig. Moreover, was mandatory to obtain a total of 40 educational credits by attending several seminars and lectures organized during the Ph. D. Course (1 credit was equivalent to 4 hours). The progress of the students’ research activities was examined by the Board of Teachers every 6 months during the Plenary Meeting which was held in Germany (at TU Braunschweig) in the month of May and in Italy (Florence, Pisa or Perugia) in the month of November. In the Plenary Meeting each student had to show the progress of its own research project with a presentation of 15 minutes (+5 minutes of discussion). This meeting lasted 3 days and the program offered in most of the cases enough time for individual meetings between tutors and students.

Stacul graduated Ph. D. in Civil and Environmental Engineering in November 2017, together with Banti and Giusti. They attended the Ph. D. Course enrolment examination in October 2013. The examination board totally admitted 11 students with only 10 scholarships. Stacul spent 6 months at the Institut für Grundbau und Bodenmechanik (Braunschweig) under the supervision of his German tutor and 3 months at the Research Laboratory of Geotechnical Engineering of the Vilnius Gediminas Technical University (VGTU). The final version of his Ph. D. Thesis [17] was reviewed by two international experts in Geotechnical and Pile Foundation Engineering (according to the Italian regulations) and by his two tutors before the official defense in Florence in front of an Examination Committee composed by 3 Italian and 3 German Professors. Based on the results obtained in this Ph. D. Thesis Stacul published 4 research papers in international peer-reviewed journals [18-21].

Giusti developed her research program mainly at the University of Pisa and at MIT. Indeed, she has been hosted by the Department of Civil and Environmental Engineering of the Massachusetts Institute of Technology for 5 months joining the Prof. Whittle’s research group. The experience at MIT has been developed within the MIT-UNIPI Project, an exchange program between the University of Pisa and the Massachusetts Institute of Technology that promotes and supports research collaboration between the two universities. Moreover, Giusti spent 4 months at the Institut für Grundbau und Bodenmechanik (Braunschweig). A part of the experimental activities was done at Pagani Geotechnical Equipment (Piacenza – Italy) that granted her scholarship. The defense of her Ph. D. Thesis [22] took place in Florence in November 2017. As mentioned before, to be admitted to the final defense, the thesis has been reviewed by two external professors, internationally recognized as experts on the specific topic (Piezocone test interpretation for transitional soils), in particular, Prof. M. Randolph (University of Western Australia) and Prof. G. Gottardi (University of Bologna). The reviewers were asked to judge the following aspects:

- Overall scientific merit: originality, relevance in the specific field, completeness;
- Methodology - Data Analysis: appropriate methods / suitable and exhaustive data
analysis;
- Introduction and bibliography: the introduction contains enough information on the object of the thesis, bibliographical references are suitable and complete;
- Research work description;
- Results: convincing and clearly presented results / suitable number and quality of tables and figures;
- Discussion and Conclusions: correct interpretation of the results / advance of the results in the research field.

In addition to that, as a condition for the candidate admittance to the final defense, the Italian and German tutors evaluated the thesis proposal and the overall research work, giving a grade.

Following the defense, the examination board of teachers had the possibility of asking for corrections and integration of the thesis. The research activity developed during Ph. D. studies gave her the possibility of publishing the following journal papers [10,23]. Other contributions are on the way.

Banti graduated with a Ph.D. in Civil and Environmental Engineering in November 2017. During her doctorate, Banti spent 6 months at the University of Braunschweig at the Institut für Grundbau und Bodenmechanik under the supervision of her German tutor. Moreover, Banti had the pleasure to be hosted for 3 months by Professor Dong Soo Kim at the Korea Advanced Institute of Science and Technology (KAIST) at the Geotechnical Centrifuge Testing Center, in Daejeon (South Korea). The final written version of her Ph. D. Thesis [24] was examined by both tutors and by two external reviewers. The external professors were two international experts on the specific topic of her thesis (seismic assessment of earth constructions). The final defense was debated in front of an examination board made up of 3 Italian and 3 German Professors and took place at the University of Florence.

Among the 11 students enrolled in our doctoral cycle (XXIX), 3 are now post-doc fellows in German Universities, and 4 are post-doc fellows in Italian Universities.

3 FINAL REMARKS

National Decrees or Laws can produce different results when applied in different contexts. Overall, it is possible to state that the requirement of credit acquisition did not modify the spirit of Doctoral studies essentially aimed at developing specific skills in doing research as well as many related soft skills. This aspect is very important, considering that the Higher Education system in Italy is quite adverse and critical with respect to the so-called Bologna process and in particular to the so-called student-centered approach. See as an example [25] and [26]. With this respect, doctoral studies represent the first and unique occasion for students to be the main subject of the learning process.

The quality of a Doctoral School mainly depends on the strength of the Teacher Council. It is preferable to have very specific Doctoral Schools (i.e. Geotechnical Engineering) or restricted to a given subject area (Civil Engineering). It is also preferable to have “many” profassors from different Institutions (consortia). Admission rules and assessment criteria seems to play a less important role. Therefore, it is strongly suggested to sign Bilateral Agreements for double (multiple) degrees.
REFERENCES


AN E-LEARNING-CONCEPT FOR RESEARCH BASED LEARNING IN STRUCTURAL DYNAMICS

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Key words: Education, E-Learning, Methodology, E-Learning, Wiki.

Abstract. As part of a joint research project between TH Köln and TU Darmstadt an e-learning-concept is being developed. This concept provides students with an opportunity to engage in research regardless of their semester and specific time within the academic year.

The project focuses both on educational development and on engineering research. The engineering part is about the load model for human induced vibrations, described in the guideline VDI 2038. The current load model needs revision and must be completed because of missing values for horizontal loads and differences compared to the latest load models used in biomechanics.

The e-learning-concept is evaluated in different areas, like the achievement motivation of the students, the acceptance of the concept and its effectiveness. Therefore, it can be regarded as a Scholarship of Teaching and Learning project.

The concept includes a wiki containing all basics of structural dynamics and measuring technology as well as information on the load model. The students work on small projects. The scope of their study is based on the required workload of the respective module. The students summarize their results in a new wiki page that subsequent students can use for their projects. The students shall obtain a good understanding of the connections between different modules and constitute a research community. They can participate in the research project in two optional modules within their bachelor curriculum, two optional modules within their master courses and in their bachelor and master thesis.

The results during the first year after implementation are predominantly positive. The students are commonly motivated and get a good understanding of the subject. The connection between research based learning and e-learning enables the instructor to supervise a lot of different student projects and the students can apply the newly learned contents to a larger research project.
1 INTRODUCTION

At TH Köln an e-learning-concept is being developed, which gives students an opportunity to engage in research projects. Optional modules, in which the students learn about carrying out experiments and measuring technique, are often chosen by few students only. Due to the fact that there is only a small laboratory with few employees there has not been going on larger research projects and there has been no link between education and research. This is the main reason why students have not participated in these optional modules. The e-learning-concept is developed to link education and research over a long time period and to enable students to work in small projects related to the research topic.

2 ENGINEERING RESEARCH

The engineering research focuses on dynamic forces caused by walking or running pedestrians. The guideline VDI 2038 – Part 1 [1] describes these loads as

\[ F_{vp}(t) = F_G + \sum F_G \cdot \alpha_v \cdot \sin(2\pi \cdot i \cdot f_{vp} \cdot t - \phi_v) \]

for vertical loads and

\[ F_{hp}(t) = F_G + \sum F_G \cdot \alpha_h \cdot \sin(2\pi \cdot i \cdot f_{hp} \cdot t - \phi_h) \]

for horizontal loads.

In these equations \( F_G \) is the weight of the pedestrian, \( f_{vp} \) and \( f_{hp} \) are the excitation frequencies of the pedestrian and \( t \) is the time. A table shows the values for the load coefficient \( \alpha_i \) and the phase angle \( \phi_i \). As seen in figure 1 this table is incomplete.

<table>
<thead>
<tr>
<th>Type of movement</th>
<th>Frequency ( f_{vp} ) resp. ( f_{hp} ) in Hz</th>
<th>( \alpha_v )</th>
<th>( \alpha_h )</th>
<th>Density of persons in Pers/( \text{m}^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking</td>
<td>1.8 to 2.4</td>
<td>0.4 to 0.5</td>
<td>0.1 to 0.2</td>
<td>0.06 to 0.1</td>
</tr>
<tr>
<td>Running</td>
<td>2.0 to 3.5</td>
<td>1.0 to 1.5</td>
<td>0.2 to 0.7</td>
<td>0.2</td>
</tr>
<tr>
<td>Jumping (sport)</td>
<td>1.8 to 3.4</td>
<td>1.7 to 1.9</td>
<td>1.1 to 1.6( a )</td>
<td>0.5 to 1.1( b )</td>
</tr>
<tr>
<td>Climbing stairs</td>
<td>1.2 to 4.5</td>
<td>1.1 to 1.1</td>
<td>0.2 to 0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Dancing</td>
<td>1.5 to 3.0</td>
<td>0.5 to 0.5</td>
<td>0.15 to 0.15</td>
<td>0.1</td>
</tr>
<tr>
<td>Jumping, bobbing up and down (events)</td>
<td>1.5 to 3.0</td>
<td>(2.1 ... 0.15) ( f_{vp} )</td>
<td>(1.9 ... 0.35) ( f_{vp} )</td>
<td>(1.25 ... 0.33) ( f_{vp} )</td>
</tr>
<tr>
<td>Applauding (unseated)</td>
<td>1.5 to 3.0</td>
<td>0.17 to 0.38</td>
<td>0.01 to 0.05</td>
<td>0.02 to 0.04</td>
</tr>
<tr>
<td>Applauding (seated)</td>
<td>1.8 to 2.4</td>
<td>0.02 to 0.17</td>
<td>0.01 to 0.05</td>
<td>0.01 to 0.04</td>
</tr>
<tr>
<td>Swaying horizontally</td>
<td>0.4 to 1.5</td>
<td>0.25 to 0.5</td>
<td>0.05 to 0.05</td>
<td>4 (to 6) resp. 1 pers./seat</td>
</tr>
</tbody>
</table>

\( a \) \( \phi_2 = \phi_3 = \frac{\pi}{2} \)

\( b \) \( \phi_h = \phi_v - \pi \cdot (f_{load}-f_{Bodendenkert}) \cdot \phi_3 = 0 \)

\( c \) Reliable figures are not available.

**Figure 1:** Table 3 of VDI 2038-Part1: Recommended ranges for frequencies, density of persons and load coefficients of excitation for different types of movement

During the research project students will carry out experiments to concretize the values of the table and compare them with the load models used in biomechanics [2].
3 DEVELOPMENT OF THE E-LEARNING-CONCEPT

3.1 Description

The e-learning-concept sets up on the e-learning-functions of the learning-management-system (LMS) ILIAS. Wikis, a glossary and a tool called “spaces” are used.

The wiki and the glossary are used to impart the basics of structural dynamics and the results of preceding student-projects (see figure 2). “Spaces” is a platform used to communicate and discuss fundamental questions. It can be compared to a social media platform like Facebook, but it is a closed platform and only used for topics related to the research project.

While knowledge transfer is based on e-learning-tools, students have the opportunity to get consulting and support in meetings with the academic supervisor and discuss problems in spaces with other project-groups.

Students can participate in different optional modules in their bachelor or master curriculum or in their bachelor or master thesis. The topics of their projects are based on the focus of their optional course and the workload of their chosen module or thesis. Therefore, there are projects with a main part in carrying out experiments and using measurement technology and there are other projects which focus on mathematical evaluation and comparison of different load models.

At the end of the particular modules the students have to write a new wiki-page and a scientific elaboration of their results. They also have to take part in an oral examination to measure whether the intended learning outcomes are reached.

Figure 2: Schematic representation of the e-learning-concept
3.2 E-learning tools

The LMS ILIAS uses courses to sort different tools and contents. All e-learning-tools and documents needed for participating in this research project are in an ILIAS-course where the students are invited to by the lecturer.

3.2.1 Wiki

The primarily used e-learning-tool in this concept is a wiki. The wiki starts with a main page (see figure 3), describing the main topics like basics of structural dynamic, measurement technology, the measurement software (MEDA), and human induced vibrations. In the pages are texts, pictures and videos to explain the topic to the students. The hyperlinks in the text link to related pages. It is important to keep the wiki well structured, because it is a nonlinear tool.

For the students a table of contents is provided as well as an overview which page they could read next. To support the students in using the wiki every topic has a main page where every related page is described. This enables them to learn the content of the pages which are relevant for their project.

The ILIAS-course contains another wiki called “HowTo: Wiki”. This wiki contains detailed instructions for generating a new wiki-page and how to structure the page. By using this second wiki the quality control for the student-generated pages is much easier and the pages generally have a good quality.

Figure 3: Screenshot of the main page.


 Dies waren:
- Baudynamik Grundlagen
- Messtechnik Grundlagen
- Messaufbau
- MEDA Grundlagen
- Durchführung einer Messung
- Grundlagen zu Fußgängerinduzierten Schwingungen

Auf der Seite Forschungsprojekt ist eine Beschreibung der gesamten Forschungsfrage enthalten. Außerdem wird auf dieser Seite immer wieder der aktuelle Stand dargestellt.

Außerdem wird eine Literaturliste gepflegt, in der relevante Fachliteratur, Veröffentlichungen, sowie Normen und Richtlinien zu finden sind. Auf der Seitenliste sind alle in diesem Wiki vorhandenen Seiten alphabetisch gelistet.

Für die Mitarbeit an diesem Wiki ist sich unbedingt die Vorgaben aus den HowToWiki zu halten.
3.2.2 Glossary

The glossary (see figure 4) is a separate tool in ILIAS where terms of structural dynamics are defined in small articles. The glossary is created by the lecturer and the terms are linked in the wiki. The students mostly do not have a good understanding of structural dynamics when they choose to participate in the project because the first optional module in which they can take part is being taught before the (also optional) module “structural dynamics”. The glossary allows students who are not confident in using the technical terms of structural dynamics to learn the necessary basics easily.

![Glossary entry explaining the term frequency.](image)

3.2.3 Spaces

“Spaces” is a new tool used at TH Köln enabling the students to communicate with each other and the lecturer. The students are supposed to write an “update-post” every week summarizing their work of the previous week. By using this tool, the lecturer is always informed about the students’ progress, even if there are no mandatory events. The students can use this tool to organize experiments and discuss their experiences during the project.

3.3 Quality assurance

To make sure that all wiki-pages written by students are in a good quality they are evaluated by the lecturer and other students in a peer-review process.

The wiki-page summarizing the results of a project is part of the grading. If there are mistakes in the page (for example wrong use of terms or discrepancies between the results) the lecturer corrects them in the page. This is important because the subsequent students use the page to learn about the content.

Every student has to evaluate a page chosen by the lecturer in a peer-review process. The main criteria for this process are completeness, reasonable use of media and connection to related pages. If there are any issues the students have to revise the page.

4 MEASUREMENT OF THE INTENDED LEARNING OUTCOMES

4.1 Requirements for the student-projects

Students can participate in different optional modules or their thesis in both the bachelor or master curriculum. The modules are chosen by their suggested content. The modules focus on measurement technology and test evaluation. For their bachelor and master thesis the students can choose the topic from the entire field of civil engineering. Depending on module or thesis the workload and intended learning outcomes varies. Every project work has to be aligned in scope, main focus and workload depending on module or thesis.
4.2 Grading

Regardless of the chosen module or thesis the students have to develop a written draft and a wiki page. After the grading of the written report by the lecturer the students have to take an oral examination. In this examination the students have to give a presentation about their topic and answer questions of the lecturer.

5 EVALUATION OF THE E-LEARNING-CONCEPT

The concept is being tested until summer 2020 regarding to the described research topic in structural dynamics. It started in May 2017 and is going to be evaluated and adjusted every semester. The evaluation focusses on the content of research and the concept itself. Therefore it is a scholarship of teaching and learning project [3]. Problems can be detected and (if necessary) removed. The evaluation is also supposed to clarify whether the concept can be used in non-optional modules as well.

The evaluation focusses on the achievement motivation of the students, the progress of every small project regarding to the research project, the ability to generate new project topics based on preceding projects and the effect and acceptance of the concept for students.

5.1 Achievement Motivation Inventory

For measuring the achievement motivation, a psychological test developed by H. Schuler and Michael Prochaska [4] called Achiivement Motivation Inventory (AMI) is used. For each participant it provides information which item of intrinsic motivation has the highest value and the lecturer can evaluate if there are any coherences between the students who choose to participate.

The LMI divides the intrinsic motivation in 17 different items. These are Compensatory Effort, Competitiveness, Confidence in Success, Dominance, Eagerness to Learn, Engagement, Fearlessness, Flexibility, Flow, Goal Setting, Independence, Internality, Persistence, Preference for Difficult Tasks, Pride in Productivity, Self-Control and Status Orientation.

Every student has to do this test; the outcomes are handled anonymously. To be able to compare the results and draw conclusions all students in a semester have to do this test (as a reference group).

5.2 Progress

For measuring the progress of every small project work a scale is developed. It values the projects regarding to following questions:

- What are the results of the project work?
- Are these results important for the research project?
- Which scientific methods has been used to get to these results? Are the results solid?
- What new assignments can be defined based on these results?

Using a scale like this ensures that there is progress in the research and the students-projects are linked to preceding projects.
5.3 Effort and acceptance

Most students are used to classic education concepts and are participating in a research project for the first time. By interviewing the students after their project (which is mandatory) it is investigated which experiences they have had, what they think about the concept using the wiki, how they get along by learning the contents of the research project and what kind of problems occurred. Assessing the answers helps to improve the e-learning concept and to draw conclusions whether the concept is transferable to other research projects and non-optional modules.

6 PREVIOUS RESULTS

The research project and evaluation of the concept is going to last till summer 2020. The previous results are predominantly positive.

Table 1: Achievement motivation Inventory (Status April 2018)

<table>
<thead>
<tr>
<th>Item</th>
<th>Median reference group (n=53)</th>
<th>Median participants (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compensatory Effort</td>
<td>49,38</td>
<td>47,90 (-2,99%)</td>
</tr>
<tr>
<td>Competitiveness</td>
<td>43,58</td>
<td>37,50 (-13,95%)</td>
</tr>
<tr>
<td>Confidence in Success</td>
<td>48,38</td>
<td>50,40 (+4,00%)</td>
</tr>
<tr>
<td>Dominance</td>
<td>47,53</td>
<td>47,60 (+0,14%)</td>
</tr>
<tr>
<td>Eagerness to Learn</td>
<td>43,11</td>
<td>42,10 (-2,34%)</td>
</tr>
<tr>
<td>Engagement</td>
<td>41,91</td>
<td>39,90 (-4,79%)</td>
</tr>
<tr>
<td>Fearlessness</td>
<td>39,74</td>
<td>44,50 (+10,69%)</td>
</tr>
<tr>
<td>Flexibility</td>
<td>47,36</td>
<td>47,50 (+0,29%)</td>
</tr>
<tr>
<td>Flow</td>
<td>51,06</td>
<td>51,60 (+1,05%)</td>
</tr>
<tr>
<td>Goal Setting</td>
<td>46,51</td>
<td>43,30 (-6,9%)</td>
</tr>
<tr>
<td>Independence</td>
<td>41,92</td>
<td>42,20 (-0,66%)</td>
</tr>
<tr>
<td>Internality</td>
<td>49,08</td>
<td>56,50 (+13,13%)</td>
</tr>
<tr>
<td>Persistence</td>
<td>44,47</td>
<td>47,60 (+6,57%)</td>
</tr>
<tr>
<td>Preference for Difficult Tasks</td>
<td>44,90</td>
<td>46,20 (+2,81%)</td>
</tr>
<tr>
<td>Pride in Productivity</td>
<td>56,60</td>
<td>57,10 (+0,86%)</td>
</tr>
<tr>
<td>Self-Control</td>
<td>46,10</td>
<td>46,00 (-0,21%)</td>
</tr>
<tr>
<td>Status Orientation</td>
<td>47,15</td>
<td>42,00 (-10,92%)</td>
</tr>
</tbody>
</table>

As seen above in Table 1 there are significant differences in Competitiveness, Fearlessness, Internality and Status Orientation. These results suggest that the students who choose to participate in the research project have a higher value in Fearlessness and Internality and a lower value in Competitiveness and Status Orientation. These data have to be validated when there have been more participants.

Every past group-project contributed to the progress of the research project and the results can be used for new projects. To get a statistically significant value of data some assignments with experiments have to be done again and the new results have to be compared to the data of the previous group.
The interviews have shown that the students are satisfied with the e-learning-concept and the opportunity to join a research project. The concept provides them to choose where and when they want to work on the project and gives them flexibility.

In conclusion, it can be stated that the research-project started very well and this e-learning-concept is useful to link research and education.

REFERENCES
SERVICE-LEARNING IN CIVIL ENGINEERING EDUCATION: NEW EXPERIENCE IN THE FIELD OF ROAD SAFETY

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Key words: Education, Civil Engineering, Service-Learning, Road safety, ethic skills

Abstract. Service-learning is an educational experience in which students participate in an organized service activity that meets identified community needs and reflect on the service activity in such a way as to gain further understanding of the course content and enhanced sense of civic responsibility. This new methodology has the potential to address many of the issues facing civil engineering education: can clearly enhance classroom learning, promote project based curricula and increase students’ retention of knowledge. Despite the numerous benefits of service-learning in civil engineering education, little research has been done to date to evaluate this new pedagogy; and until now, literature is focused on the limited experiences of Engineers without Borders, organizations which promote and facilitate the integration of international service projects into local engineering curricula.

In terms of road safety, the prevention tools and the management of the traffic accidents is a discipline that can be better understood through the road victims’ associations. Working with victims’ associations can help to better understand the accident risk indicators, the types of injuries caused by these accidents and their physical and legal consequences. This paper contributes to this limited literature by assessing the positive and negative experiences encountered by students when undertaking a service-learning project for the first time. The methodology was tested on a survey sample of 61 students enrolled in the “Traffic Management” module in the Civil Engineering Master’s degree at the Technical University of Madrid (UPM). Students were organized in groups of 6 and 7 members and each group was assigned with a road accident victims’ association in order to develop a case study during four weeks. This pilot experience has been supported by Spain's Directorate General of Traffic (Dirección General de Tráfico) and by UPM, as part of the 2016-2017 Competitive Funding Programme for Educational Innovation Projects (IE1617-0401).

1 SERVICE-LEARNING IN HIGHER EDUCATION

In 1996, Bringle and Hatcher [1] defined Service-Learning (SL) as a “credit-bearing educational experience in which students participate in an organized service activity and reflect on the service activity in such a way as to gain further understanding of course content
and an enhanced sense of civic responsibility”. This definition is quite complete because stresses the focus on the course content and not only on the voluntary service. From a programmatic perspective there are two salient means through which universities support voluntary service: (a) extracurricular and (b) curricular. Extracurricular community service through student organizations has a long tradition, especially in the US. In American Universities is very common that many faculty, staff, and students are involved in their communities (for example, churches, neighborhood development or youth work) with independence from university courses.

Figure 1 (based on the quadrants defined by the Service-Learning 2000 Center, 1996) shows how, unlike extracurricular voluntary service, service-learning is an experience in which service activities have to be quite related to course material. Service-learning is not only community work or even a volunteering activity; the learning process has to be linked to the contents of a course. Reflection activities as directed writings, small group discussions, and class presentations usually help to adapt the service works to the course contents. As a consequence, we can identify four key components of service-learning: the service component, the academic component, the partnerships with community organizations or members (which provide the scenario and structure for the service component), and the student analysis and reflection.

Many authors [2, 3] have demonstrated the benefits of this methodology for students, teachers and community members, improving the teaching process, the academic involvement and motivation. Kuh [4] even identifies Service-Learning as one of the ten best teaching methodologies in the United States, a country where this methodology was first developed and with many examples of implementation. There are authors that find a close relationship between the employability success of the student and the service-learning experience [5] as SL provides a real life context in which students practice what they learn [6].

In relation to the type of courses suitable for the service-learning methodology, we can traditionally find many examples of implementation in degrees associated to Social Sciences and Health Sciences (medicine or nursery). Sotelino et al [5] have observed that teachers from the fields of Legal and Social Sciences are more prone to regard civic and ethical training in university as a means to the labour insertion of students but there are also isolated study cases in experimental Education like Engineering. Oakes [7] has grouped all the US Engineering experiences in an interesting Resource Guidebook where Civil Engineering is also mentioned. Although service-learning in engineering is a relatively new area of endeavor, many successful examples exist, including two pioneering models: Engineering Projects in Community Service (EPICS) and Engineers without Borders (and partner organization Engineers without Frontiers). EPICS brings multidisciplinary undergraduate design teams into long-term partnerships with local community organizations and agencies while Engineers without Borders (and partner organization Engineers without Frontiers) promotes and facilitates the integration of international service projects into local engineering curricula. These two models are not associated to any course in particular and most of the times constitute an extra-curricular activity. In relation to Civil Engineering, there are few experiences linked to road traffic engineering, but not directly to road safety. We can find an
isolated example in the University of Utah (Civil and Environmental Engineering) in a Traffic Engineering course where the Goals are to introduce the theoretical concepts that underpin traffic engineering and to apply these ideas to a series of practical traffic engineering problems. The service-learning project will address real traffic problems in real communities and relate to the practical application of the theory provided formally in class, providing service interactions in the community. Student will present reports to the community and the local groups will assess the student contributions. This learning experience is directly linked to Public participation processes of transportation plans. Public Participation has long been established for laws, regulations, and guidance issued by government agencies in the developed countries. The practice is intended to increase the efficiency and productivity of transportation plans and programs.

Once we have clarified the concept of service-learning and the existence of referenced experiences, the methodology used to assess this learning strategy is also very important. Surveys on student perception seems to be the suitable tool to assess service-learning experiences although there is not a specific survey format accepted by the scientific community because minimal research has investigated student perceptions of their service-learning experiences [8]. Toncar et al [9] were the first to develop a scale to measure student perceptions of service-learning experiences. Known as the SELEB scale (SErvice LEarning Benefit scale), the instrument contains items that quantify four underlying experiential dimensions—practical skills, interpersonal skills, personal responsibility, and citizenship. Some years later, Werder and Strand [10], assessed the effectiveness of service-learning in the field of education of Public Relations by measuring perceived student learning outcomes through a survey. The survey included, for example, measures of practical skills, interpersonal skills, personal responsibility, and citizenship, as well as discipline-specific functional, creative, and research skills. A similar survey was designed by Berasategui et al [11], in order to assess an experience of service-learning within the university Degree in Social Education at the University of the Basque Country. The questionnaire sought the opinion of the students about the teachers carrying out the service-learning experience and results provided positive evidences about the impact this learning process has had over the students, mainly in aspects
such as involvement, motivation and reflexive attitude.

The study of the evolution of the student curriculums through the Master degree is another alternative to surveys in order to assess the service-learning experience. Packard et al [12], for instance used multiple regression analysis applying generalized estimating equations to assess for relationships between pre and post score changes in Medicine students curriculum. This last methodology requires a considerable sample size and requires implementing the same service-learning experience during successive academic years. Due to the fact that in most Universities this experience is relatively new, databases do not allow yet to use this tool properly while surveys on perception could be a solution for the first years of implementation. Many authors have recognized [13, 14, 15] that surveys of opinion done with university students about the quality of higher education, are valid and reliable methods to obtain results related to a self-perception of the students about their own teaching-learning process. These surveys can represent an opportunity (as feedback) for the professors to re-orientate their teaching methodology [15].

Next section describes the case study used in this research focused on a pilot SL experience on road safety in higher education (School of Civil Engineering of the UPM-Spain). Surveys on student perception, based on the SELEB scale criteria, have been the tool to assess the first year of the service-learning implementation.

2 THE CASE STUDY: SERVICE-LEARNING ON ROAD SAFETY

As mentioned before, there are not many experiences of service-learning on road safety in higher education but there are examples of how public participation [16, 17] has demonstrated to promote the “sharing responsibility concept” in this scenario. Kowtanapanich et al [16] show how a public participation approach can be used to assist in identifying black spot locations through the framework of an Accident Public Participation Program in Khon Kaen City, Thailand. Road safety is directly linked to the social welfare, as the reduction of the number of severe accidents and the feeling of insecurity increase the level of welfare. Students of a course on road safety could work in the future as professionals of the road safety sector, but they are also drivers and pedestrians and, under this approach, responsibilities should be shared between all of the players involved in the road safety system (Administration and users) to reach the optimum goal. Other than the acceptance and support by the community, service-learning (like public participation) can create much awareness and more concern on road safety throughout the society. After this type of experience, students will regard their rights and obligations in the traffic safety and not only consider road accidents as a problem of driver’s behavior but realize as a complex problem that can be solved.

Road safety is usually linked to the studies of traffic engineering, a subject traditionally taught at the Civil Engineering degrees. Nowadays, the complete civil engineering education community in Spain has been involved in a strenuous debate in order to determine the skills (competences) necessary for the practice of current and future engineering. The new Europe-
wide system of comparable degrees to increase student mobility (European Higher Educational Area) has been an important inducement to review university degrees and identify basic, transversal and professional skills. Moreover, engineering education has been undergoing changes promoted by the Accreditation Board of Engineering and Technology [18, 19] and corporations that hire engineering graduates. EC 2000 Criterion 3 [19] stipulates that engineering programs must demonstrate that their graduates have, among other an understanding of professional and ethical responsibility, and the methodology of service-learning has demonstrated to provide a natural opportunity for students to examine the professional and ethical responsibilities of their profession. Civil Engineering is an university degree where service-learning has always been associated to infrastructure projects in developing countries, but rarely to road safety.

In recent years, the Civil Engineering School at the Technical University of Madrid (UPM-Universidad Politécnica de Madrid) has been under a transition from the outdated degree (a six-year course) to the new Graduate and Master’s degrees and the design of new courses, like “Traffic management”, have represented an opportunity to implement new teaching methodologies and service-learning is one of these examples. Traffic management is an optional course (subject or module) in the fourth and last semester of the Civil Engineering Master’s degree and it’s taught by staff from the Department of Transport and Urban Planning. The degree is organized in four semesters (120 ECTS) and entitles the holder of this qualification to work as a Civil Engineer. After the experience of two academic years, the course “Traffic Management” has been provided with a service-learning activity and nine different Road Victims’ Associations have been selected to work with students. In one semester, students are supposed to learn how to manage road traffic and all those aspects related to road safety. The subject is divided into five parts that will help students to become familiar with laws and road policies applicable to road management, the existence of different types of accidents, the risk factors influencing crash involvement and finally the best practices and the intervention tools.

The preparation of the experience, from the teaching point of view, required significant efforts in terms of time dedication and followed the following stages:
  a) Searching bibliography about experiences carried out in similar context (service-learning)  
  b) Diagnosis of the type of organizations, which are object of intervention (Road victims’ Associations)  
  c) Selection of a group of organizations to work with the students (9 Associations)  
  d) Designing a socio-educational intervention (problem definition)  
  e) Implementation of this socio-educational intervention among these organizations  
  f) Evaluation of the socio-educational intervention.

Once the group of organizations (road victims’ Association) has been selected, students will apply the knowledge acquired to a real case, collaborating for a month with them. They must know firsthand the work developed by the different associations and contribute to propose improvement measures in the different activities that each association carries out. The main goal of service-learning methodology is to develop the students’ competences compiled
within curricula, through a design and start-up of a socio-educational intervention for road accident victims that should also consider the necessities contemplated by those organizations. The case study goes from the incorporation of the students’ in the daily life of the Associations to the understanding of the activities’ organization, management and funding. The problem definition of the case study is shown in Table 1.

Teamwork on Victim’s Associations is combined with conventional classes and, using the content of these lessons, the project work is organized in four weeks. The groups comprise six or seven members, and the project work is based on the realization of a practical case study on a Road Victims’ Association. All the groups were selected according to the teacher’s criteria and all of them work on the same project work. The only distinction between groups was that each group was assigned one different Victims’ Association, which will allow a great variety of solutions and proposals. Each group has a team leader (selected by the lecturer), who has the task of coordinating all the members of the group and who at the same time is the spokesperson. The rest of the group members have as their main tasks the composition of the final report and the final presentation. By doing this distribution of responsibilities, not only the students’ social skills are being developed, but also their teamwork abilities. The project work is carried out outside the classroom during the assigned timetable (four weeks). The teaching staff tracks the group progress through coordination meetings, answering queries and contacting the Associations when necessary. At the end of the workshop each team hands in a written report with the results of the case study to the teaching staff and two weeks later, all the groups present orally their project work in order to share their experience with the rest of the students. This service-learning activity, from the student assessment perspective, accounts for 30% of the final mark of the course, and the other 60% of the assessment carried out with a continuous evaluation based on periodic contents comprehension controls.

According to the Spanish Directorate General of Traffic (DGT), there are more than twenty-eight road victims’ Associations constituted in Spain. Moreover, some of this Associations proceed as Federations. Hence, they are formed by smaller organizations with fewer resources and only exceptionally Spanish Associations are members of the FEVR (European Federation of Road Traffic Victims). The founders of the Associations use to be road traffic victims. One of the main reasons for their establishment is to help and guide people that are suffering from a road accident experience. Moreover, they also help to prevent and to aware people from the consequences. In other to achieve these goals, they organize and perform mainly three kinds of activities: pre-accident activities (example, road prevention campaigns at schools), post-accident activities (at hospitals, giving psychology and legal counsel to the victims and their families), and tasks devoted to “reoffended users”. The third ones try to prevent the offender to repeat the incident again by making them more aware of the risks presented in the road, for example by their participation in road safety conferences. Something to highlight is that road victims participate in these activities, either during the project organization or the project implementation, what gives an important point of view. It is frequent that this type of activities is organized as blocks of “projects”, and sometimes these projects are funded by the DGT.

| Table 1: Problem definition for the students |
1. Contact and involvement with the Road Victims’ Association.
   1.1. First contact with the Association.
   1.2. Participation in the Association’s activities as a volunteer.

2. Road Victims’ Association profiling.
   2.1. Legal and organizational structure.
   2.2. Fundamental activities.
   2.3. Geographical framework of activities.
   2.4. Funding sources and their alternatives.

3. Activities categorization.
   3.1. Activities typology and description
       3.1.1. Pre-accident activities.
       3.1.2. Post-accident activities.
       3.1.3. Reoffended activities.
       3.1.4. Other ongoing activities.
   3.2. Statistics of each road safety intervention.
       3.2.1. Legal counsel.
       3.2.2. Psychological counsel.
       3.2.3. Statistics of other nature.
   3.3. Aided projects by Directorate General of Traffic.
       3.3.1. Number and content of the projects.
       3.3.2. Project duration.
       3.3.3. Staff assigned.
       3.3.4. Final results of each project.
   3.4. Analysis of the institutional support.

4. Improvement proposal for the Road Victims’ Association.
   4.1. Improvement proposal in the Association management.
   4.2. Measures for raise their range of action in road safety.
   4.3. Measures for raise their social visibility.
   4.4. Suggestions for road safety interventions, road safety education and training.
   4.5. Suggestions of new projects.

3 ASSESSMENT OF THE EXPERIENCE: SURVEY ON STUDENT SATISFACTION

The evaluation of the socio-educational intervention has been carried out through a questionnaire that seeks the opinion of the students about the knowledge on road safety achieved and also about the motivation and social attitude developed on road safety. Surveys on student perception, as mentioned in the state of the art, have demonstrated to be a useful tool to assess the service-learning methodology.

The survey presented to the students was arranged in six different blocks. The first block was composed of 3 items which collected “Yes” or “No” responses and contained questions about students’ profile, such as their previous volunteer activities, their prior road safety knowledge and also if they had ever attended a similar teaching experience. Within the next three blocks, different aspects have been compiled: the evaluation of the learning process, the relationship between students and associations and finally the ethical competences acquired. These items were Likert type with 5 different values (1= in total disagreement, 2=disagree, 3=agree, 4= quite agree, 5= totally agree). Data related to the teaching methodology, the comprehension of the course contents and also the employability has also been considered to
evaluate the learning process. Additionally, students’ perception about their experience and communication with the different associations has been analyzed (the assistance and training received by the association, the frequency of contact, the provided information by the association, etc.). The ethical competences block was about how the students’ perception of road safety has changed after having done this practical case study and also after working with victims, including questions about the importance of road safety in students’ everyday life. The fifth block consisted in a rate table to evaluate the teamwork student’s experience. The final block included some questions that summarize and evaluate the whole service-learning experience. Each block of results was analyzed based on the statistics for each question, and as all the surveys were anonymous and had an identical format, the distribution did not follow any random procedure.

The students filled this survey on May 9th, 2018 in about 15/20 minutes and was provided to them in a digital format, through a website, collecting information automatically. This fact has facilitated the analysis of the results. Following the already mentioned survey blocks, something to highlight from the students’ profile is the higher percentage of students that have not attended to a course that offers a service-learning experience (93.22%). This result confirms that the SL is not implemented at all in the Spanish teaching methodology (Civil Engineering Degrees) and it is an innovative and unknown methodology. For that reason, the results could be only compared with the traditional teaching methodology.

If the Likert type questions are analyzed it is observed that the mean reaches 4 (quite agree). In these terms, it can be stated that this new teaching methodology has been helpful for the comprehension of the course and should be incorporate in more courses. In fact, this experience has affected the students’ ethics, causing them to have more social awareness and to become more careful road users. Moreover, according to students this experience has not only helped them from an academic point of view, but also helped them to improve their personal skills, especially according to their team work abilities. An example of these questions could be seen in Figure 2.

![Figure 2](image-url)

**Figure 2:** Answers Likert type questions from Block 2: Service learning experience.
As for the evaluation of personal experience, the students agree that the experience has been very pleasing, helping to raise their awareness of social aspects and, more specifically, of the causes and consequences of traffic accidents. It has all been thanks to the Victims’ Associations that have facilitated and shown them this new perspective, which it is based not only in what they are doing, but also about the technical improvements they offer. Finally, it only remains to be mentioned that the majority of the students believes that the case study and the service-learning methodology as an indispensable complement to their education.

4 CONCLUSIONS

This paper describes an innovative experience of SL in the field of road safety, in which 61 students of higher education (Master of Civil Engineering of UPM-Spain) are divided into groups and assigned a road Victims’ Association. Literature reviewed has shown the benefits of the SL methodology, but at the same time little research has been done in the field of road safety with exception to some related cases of public participation. Based on other referenced assessments of SL experiences at higher education, surveys on students’ perception have been selected as the most suitable tool to evaluate this pilot experience. Results reveal a students’ positive satisfaction with the SL experience on road safety, which has helped them in both technical and human skills and abilities. And all of them are willing to recommend this experience to other students and consider it as a pillar in their academic, professional and personal training.

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DOBOOKU ASSOCIATION ACTIVITIES

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1 WHO WE ARE

If you collaborate with dobooku, you build dobooku.

Dobooku is an open and permeable group of civil engineers, structural designers, architects, urban planners and public works lovers - students and professionals alike. Dobooku is a Cultural Association that fosters the Culture of Design in Public Works. Dobooku was created on April 23th 2013 with a simple aim: spread the word on public works through design, aesthetics and creativity.

Dobooku is supported by four fundamental pillars: The Association, the web-site magazine, the social media network and all the activities we promote or support in order to cultivate debate around public works. Combining these, we seek to strengthen a fresh and holistic environment that helps all public works lovers to join and share ideas.

The relationship between public works and design has a rigid correspondence but we are increasingly more people interested in diversifying and enriching this context. Both, design solutions and the culture of aesthetic reflection on public works are a growing topic that needs to be feed back through a proactive attitude to the need of sharing knowledge, information, concerns, passions, wills, and accumulated experiences on public works. Following this, dobooku takes shape in a cultural and non-lucrative Association where all public works stakeholders, people and entities, can join and interact. Anyone interested in generating opinion, debate and critics on design, aesthetic and humanistic values of public works; anyone who would like to share personal thoughts and experiences through an open attitude can be part of dobooku. The more plural dobooku is the better dobooku will be.

Dobooku publishes personal concerns through an online magazine with plural contents. Through our website (www.dobooku.com) we all express and share opinions through articles. The content of these articles is open but they should be linked to design, aesthetics and public
works.
- Design such as a project design, innovation, construction ideas, creativity ...
- Aesthetics such as theoretical reflections, historical visions, philosophy of arts, craftsmanship, beautiful works, feelings, attitudes, perceptions ...
- Public works such as infrastructure, architecture, urban planning, landscape interventions, urban spaces, ephemeral installations, public art ...

We promote public works based on criticism, dialogue and content sharing. We are critical of our own and other's activities. We can only contribute to the birth of quality public works in that way. We need to express and exchange ideas and opinions. Thus, the web-site is not only a spot to find and comment on design and aesthetics in public works, doobooku is also at the forefront of the use of social media and multiple communication channels to create new forms to interact, including social media and networking; using informal debates, meetings and collaborations.

Dobooku promotes activities where participation is the main focus. Our goal is to integrate different views in a given space in time. To teach through design-thinking, to learn through design making, to understand through collective actions.

2 WHAT WE DO
Dobooku walks through the path of education with these purposes:
- As an Association, we learn by doing common activities.
- We award design competitions for students.
- We bridge students to the professional environment.
- We collaborate with each other and with other entities.
- We create spaces where we all can share thoughts about public works.
- We cultivate collective atmospheres around personal opinions to get people in touch.
- We curate public works contents related with design, aesthetics, creativity and reflection.
- We educate our professions through interpersonal communication.
- We enjoy talking about public works. To have fun as an aim itself.
- We entertain without falling into superficiality or impersonality.
- We give voice to professionals and students alike.
- We incorporate theoretical reflection on current issues that concern design in public works.
- We internationalize contents.
- We join the means and opportunities to perceive and experience public works as cultural tools.
- We joy on Public Works.
- We look to the past and to the future.
- We manifest our idea through actions.
- We participate in all kinds of public works events.
- We promote students internships.
- We set annual targets as a collective.
- We share opinions through casual meetings and social networks.
- We stimulate debates.
We talk about the advance of design in the broad field of contemporary world. We understand design as a tool to look toward the future. Hence, we educate by doing common activities.

3 OUR PATH

Dobooku is work in progress. Through years we have all grown together, we have all generated nice and dynamic synergies. The following is a more detailed explanation of our story.

2013, doobooku begins. Three structural engineers based in Barcelona create a web-site magazine open to all those interested in design and aesthetics in Public Works. Public Works as the main element of discussion to be inclusive and to go beyond Civil and Structural Engineering. Doobooku expands to multiple social media communications channels in order to allow interaction and social networks.

2014, doobooku educates. Dobooku takes shape as a cultural and non-lucrative Association. Dobooku’s Awards are launched to award students and also the opportunity to gain practical experience in professional environments. Dobooku’s design-thinking workshops start. The goal is to create a preliminary bridge between the educational environment to the professional world. We realized how basic the connection with the students and the university is in promoting the Culture of Design. This linkage will bring reward in the coming years.

2015, doobooku collaborates. Dobooku contacts and gives support to other organizations that promote similar purposes through open activities. Collaborations are set with the basic idea to share, build and shape doobooku’s purposes. Dobooku collaborates with entities and companies that give support to outreach common activities, as well as scholarship programs with design practices for students.

2016, doobooku expands. Architects and urban planners join and enrich the Association. Collaborations grow strong and international interchange starts. The doobooku atom is created: the core were all partners manage and guide the Association; the satellites or those collaborators who often enrich doobooku with new and fresh ideas; and the comets or those who from time to time set a contribution or they simply have a less active attitude but they want to keep in touch with doobooku. With all of them doobooku grows in volume and, better than this, it makes sense.

2017, doobooku manifests. The doobooku Manifesto for Public Works defines doobooku’s aims. In order to engage users with public works it is necessary to share our opinion. Debate is needed to learn and enjoy better Public Works. Dobooku to promote the Culture of Design in Public Works.

2018, doobooku looks far ahead. To collaborate as Digital Media Partners at the EUCEET IV International Conference on Civil Engineering in Barcelona provides a portal into International Public Works environment. Next step is to work towards the English web-site. We are working on it, seeking sponsoring.

4 HOW DO WE PROMOTE THE CULTURE OF DESIGN IN PUBLIC WORKS

In order to foster the Culture of Design in Public Works, doobooku Association is always thinking outside the box, promoting and giving support to different activities. We have called them experiences.
4.1 Experience 1: The Dobooku Awards for students.

Dobooku Association launched the Dobooku Awards on March 2014. Since then, 4 years awarding the public works projects designed by students. Until now, the Dobooku Awards are only for Civil Engineering students of BarcelonaTech University in Barcelona. Next milestone would be to extend the Awards to other universities and to promote multidisciplinary teams with other disciplines.

To take part in the Dobooku Awards it is required a public works project designed recently as part of a university program. All project graphic material and descriptive documentation needs to be synthesized in two DIN A2 panels. It is useful for the students to have the ability to choose the key points of their projects, a nice project without a direct and understandable presentation can be irrelevant. Students should not assume that the project is a finished product with many administrative formalities, projects are very much alive and undergoing an ever-changing process of creation.

From all entries of the competition, a judging panel consisting of renowned professionals of all public works areas evaluates the projects taking special value of the following bullets:
- Emphasis on design;
- Originality and innovative nature of the proposal;
- Technological quality, constructability and economic viability;
- Environmental fit;
- Sustainability and manufacturing procedures;
- Format of the presentation and;
- In general, everything that contributes to give an added value, humanistic and aesthetic to a public works project.

In addition, the panel will be able to discuss and analyse the projects with the students. Finalist young authors will have to present their projects in a public event organized by dobooku. How young designers defend their projects will be the key point to finally convince the jury to select their project as the winner. Both the winner and the finalists projects are also advertised on dobooku website.

![Figure 1](image)

*Figure 1*: In circle, we debate.
A cover letter and a curriculum vitae are also required because finalist projects will have the opportunity to obtain an internship at professional technical offices according to educational cooperation agreement between universities and companies. Six internationally recognized offices supported last Awards. Hence, the Dobooku Awards go beyond mere economic reward and design recognition; they are an opportunity to bridge students to the professional world while they are still learning. Last steps of academic education are crucial for a rewarding career from both professional and personal point of views.

The Awards event is closed with an open debate. Debate is one of the aims of dobooku, so the jury, the young designers and all the attendees use to engage into an open and friendly debate focusing the awarded projects to one topic that varies from year to year.

- 2014: Towards a new Engineering.
- 2015: Does the place make the project?
- 2016: The Culture of Design in Public Works.
- 2017: The importance of the Project.

4.2 Experience 2: The Dobooku Manifesto for Public Works.

Dobooku Association launched on April 2017 “the Dobooku Manifesto for Public Works” as a radical defence of the Culture of Design in Public Works.

The Manifesto meant a turning point for dobooku as an organization and came to respond to the need to better define ourselves. The online magazine scope needed to be overtaken and several months of collaborative reflections between sixteen collaborators of dobooku set the basis to foster the Culture of Design (the good one) in Public Works as the main aim of the Association.

1. Support and promote the culture of design in public works.
Planning, construction, management and maintenance require good design.
2. Design in accordance with social and environmental needs.
Public works requires intelligent, sensitive and responsible intervention.
3. Put your creativity and ideas to work.
Public works are more than the result of calculations and technical specifications.
4. Observe, analyse and detail.
We must analyse the bigger picture but develop details with precision.
5. Design for and with the user.
Design process must engage and empathize with the citizen.
6. Work as a team and with other disciplines.
Public works require communicative and collaborative tools.
7. Respect the intellectual work of professionals.
Awarding contracts and decision-making processes must give value to the professional.
Champion educational programs that foster design, planning and strategic management.
9. Get involved, be critical.
Discourse and debate are vital for education and enjoyment around public works.
10. Share the Manifesto.
¡We must talk more publicly about public works!

The result was a manifesto intended to be revisited, reinterpreted and shared. A manifesto
intended to be criticized. A manifesto intended for thinking about public works from the point of view of sensitivity and good craftsmanship. A manifesto with a collaborative spirit, as a meeting point for connecting with citizens. A participatory, synthetic and proactive manifesto, because society, understanding and action are essential and identifying in public works. A manifesto as an activist framework for all of us who are interested in promoting reflection and good design in public works.

Ten synthesized and schematized ideas that pretend not only to push the boundaries of utopic and theoretical manifestos, but also to empathize with the willingness to understand and to take part in the Manifesto. To highlight that the Institution of Spanish Institution of Civil Engineers in Catalonia adhered and published the Manifesto in its magazine “Camins.cat”. Moreover, the Manifesto appeared on the front cover of the magazine and it was presented at its courtyard in Barcelona on July 5th 2017.

The Presentation was highly impressive. A contemporary dancer uncovered and taught to all attendees the Manifesto, divided into ten boards. We wanted to dance, as a symbol of joy and work in progress; as a creative and communicative process; as a reaction to enhance Public Works perspectives; and as an aesthetic response to show how to go beyond traditional Public Works environments.

We are currently working to present the Manifesto in other cities. We are on tour.

![Figure 2: Contemporary dancer presenting the Dobooku Manifesto for Public Works](image)

4.3 Experience 3: Dobooku Curatorial Activities.

Technology is driving us to contemporary culture where everything, public works in particular, can be shared from all around the world. Even this fact enables people to share personal experiences or opinions there is a lack of community conception regarding this matter. Dobooku wants to bring different public works stakeholders together in order to facilitate communication between each other. We act as a curatorial platform that offers a meeting place for all public works lovers. Main idea is to curate public works contents in order to agitate ideas
and bring opinions to the table. It might be called Public Works Activism, a cheerful but determined way to empower public works. Our commitment is not lightly, we take it in a serious and joyful way.

To date doobooku’s curatorial guideline has three areas of action:

4.3.1 Editorial line.

The editorial line pretends to be simple: quality first. Quality is the motive and the main driving force in the choice and editing of content. Many authors leads to a desired variety of contents and styles and the mixture of this eclecticism with quality creates a powerful atmosphere, close to contemporary trends. Our commitment to quality contents is our biggest brand.

In five years we published 150 posts or articles in 8 different categories: news, engineering, architecture, urbanism, landscape, education and aesthetics. Also, we opened a blog where short articles are published.

Doobooku’s website articles are curated through an editorial line. Even doobooku website is open and free to express own thoughts we set an editorial line in order to encourage authors to become collaborators. Interaction between authors and reviewers is a first step to know each other and to open debate to improve article contents or to talk about other subjects related with public works. This networking allows the Association to grow in renewal and fresh ideas. That was how the Doobooku Manifesto, explained above, was originated.

In addition, to set our activities or to promote those events that we give support or whose aim is related to doobooku it is necessary to record all ideas into an article. Hence, the editorial line is useful to reconnect with who we are, what we do and how we do it.

4.3.2 Conference line.

We display and arrange public works events, such as conferences, keynotes and debates.

In the field of Structural Engineering, to highlight the Conference that took place in La Coruña Spain on June 21st 2017. Thanks to an initiative of the ACHE Youth Group, the Doobooku Association, taking part of ACHE Engineering and Society Commission, had the opportunity to present the W + W + W at the VII Triennial Congress of ACHE - Spanish Scientific-Technical Association of Structural Concrete.

W + W + W was a proposal to develop a website of Spanish Structural Achievements. The goal was to create a “sexy” catalogue where all those interested in structures, professionals and user devotees alike, could have access. ACHE over the years has collected an excellent content but its visibility need to be updated using current communication channels. The W + W + W project aimed to make it possible giving emphasis to aesthetic or visual approach and synthesized data base information.

With an online catalogue where most significant structural achievements are shown, it is possible to improve Public Works prestige, heritage and future. Whether all stakeholder involve in this project, whatever is convenient, it would facilitate to approach structural field to all devotees or users interested. We are in the 21st century, the information must free, open, self-editable and must have visual impact. Current web tools allow to collaborate, to participate, to share, to link, to give opinions and the good thing is it does not take a lot of effort. Of course, impartial and independent contents are part of a successful idea. To create a win-win effect
contents must be part of a collective, must have a quality in its content and presentation.

In order to make it possible we decided to divide its management in three areas of work: system operational management tasks, curation of contents and document management and also a complementary project using wikipedia platform. This final point will be analyzed in greater detail in another paper named “dobooku Workshops: learning by making design-thinking activities” where we dobooku workshop philosophy will be presented through general educational contents and particular workshops given in recent years.

4.3.3 Project line.

We encourage new ideas. Right now, we have 3 projects under development: Bridging Senses, Bridging Cultures and Dobooku Fusion.

Bridging Senses was originated as following up of “Sublimation (footbridge transition)” conference that one dobooku collaborator presented in Berlin at the 6th International Footbridge Conference. Since then, three structural engineers are joining efforts to move forward the conference idea into an ambitious project. The project wants to set ideas in order to design a beautiful bridge for visually impaired people. Accessibility and adaptation means are often seen as insufficient or at worst, missing from pedestrian infrastructures in our urban context. It is imperative that all users, including physically impaired deserve to enjoy the beauty of pedestrian infrastructures, such as bridges, in one way or another. Therefore, first step should be to interview those with visual disabilities to get deeper into the matter.

Bridging Cultures was created on behalf of a conference that took place at Catalan Group of the Spanish Institution of Civil Engineers on February 1st 2018. The keynote “Coordinating Cultures at the New Champlain Bridge in Montreal” had two purposes: The first - and most obvious - was to explain the project currently under construction. The second purpose, reflected in the title, was to talk about the importance of coordinating abroad mentalities. Civil Engineering is one of the most widely known as potentially reactionary, with strong roots on the construction entrepreneurial culture rather than innovation or technology itself. Each country or each construction particular market takes into account closest ecosystem-scale habits without relating with abroad linkages. It would be great to talk about each one in particular, how they interact each other in large-scale international projects. Thus, more conferences will follow. There, we also initiated contact with some cultural entities in order to move these preliminary ideas out of the sector to engage in an inclusive dialogue with the public works professionals and civil society at large.

And finally, Dobooku Fusion. This is a overall picture idea originated in an dobooku meeting that took place on the beach. Fusion because we want talk about Public Works from all perspectives and volumes. To display public works legacy, to talk about contemporary aesthetics on public works, to agitate public works devotees, to make criticism a tool to emphasize public works relevance, etc. it is not enough. We want to create new public works environments based in transversal collectivities. Other expertise, disciplines and sensitibilities are needed to go beyond public works. This could allow us expand the perspective of public works towards wider horizons. The importance of people’s participation is crucial for the empowerment of public works development.

Just as important as the creation of new ideas is the growing need of sharing them. Projects are open to new collaborators looking for new inputs.
4.4 Experience 5: Dobooku Workshops.

Good design must be taught. Good design must be expanded. That’s why we organize and curate workshops. We want to introduce students and young professionals into a new way of thinking Public Works. Public Works cannot be only understood through exams, master classes and mathematical approaches. Students must refresh their ideas and understand why society requires good design on Public works.

Education is not a closed goal, education must be opened and experienced through alternative methods through all career life time. Nowadays the classical education bounders tend to disappear. In a digital and connected world, a lot of new ways of learning will appear, in this regard the IV International Conference on Structural Engineering. Education Without Borders is paradigmatic. Dobooku wants to play a role in this context. We want to be one of the everyday more essential bridge between universities and professionals.

We do what we make because we think that we may add other ways of thinking to the theoretical and technical knowledge and it must be done through transversal education where other professions, disciplines or approached can supplement and take another look to Public Works. Indeed, transversal knowledge is what make Public Works public or even more, something public is used by people so then it can, perhaps must, be criticized. In fact, the more Public Works are used, the more they must be criticized. Students or future professionals must be aware of the importance of a continuous dialogue on this matter.

Dobooku as a Cultural Association not only manifests but takes action. Since 2014 dobooku has been making several design-thinking workshops where we show students how to create an idea using design and communication. Dobooku workshops are great:

- We awake, refresh and highlight the great significance of our profession.
- We brand workshops to bridge ideas into actions.
- We build workshops with students through design-thinking environment.
- We complement academic education.
- We challenge workshop audience with confidence.
- We create interaction opportunities between students, young professionals and experienced ones.
- We educate towards creativity using spaces and methodologies that allow students to learn in nice, close, affective, dynamic and interactive environments.
- We explore the chance of participate actively in a sort of building contests.
- We encourage students to debate, discourse and a constructive discursive frames.
- We foster holistic approach on Public Works.
- We generate opened paths for brainstorming, reflection, opinion and criticism.
- We give expertise advice to young designers.
- We help students to create their own designs.
- We integrate different views in a given space in time.
- We join and share personal thoughts.
- We link university with business.
- We make Public Works comprehensible.
- We mix students with professionals to enrich each other.
- We offer the students the possibility to learn on Public Works through real cases.
- We prepare creative and pleasant procedures to work with.
- We point key matters first.
- We promote the interaction between users, students and professionals.
- We rehearse the creative processes.
- We revise how to make a positive and active impact.
- We set references to help to decide on professional careers.
- We spread out the knowledge.
- We show how to create solid ideas.
- We teach how to design using communicative strategies.
- We wonder about Public Works education, for what purposes students are and should be educated.
- We win working in short groups.
- We work by projects, from random ideas to particular concepts.

In five years we have offered many workshops where participation is the main axis. They are classified in three areas or experiences: inside, on site and online workshops. Below listed some of them to be explained at the Congress. There is not enough space here to detail them all.

- April 6th 2016: Creativity on Public Works workshop.
- November 24 2016: Designing Concrete Structures workshop.
- January 11th 2017: Design-thinking workshop.
- April 4th 2017: Build a Road Challenge.
- November 4th 2017: Juan Bravo Bridge walk through.
- November 16th 2017: Ephemeral Urbanism.
- November 22nd 2017: Why do we love bridges?
- February 2nd 2018: After the End of the World Exposition walk through.
- April 11th 2018: Papercraft workshop.

Figure 3: As a result, happiness.
THE RELEVANCE OF SELF-FORMATION IN TEACHING STRUCTURAL DESIGN

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Key words: Self-formation, Teaching-method, Integrated Design, Active Bending.

Summary. The paper discusses the relevance of teaching Self-formation processes using active bending only for the form-finding, whereas the long-term load-bearing structure is determined from a number of hybrid solutions. The Research & Development Project Neuschneewolke serves as a vehicle to develop a method for a dialogue based workflow between Architects and Engineers, which has the capacity to bridge the gap between computational design and practical implementation.

1 BACKGROUND AND INTRODUCTION

The ongoing collaboration between the Architect Walter Klasz and Format Engineers has its origin in the commissioned and realised research & development project Neuschneewolke [1]. This publicly funded project aims at developing a multifunctional light-weight structure to provide space for the artificial generation of snow-flakes for usage in sustainable winter-tourism. The shell was intended to be constructed in the landscape with a minimal impact on the environment and with the challenge to achieve a high level of aesthetic quality.

Following on from an earlier experimental structure in this context – The Cloud for fresh Snow [2] – there were identified three representative bent typologies [3], where material change can happen without affecting relevantly the long-term load bearing capacity of the structures. Figure 1 shows Photos of the assembling process of those structures using scaled models.
Instead of following the idea of the anticlastic wooden membrane, the four surfaces of the Neuschneewolke-Lüsens present synclastic bent surfaces. On-site assembled wooden double T-Beams provide the necessary stiffness of the structure. The phenomenon of Active Bending is used mainly to find the form and to simplify the assembling. The pre-tensioned edge beams create the initial form and give the structure its primary form. In the final hybrid configuration, active bending has no structural relevance.

The following research investigates the relevance of Self-formation in teaching structural design. There are discussed different aspects of Self-formation. That is why the next chapter deals with the terminology.

2. TERMINOLOGY OF SELF-FORMATION
2.1. SELF-FORMATION IN THE CONTEXT OF ENGINEERING
In 2013, Engineers used the word Self-formation process to describe the phenomenon of active bending: “... structures, where bending is used as a Self-Formation Process” [4]. Since then the internationally growing scientific community use the word Self-formation mainly in the context of active bending. Wooden (or even aluminium, carbon fibre etc.) members can be bent to a predictable shape, with a built in prestress, and then continued to be bent with control over the final geometry. It is a repeatable and describable process to produce complex curved forms easily. The new aspect in the context of Form-finding consists in the fact, that the designer focuses on the boundary conditions and on the parameters and not on the form itself. The first internationally recognized realized architectural project in this context is the Theme Pavilion Expo Yeosu by soma-architecture. The parametric software K2E was developed by Cecile
Bandt-Olsen in close collaboration with Format-engineers [5]. It enables the real-time development of three-dimensionally bent structures in relation to the used sections and to the E-Moduli of the materials. Figure 2 shows the sequence of the self-formation process of one conceptual option for the spherical tetrahedron of the Project Neuschneewolke Lüsens.

2.2. SELF-FORMATION IN NATURE

In Nature, Self-formation is the norm. Forms emerge out of the boundary conditions in a self-forming process. Consequently, there is always a strong relation of forms and their boundary conditions.

In this context, the example of water is exemplarily chosen to present the variety of forms emerging out of one material due to different boundary conditions. Figure 3 shows a meandering river, a snow-flake, and a snow-drift against the wind direction. All forms are completely different, but in every form there can be identified a typical implicate order. A snow-flake has always six spikes, which is linked to the molecular structure of water. In homogenous conditions, a meandering river finds its inherent form of a sinusoidal-curve with the proportion 1:11, which was observed and investigated by researchers in California [6].
2.3. SELF-FORMATION IN AUTOCHTHONE ARCHITECTURE

Human settlements and buildings interact with nature. The conception of Self-formation could help to understand the deep relationship of architecture without architects in complex boundary conditions. Looking at such autochthonic architecture, this close relation to the surrounding is obvious from the usage of local materials to the logic in the forms. In the context of teaching, architects and engineers can learn from the relevance of the close relation between both disciplines and the resulting aesthetics. Farmers worked intuitively based on experiences and knowledge.

![Figure 4: Photo by Josef Dapra in the Book by Raimund Abraham: Architectonics, P.22](image)

Contemporary tools like K2E allow architects and engineers again to work intuitively, while calculating the structures in real-time. Intuition is a human inherent resource to get a Form-finding-process started and controlled in the holistic context, which is discussed in the following chapter 2.4.

2.4. HOLISTIC SELF-FORMATION IN A COMPLEX FORM-FINDING PROCESS

This paper introduces the new term Holistic Self-formation. It implicates a physical and a metaphysical aspect of Self-formation. In the Book On Dialogue, the Physicist and Philosopher David Bohm describes the analogy between formation processes in quantum physics and the Form-finding happening during a dialogue in the spirit of David Bohm. The words Holistic Self-formation describe a method of dialogue-based collaboration in a complex architectural form-finding process (see the following Chapter 3). In contrast to the accepted convention, that the architect defines the main form as the leader of a multipart team, this new approach considers the Architect responsible for ordering the boundary conditions and to define the relevant parameters in a process. The initial intuitive input in form of a sketch or a concept model serves as a seed or a nucleus of a crystallization-process in an interdisciplinary working-group.
3. THE R&D PROJECT NEUSCHNEEWOLKE LÛSENS AS A VEHICLE TO DEVELOP A TEACHING METHOD FOR SELF-FORMATION

The Form-finding process itself was and is the core competence of architects. Instead of guiding this process hierarchically, the project Neuschneewolke is a successful case study to prove the efficiency of a Self-formation process on both levels: Physical Self-formation with bending wood and holistic Self-formation in the interdisciplinary group including the engineer, the client, landowners, tourism experts and users.

The intuitively built physical concept model (see Figure 5) served as a first step for the application of the public funding and in a second step to get the professional Form-finding process started. The whole group met only twice physically in two-day workshops. The role of the architect was mainly to organize the parameters and to give the relevant people at the right time the word to contribute to the common solution. Instead of debating different positions, Holistic Self-formation holds the emerging solution in suspension. It gives a freedom, to let things happen. This is reflected not only in the detailing of the structure but also in the concept of interacting in the environment. The architect and the engineers visited the location together to choose the appropriate rocks. Then they immediately adapted the

Figure 5: Collage with relevant Snapshots from the Form-finding-Process Neuschneewolke; Photos W. Klasz
structure using the parametric script. Later users of the fresh snow, which is generated by Neuschneewolke, shaped the snowskate-lines themselves, which is seen in the aerial photo of Figure 5. Figure 6 presents an abstract organigram of the Self-formation process from the very beginning to the final integrated design solution in avant-garde winter-tourism. Comparing the physical Self-formation and the holistic Self-formation in the second part of the process, there are identified the same soft boundary conditions, which are confidence, empathy, peacefulness, time and pleasure. The digital parametric toolbox consists mainly of K2E and Karamba (a finite element structural engineering analysis tool). The metaphysical parametric toolbox names firstly the Bohmian Dialogue. This communication tool is contemporarily used in organisational development but not yet in architectural form-finding. Analogies between physical Self-formation and the Bohmian Dialogue are discussed in a separate paper [7].

In the research team of the Neuschneewolke, there are two students involved, who work on the same eye-level with the other experts. The key issue of success in the ongoing project is the focus on the common vision and mission. The clearer this is, the less structured organisation is necessary. Members of the team know on their own what to do and how and when to contribute. The common vision intrinsically motivates team-members. Intuitive physical modelling, digital parametric modelling and experimentations go hand in hand enriching each other. The architect guides this process focusing on the boundary conditions and keeping the common mission in the centre of the conscience. An important new aspect of the method is that the client plays a creative but listening role in the process. He has to be open to get something unexpected. The client takes part - less demanding solutions but rather contributing and reacting creatively in the process. Figure 7 shows the framing of teaching Self-formation processes. Firstly, teachers
and students work on eye-level. The client frames the Form-finding concerning the link to society. Generally, constraints are not charged as negative limitations but as potential parameters for creative form-finding.

Figure 7: Framing the Teaching of Self-formation Processes

On the one hand, teaching Self-formation is characterized by a not hierarchical structure, but on the other hand, there is a clear method to develop physically self-formed structures. Figure 8 shows ten steps of the emergence from the first intuition to the final product or building, illustrated with photos and images of the project Neuschneewolke: Intuitive Modelling / Parametric Modelling / Scaled physical Detail Models / Physical Testing of 1:1 Elements / Scaled physical Over-All-Model / Site Specifications / Detail Specification / Production of the Components / Test-Assembling of selected Parts / Transport and Assembling. These ten steps can be seen as a proposed framework, but they want to be customized to individual projects. It is up to the teaching team to select the relevant steps during the process, keeping the common vision and mission in mind (see Figure 7). Especially the ongoing experiments of the students in the different phases of the project can contribute to new solutions in the overall conception as well as in detailing innovative solutions. The teaching team should frame these experiments in the relevant field trying to keep creativity lively and to keep the development focused at the same time.
Figure 8: Ten Steps to develop Self-formed Structures from the first intuitive Modell up to the Implementation to the Market

4. EXPERIENCES IN TEACHING SELF-FORMATION

The teaching team tries to provide the soft boundary conditions mentioned in Figure 6. Students receive the following physical resources: Wooden strips, twine, clue and clamps. After receiving a briefing on the design topic, they get started to experiment freely. At the beginning, students try to focus mainly on the sculptural quality of their work and less on functions. During four years of teaching experience, it is found out that intensive one day workshops are very efficient to achieve interesting solutions in the concept phase. Students learn from each other and the emerging atmosphere stimulates them to get more out of the given resources. Concerning the collaboration with real clients or partners from industry, two experiments of one semester each were performed. In 2017/18 Klasz was invited to teach one semester at the TU-Vienna at the Institute of Art and Design. The traditional furniture company Thonet was...
invited as a sponsoring and collaborating partner. In the final Jury, at the beginning of the Vienna Design Week, Mr. Thonet was positively surprised about the huge variety of new concepts developed in Self-formation processes using active bending. The emerging sculptural quality of the majority of the wooden projects was convincing on an aesthetical but less on the functional level. The team understood that it would have been better to involve the furniture expert more deeply during the process. On the other hand, the distance allowed the students to work freely and to risk suggesting very unconventional ideas. One main result of this experimental research was, that the clients should be constructively involved taking part to risk together with the team to develop new ideas.

The second collaboration-experiment was carried out with 18 students at the University of Innsbruck at the Institute of Design in the department of Structure & Design in 2017/18. The Tyrolian Company Sunkid was an industry partner to help develop new ideas for outdoor structures in bent wood. Figure 9 presents two projects of high aesthetical quality. The involvement of Marco Pellegrino from Format Engineers during the design process helped guiding the design evolution towards realistic dimensioning and proportions. In the ongoing collaboration with the University, Sunkid wants to realize a full scale Prototype with a local client in the team.

![Figure 9: Three Student-projects developed with the presented Method to teach Self-formation processes using bending wood and collaborating with commercial partners at the University. On Top: Project Bondage by Johannes Fandl and Laurenz Greger; In the Middle: Project Wooden Wave by Bernard Blaschette; On the Bottom: The Project Ray-fish by Sandra Camini](image-url)
12 CONCLUSIONS

- Self-formation plays a relevant role in teaching structural design. On two different levels, students learn to develop and to realize free forms: On a structural level, active bending is used for Form-finding. On a holistic level, students, teachers and clients find together hybrid structural solutions to match all requirements of a project.

- The method of Self-formation implicates a useful training for students to sharpen their intuition for choosing the appropriate tool at the right time bridging the gap between computational design and 1:1 production.

13 PERSPECTIVE

In order to get new results and to sharpen the method of teaching Self-formation in the future, there will be organized an experimental winter-school in Tyrol for international students. The whole course should be financed by a commercial partner in a fair win-win situation. This could be further developed as a way of funded academic teaching without losing independency of the university. It may interconnect economy, research and teaching in a deeper way [8].

REFERENCES


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MODERN LEARNING STRATEGY FOR TEACHING ABOUT CONSTRUCTION MANAGEMENT IN POLAND

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Key words: Learning strategies, Construction management, Methodology, Teaching, Generation Y.

Abstract. Today, more and more employees are marked by an increased familiarity with digital solutions. On the other hand, an impact of the information technology on the accuracy of decision making processes is significant. In search of a competitive advantage employers have to learn how to profit from a competence of such people. However, digital natives have to be educated in a correct way, in terms of both hard and soft skills. Unfortunately, education programs, also those related to construction management, not always meet the market requirements. Therefore higher education institutions start to answer the challenge and convert their policies and teaching programs into 21st-century-friendly.

The paper describes a specificity of the teaching about construction management. It explains modern strategies to attract student’s attention and to provide him/her necessary capabilities useful in a future job. First, articles indexed by the Web of Science database from 1999 to 2017, were examined in order to verify a specificity of higher education as well as main factors conditioning teaching about construction management. Moreover, a comprehensive analysis of the new program contents and methodologies used was executed. Then a course model was proposed which provides a reconciliation between traditional and unconventional approaches. Whereas that every change requires preparation, some opportunities and threats were explored.

The article refers also to examples of good practice implemented at the UTP University of Science and Technology. Construction management students witness new didactic strategies (blended learning, case studies, site visits, webinars, conferences) as well as learn about innovative solutions useful in construction management: Building Information Modelling (BIM), Unmanned Aerial Vehicles (UAV) or machine learning. Conclusions of the analysis show that the course model can be useful for implementation in the higher education, especially in construction management.

1 INTRODUCTION

The problems of generational diversity of students have been known for a long time. However, at the turn of the 20th and 21st centuries, a new group, particularly different from the previous generations, appeared at universities. It is now known as the Generation Y,
which includes people born in the early eighties. Their specificity is associated with a significant acceleration of globalization processes and the simultaneous development of information technologies and the creation of the *information society*. Young people, almost all over the world, felt to be inhabitants of the global "village", familiar with innovative communication tools from the very beginning of their lives.

Currently, universities should be able to modify curricula, as well as the methodology of education to new realities, so that in modern generations of students arouse the passion of discovering the secrets of science, and a potential hidden in them could be used. It can be claimed that an opportunity for the success of technical universities that offer, among others civil engineering, is to adapt to the requirements of the Generation Y. Young people very often articulate the willingness to participate in some projects. Therefore, it is crucial to include project-based activities in the ways of guiding the students' work during the teaching process. It may become useful in practice, because most of the tasks carried out in the industry are of investment and construction projects.

### 2 THEORETICAL FRAMEWORK OF CONSTRUCTION MANAGEMENT EDUCATION

#### 2.1 Main challenges in education development

Nowadays, there are more and more modern strategies to attract student’s attention and to provide him/her necessary capabilities useful in a future job. In search of the specificity of teaching about construction management, a comprehensive literature analysis was performed in order to verify a specificity of higher education as well as main factors conditioning teaching about construction management. Articles indexed by the Web of Science database were examined. Details of the search are presented in Table 1. Two-step search produces a number of results filtered by the most suitable categories from the initial query (column 9). These articles were taken to further consideration.

<table>
<thead>
<tr>
<th>No.</th>
<th>Query</th>
<th>Timespan</th>
<th>Number of results</th>
<th>Proceedings paper</th>
<th>Articles</th>
<th>Other</th>
<th>Relevant categories</th>
<th>Number of filtered results</th>
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<td>29</td>
<td>10</td>
<td>1</td>
<td>Education, Educational Research, Construction, Building Technology, Engineering Civil and Management</td>
<td>29</td>
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*Table 1: Search results from the Web of Science queries*
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<tr>
<th>No.</th>
<th>Query</th>
<th>Timespan</th>
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<th>Proceedings paper</th>
<th>Articles</th>
<th>Other</th>
<th>Relevant categories</th>
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<td>1999-2017</td>
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<td>4</td>
<td>1</td>
<td>0</td>
<td>See above</td>
<td>3</td>
</tr>
<tr>
<td>1.2</td>
<td>“construction management” AND “higher education” AND &quot;UAV&quot;</td>
<td>1999-2017</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>See above</td>
<td>0</td>
</tr>
<tr>
<td>1.3</td>
<td>“construction management” AND &quot;higher education” AND &quot;Big Data&quot;</td>
<td>1999-2017</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>See above</td>
<td>0</td>
</tr>
<tr>
<td>2.1</td>
<td>“construction management” AND &quot;teaching&quot; AND “BIM”</td>
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<td>8</td>
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<td>1999-2017</td>
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<td>2.3</td>
<td>“construction management” AND &quot;teaching&quot; AND “Big Data”</td>
<td>1999-2017</td>
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</table>

The examined queries reveal some significant remarks. There is no shortage of articles describing general background of the construction management teaching problems on the higher education level. Among them there are some manuscripts about specific domain of BIM [1]–[14] whereas there is no papers about unmanned aerial vehicles or the Big Data in
Recently, in construction management education, which is under a constant transformation [15], there is an increased interest in games used for didactic purposes [16]–[19]. Moreover, online courses get more and more significant in shaping current teaching programmes [20], [21]. Blended learning models are frequently incorporated to construction management studying strategies [22]. Besides, many new ideas for methodologies used in this specific area are usually consistent with the innovations found in general approach to civil engineering education.

2.2 Specificity in construction management education

Regarding the specific features of construction, it should be pointed out that erected building structures shape the environment, have a long life cycle, are implemented with the participation of a number of specialists from many industries ( constructors, electricians, heavy equipment operators) and their work is connected with a special licensure.

All this makes it necessary to educate students who understand not only the structural mechanics, but are sensitive to respecting the formal and legal bases, or are able to respond to environmental problems in each phase of the project life cycle. Graduates must also be orientated in meeting the requirements of investors, and creating customer satisfaction with the products and services provided. It should be remembered that civil engineers play a key role at every stage of the construction life cycle - they design (construction, finish works, equipment), prepare a feasibility study, deal with administrative matters connected with the construction process, undertake construction projects, and participate in operational processes (maintenance of facilities) and their decommissioning (demolition site manager).

Graduates also work in insurance in the construction industry as well as in institutions financing construction projects. They play roles indicated by the construction law (known as independent technical functions in construction), as well as they become project managers or risk managers in the project. Their activities very often require specialized professional knowledge, when they are construction experts or expert witnesses. In conclusion, it should be stated that they are specialists who participate in decision-making at every level of the life cycle of construction works. Therefore, their proper preparation, described in professionally prepared study programs, containing modern and practical content of education, is crucial for the success of construction investment projects.

3 CONTENT ANALYSIS OF MODERN PROGRAMS

3.1 Building Information Modelling (BIM)

BIM is very often treated as the future of construction, because it means having a 3D model with its exact location and all necessary, easily accessible information for both designers, investors and contractors. BIM topics are interdisciplinary, combine technical, legal and organizational elements. The biggest benefits of using BIM include reduction of errors and delays in design, reduction of modification work costs and shorter duration of the project. The use of BIM in order to improve cooperation between design offices and
contractors indicates a trend towards greater integration of team members. New challenges, such as improving safety and shortening the workflow cycles, are constantly emerging.

Discussing the problems of BIM, both in the context of advantages and disadvantages, opportunities and threats resulting from the implementation of such solutions, should take place in the course of developing the competences of young people in the field of construction management. Therefore, in addition to practical activities integrating individual parts of design branches (architecture, construction, installations) what results in mastering the software, there should also be lessons about the use of BIM at the managerial level.

3.2 Unmanned Aerial Vehicles (UAV)

The use of drones in the world has increased significantly in recent years. The drone is not only a toy for mature children, but also a tool for working in the media, sports, agriculture and, more recently, also in the construction industry. Periodic drone flights before, during and after construction work enables for an inspection and a supervision of progress in the project. This allows to avoid delays in performing tasks. It enables for carrying out precise measurements, to detect insulation failures and to create complete project documentation.

Inspections of office buildings and public utility buildings can be carried out with unmanned aerial vehicles. This significantly facilitates real estate management. It also enables for quick and efficient thermovision and visual inspection of hard to reach places.

When educating students in the field of construction management, it is necessary to indicate strengths, potential opportunities and the possibility of using unmanned aerial vehicles during construction. In addition, it is also worth to make them aware of weaknesses, limitations and threats resulting from technical and legal conditions.

3.3 Big Data and Industry 4.0

Data in the analogue format at the present time are less and less used, because it can not be managed with by computers. Digital technology is constantly evolving, and the number of digitally recorded data is constantly growing - it has grown to such a large extent that effective data management is becoming more and more difficult. Big Data (BD) is understood as a large, diverse, complex and/or diffused data set generated from instruments, sensors, online transactions, e-mails, videos and/or other digital sources.

The use of BD in construction stimulates the need to manage the risk of construction projects. Generally, the risk can be defined as the difference between predictions and reality. It means the probability of lack of success in terms of undertaken activities [23]. It should be associated primarily with the measure of deviation from the values previously planned. The attempts to parameterize it relate to the estimation of the probability of achieving the objectives of the planned undertakings and the effects of their failure to achieve, expressed in physical or financial units [24].

The Big Data analysis used for risk management can increase the efficiency of management in the construction industry. In the management of investment and construction projects, both physical and virtual data derived from controlling, BIM, tender bids, schedules, data from construction contractors obtained on the construction site should be used. Thanks to the precise analysis of all data sets, the company can discover new characteristics of its customers, partners, markets, costs and operations [25].
However, apart from the significant advantages, there are also some disadvantages of BD. Poor data quality leads to incorrect results of the analysis. A challenge connected with the quality of data is also their non-consistency. In addition, any data breach or leakage is a serious threat to any organization. The breach is treated as the theft of BD's assets as a result of a burglary into the information and communication system at the level of collection, processing, transformation or to the user who stores them. Data leaks can be defined as the total or partial disclosure of BD assets at a given stage of the project life cycle.

Creating coherent systems based on Big Data is yet to come. In principle, everything is uncertain, both in the theoretical sphere as well as in the implementation of BD. Thus, a risk arises, the consequences of which are difficult to predict. However, there is a need to make students aware of both the advantages and disadvantages of implementing in the building sector achievements of the Industry 4.0 and to teach them so-called Construction Management Intelligence (CMI).

4 MODERN TEACHING MODEL

4.1 Student-oriented methods

Teaching in the field of construction management at the UTP University of Science and Technology in Bydgoszcz has a relatively long tradition. The specialty Technology and organization of construction is the oldest of the three currently operating in the field of civil engineering, at the Faculty of Civil and Environmental Engineering and Architecture. It has been present since the very beginning of the Faculty. Its graduates successfully carry out many investment and construction projects carried out in the Kujawsko-Pomorskie region and beyond. The author made effort to establish cooperation with a significant construction company, which has been organizing a series of events dedicated to the management of construction projects and issues connected with occupational safety and health at the construction site. During one series of such meetings, participants had the opportunity to take part in simulations of the implementation of construction projects maintained in the convention of educational games (Figure 1).

Figure 1: Construction project management in educational games
These events enjoyed considerable interest, and apart from fun, students discovered relationships that determine the success of investment and construction projects.

4.2 Site visits

It has to be underlined that thanks to the author, recently many student trips were organized to interesting and spectacular construction sites in Poland. One can mention here the construction of the A1 highway (Figure 2), the tunnel under the Martwa Wisła in Gdańsk, the sports hall in Bydgoszcz, a skyscraper in Warsaw, shopping centers, public facilities, etc. The preparation of this type of events requires not only managerial skills, but also knowledge of industry and having extensive personal contacts. Co-operation with external entities, such as the Polish Association of Construction Engineers and Technicians Office Bydgoszcz, helps in this. The organization integrates civil engineers and enables the exchange of experience between representatives of different generations of construction engineers.

![Figure 2: Participants of the site visit, A1 highway, 2010, Nowe Marzy (Poland)](image)

The trips to construction sites are usually quite popular among students. Thanks to such events, a practical point of view of theories taught by the traditional approach can be passed.

4.3 Conferences and webinars

Scientific development of the youth may take place not only thanks to participation in obligatory classes. The University's offer also includes a number of scientific groups. The "COMA" Student Scientific Group of Construction is one of the most thriving organizations. It organizes a series of CEPPIS international scientific conferences (Figure 3) devoted to contemporary construction problems, with particular emphasis on construction project management.

The participants of these events are students and research and teaching staff from Poland and foreign countries. They debate on the experience presented by scientists from around the world.
Furthermore, during the classes, students have an opportunity to participate in webinars devoted to a chosen subject (e.g. computer aided construction management, risk analysis of construction projects). In November 2017, by taking part in this type of event organized by a nationwide journal, the author proposed to students an additional form of education based on participation in a webinar that was broadcast live [26] and online.

4.4 International cooperation

For construction engineers, the awareness of the complexity of problems occurring during the implementation of construction projects should be extremely important. The spectrum of technical and organizational complications related to construction should be explained in the context of global experience. In the era of common mobility of people, education based on local rules is at least impractical, if not incorrect. Responding to this need, scientists from abroad are invited to the Faculty of Civil and Environmental Engineering and Architecture, who, in frames of the Erasmus+ program, arrive to Bydgoszcz and provide English classes for Polish students (Figure 4).

Such exchange is possible thanks to the intense work of the author who, playing a role of the departmental coordinator of the Erasmus+ program, encourages foreign scientists to visit the University and to share their knowledge with students. International cooperation in the field of teaching is possible thanks to the mobility of research and teaching staff, who are increasingly representatives of the Generation Y. They become educators for Ys or Zs in the field of construction or construction management.
5 CONCLUSION

Particular definitions of generations are matrices facilitating the characteristics of a certain group of people. Such a generalization turns out to be useful in finding and developing new and more effective ways of teaching a specific subject by analyzing the goals, contents, methods and organizational forms of education.

In search of the teaching model for the Generation Y (and soon Generation Z) in the field of construction management, two approaches can be applied: evolutionary and revolutionary. The evolutionary approach should take into account the existing contents and methods of teaching, and in their search for improvements that update the present state of affairs to new realities. On the other hand, the revolutionary approach requires a thorough reconstruction of the model of functioning of education at universities, in which modern content and innovative methods of education will play the leading role. The choice of the model depends on the degree of the university's organizational maturity, the quality of the teaching staff employed, as well as the market needs with which the closest possible contact should be maintained.

REFERENCES


THE IMPROVEMENT OF COLLABORATIVE PROJECT WORK USING ORAL PRESENTATIONS: THE EXPERIENCE OF ROAD ENGINEERING STUDENTS

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Key words: Education, Civil Engineering, Oral presentation, communication skills, Pecha Kucha.

Abstract. A successful road engineering project is often a highly collaborative team-based activity, and the engineering education community must therefore prepare graduates to work in this type of environment. A large body of research has demonstrated the considerable benefits and minor organizational problems of collaborative work in engineering education. However, there are only a few case studies reported in the literature that evaluate the positive and negative experiences encountered by students when undertaking group projects. The prevailing scientific view is that the “soft skills” derived from collaborative learning through teamwork are obtained automatically by the students once the project work is finished, but some “soft skills” are not obtained at all. The ability to express orally oneself and defend technically the solution adopted by the team, is a “soft” skill which is not enough trained in most of the cases.

This paper contributes to this limited literature by assessing previously methodologies applied to group projects with students enrolled in the “Roads” course (Civil and Territorial Engineering degree at the Madrid Technical University -UPM). Results obtained through a survey campaign to students have led to analyze the reasons why a panel of oral presentations (focused on the project work technical solutions) at the end of the course of “Roads”, could improve the learning and the acquisition of some “soft” skills. Attending the results of this study, oral presentations will be incorporated in the academic year 2018-2019.

1 INTRODUCTION

For engineers to be effective global leaders in the workforce, they need to master a range of interdisciplinary and interpersonal skills such as teamwork, critical thinking, decision making and communication skills. These are what are known as transversal competences and engineering education has been undergoing changes promoted by the Accreditation Board of Engineering and Technology [1] that include these competences. The main problem lies in the fact that these “soft skills” require continuous training throughout the engineer's education process. Technical oral presentation is one of those important skills or requirements that every engineering student needs to go through prior to graduation, as it is necessary not only for
academic performance, but also to secure employment after graduation. nevertheless, most students find the idea of oral presentations frustrating and intimidating. This is because they may feel a slight apprehension about their communication skills, and also about the content of oral presentations. therefore, it is clear that students need to master both the content as well as the skill of oral presentation in order to make an effective one.

This paper focused on an experience of teamwork in a “Roads” course within the Civil Engineering Degree of UPM (Technical University of Madrid). Students were working in groups during four workshops and previous surveys (carried out in 2015) on the student’s perception had revealed that a new learning tool was needed to present the projects developed by the groups as a way to go through and share the long list of contributions and group solutions to the workshops. Oral presentations seem to be one of the best tool to help to achieve this target but, due to the high number of students in the course (more than 90), this initiative (if we use traditional “PowerPoint” presentations) would consume one entire day. For that reason, the faculty staff has decided to introduced the short format of “Pecha Kucha” oral presentations. By forcing students to simplify the content, it meant more hours of work and more effort in understanding the subject matter. The following sections shows the preparation phase of this new experience to be implemented in the academic year 2018-2019, together with an assessment tool to evaluate this new initiative.

2 ORAL PRESENTATION IN ENGINEERING EDUCATION

Literature on the specific areas of difficulty that students face while performing an effective oral technical presentation (and the different ways to improve them) have been analyzed by the literature. In a first approach, a qualitative study was conducted at a private university located in Perak Darul Ridzuan, Malaysia [2], which attempted to find answers to specific areas of difficulty that students face. In the context of this study, the selected participants were members of three focal groups (26 students, 13 lecturers and 12 professional engineers). This research aims to discuss the perceptions held by focus groups on the apparent discord between academia (students and teachers) and industry (professional engineers) over communicative competence in technical oral presentations. the study also aims to explore the preparation of graduate’s communication skills for the future workplace and its pedagogical implications.

In a second approach, another study conducted at Universiti Teknologi Malaysia, Johor Bahru Campus [3], analyzed student perception on oral presentations. In this case, respondents were students from five different engineering faculties and data was collected through the distribution of a questionnaire to 235 students. This questionnaire consisted of three sections. Section A focused on the collection of demographic information from respondents; section B focused on the area of oral technical presentation difficulties commonly faced by students; and finally, section C looked at respondents' perceptions of how to improve oral technical presentation. Some of the difficulties common faced by students were linked to the inadequate knowledge of presentation skills and low confidence. Finally, the data collected were analyzed by frequency counts using the SPSS Statistical Package.
In the first area of difficulty experienced, when students were surveyed before their presentations, concerns about this issue are among others:
- Do not know the proper pace of presentation.
- Not paying attention to intonation.
- Do not know how to use nonverbal communication in presentation.
- Reading notes/slides prepared.
- Present points that are confusing and long.
- Do not know how to answer questions.
- He doesn't give examples.
- Do not know how to organize the content.

In the second area of difficulty, low confidence correlates with the question of what students feel when asked to make a technical oral presentation, in which their response was summarized as feeling stressed, worried and anxious. In light of the above difficulties, the three best valued solutions for improving technical oral presentation seemed to be: reading books and articles focused on oral expression techniques, followed by self-study multimedia courses and, finally, viewing presentations on the internet.

Oral presentations are not only important for the student’s education, as a “soft skill” to acquire but also for the teaching staff, in their expositive classes. Some authors [4], based on faculty conferences, had identified strengths and weaknesses that need to be improved in an oral presentation and these strengths and weaknesses can also help student to improve their own oral presentations. For the three main phases of an oral presentation, the beginning of the presentation should not exceed 10-20% of the time allotted to the presentation, the body of the presentation only 60-80% of the time and the end takes 10-20% of the time allotted. As regards the initial part of an oral presentation, the audience appreciates more the ability of the interlocutor to attract attention, then the enthusiasm and less the ability to motivate the audience. In the central part of an oral presentation, the following indicators were selected: clear structure; accessible, easy to understand presentation, self-management and trust; accuracy and relevance of oral expression; appropriate posture; modern visual aids used effectively. In this case the audience, from the most important and highly appreciated to the least, considers: speaking accurately and appropriately; self-control and confidence; modern visual aids and finally clear structure. The end of an oral presentation was analyzed according to the following indicators: allow students to ask questions; repetition and clarification; bibliography and complementary materials. The results have helped to identify the strengths of an oral presentation itself and those of the speaker himself: indicating a bibliography and allowing the audience to ask questions in the first case, and an appropriate posture and suitable speech in the second case. By contrast, the least appreciated were repetition and clarification, motivation and enthusiasm. The conclusions of this study can definitively help students to prepare their own oral presentations, avoiding the least appreciated behaviors.

In traditional presentations too much time is usually spent on telling a lot of information without focusing on the main ideas. Power Point is the common resource for oral
presentations and usually text is overused in the slides, which causes the speaker to turn his back on the audience most of the time, or in the excessive use of notes. The issue of the impact of PowerPoint on student learning, especially in relation to traditional classes, continues uncertain. The effectiveness of PPT as a teaching tool may continue to diminish over time [5]. Pecha Kucha has appeared because it was necessary a new kind of learning that helps to internalize ideas, understanding, and remembering the material learned through active learning. The structure consists of a presentation of 20 slides at a rate of 20 seconds per slide, which limits the total presentation time to 6 minutes and 40 seconds. The interlocutor is challenged to use more visual images on the slides and to relate them directly with his verbal presentation, so it is necessary to know the material well enough to present it without the support of notes. At the beginning, Pecha Kucha was planned for an individual presentation through a timed presentation; nevertheless, research has been carried out to modify the main rules of the original style [6]. In this case, these traditional rules are modified to be used in group presentations, being from 3 to 5, the number of speakers and the time allowed per slide varies as long as it does not affect the total duration of the presentation of 6 minutes and 40 seconds. Students can "borrow" time from a slide to focus more on other important points.

Although Pecha Kucha is a very recent tool for oral presentations, literature on his effectiveness is beginning to spread. One first approach for researchers is to use an experimental post-test design to determine the effectiveness of a Pecha Kucha presentation compared to one with the traditional Power Point style. The advantages of this new style of presentation are accompanied by some disadvantages. Pecha Kucha emphasizes the rapid transfer of information from the speaker to the audience. It does not allow the use of flexibility of the traditional Power Point where you can pause the presentation for questions or change the content based on the public's understanding of the topic. In fact, the presentation is blocked and cannot be altered along the speech. The speed of a timed presentation of Pecha Kucha makes a nuanced explanation of many complex concepts impossible. Therefore, the topics that can be expressed must be carefully chosen. In addition to prepare the slides, Pecha Kucha presentations should be rehearsed as a lecture, so that they are understandable to the student audience and flow uniformly, fluently, and without delay.

This type of presentation was experienced at Texas Tech University in 2012, in a class of 60 students and then again in 2014 in a class of 42 students [7]. It was found that the students spent at least 2-4 times more time and effort preparing and practicing for the Pecha Kucha presentation than they would have required for a standard Power Point presentation. Texas students were rated using a rating rubric that measures content accuracy, presentation clarity, slide quality, presentation quality (with or without notes), creativity and interest generated. By forcing students to simplify the content, it meant more hours of work and more effort in understanding the subject matter. They learn to synthesize the essentials in a few slides. More time is spent on preparing this type of presentation, due to this format takes students out of their comfort zone. On average, students practiced more than two hours, while traditional presentation groups practiced half an hour, an hour or less. In addition, the student audience was more involved and interested in the presentations, asking more questions than in the traditional PPT. Nevertheless, it results in a more professional preparation and content and more self-confident speakers in the public exhibition. Most students enjoyed the presentation
and learned the exam subject much better than if they had just studied it. In terms of exams, grades were not significantly different from other subjects with similar characteristics, where the Pecha Kucha presentation style was not used. Although there was no quantitative support for the Pecha Kucha format to improve understanding and retention of content, it seems to focus on enhancing students' presentation skills.

Another method to reinforce students' oral presentation skills was based on the use of video recorder [8]. Tugrul conducted a research in 2012 with 82 students and examined the impacts of both the video recording process and group project presentations in class and the discussions that result of seeing these recordings on students' perceptions. This study implies that the recording of video presentations of group projects and the use of these videos to evaluate student performance were perceived as an effective, useful, satisfying and good educational technology to promote learning. The added value of Tugrul experience is the items used to measure oral presentation skills and communication skills. Oral presentation skills were studied using five items: ability to manage speech tone, manage body movements, maintain audience attention, maintain adequate eye contact, and answer questions effectively. The communication skills were studied using three items: ability to speak effectively to groups, communicate with an appropriate level of detail, and communicate orally. In career-related skills, applying for employment is studied and those skills that are needed later, related to job performance. The motivation for learning was measured using two items: working hard for the presentation and studying more to learn more about the topic of the presentation.

As conclusion, the literature review has reinforced the importance of the role of oral presentations, as learning tool in Engineering education, but at the same time has revealed that students are not enough prepared and trained to make efficient oral presentations. Students should be provided with documentations and instructions related to how to prepare a successful oral presentation. The items that faculty should use to assess an oral presentation are also an issue that need further research (technical contents should be evaluated separately from communication and oral skills). Some studies have demonstrated that surveys on student perception (before and after their oral presentation) can be a good methodology to assess a pilot experience of oral presentations. Next section describes the case study where our experience will take place.

3 THE CASE STUDY: PROJECT WORKS ON ROADS INSTRUCTION

In recent years the whole civil engineering education community in Spain has been immersed in a vigorous debate in order to establish the competences needed for current and future engineering practice. The new European Higher Educational Area has served as a major stimulus to revise university degrees and identify basic, transverse and professional skills. Once these new programs have been established, the issue is how to implement this new scenario in current subjects. The new Civil and Territorial Engineering degree was launched in September 2010, and is organized in eight semesters (30 ECTS each), and each student must choose one specialization (Civil Constructions, Hydrology and Transport and Urban Services) at the beginning of the sixth semester.
“Roads”, the UPM scenario in which this empirical research took place, is a compulsory course (subject or module) in the seventh semester of the Civil and Territorial Engineering degree, with a workload of 4.5 ECTS (European Credit Transfer System) credits. There are other previous modules related to “Roads” but this is the first to be specifically based on road design. In one semester, students are supposed to learn how to design roads using four aspects (approaches): traffic, layout, geotechnics and drainage (hydraulics and hydrology). Teamwork is combined with conventional classes and, using the content of these lessons, the project work is organized in four sessions (four cases of study): planning and traffic, layout (road alignment), geotechnics and drainage. The project work, which represents 20% of the total workload in our course (Roads) syllabus, taking into account the project workshops and preparatory practical classes. This project is based on the design of a real road. The group for each project, comprise four members (formed with the student selection criteria) and work on the same map (the same location), although the project solution may differ from one team to another. Each workshop is conducted by the student groups inside the classroom during the assigned timetable (each workshop has a maximum duration of 2 hours and 30 min); all the teaching staff are present in the classroom during the workshop in order to track student progress and answer queries. At the end of the workshop each team hands in a written report with the results of the workshop to the teaching staff, with no option for the team to complete the report at home.

Surveys on student perception, carried out in 2015 [9], revealed that the project work itself was very appreciated for students but the least-liked element of the Madrid project work for the students (66.7%) was the problem of time management. Firstly, it was very important to research the theory before attending the workshops, which some students probably failed to do (48.96% of the students confirmed they would improve this aspect if they repeated the teamwork). Secondly, as far as the authors know, Madrid students had very little background in class teamwork under time limitations in the degree so far. By forcing students to prepare an oral presentation on the project work, once the project is finished, and simplify the content, it meant more hours of work and more effort in understanding the subject matter, before the final exam. Pecha Kucha format could also help to select only the most important results of each workshop, coming back to the usual mistakes and also to the most brilliant contribution of each group.

Next academic year (2018-2019), with a workload of 10% of the total, there will be an oral presentation and a defense of the four workshops proposed during the course, using the Pecha Kucha methodology. Each oral presentation will be conducted by one of the members of the group, who will be selected by the teacher immediately before the exhibition. Prior to the delivery of each practical case, the student must compile the information which considers necessary for the preparation of the presentation. A maximum of 2 hours and 30 minutes (150 minutes) will be available for the whole process. Each group, composed by a maximum of 4 students, has about 6 minutes to show their work, following the Pecha Kucha method. Therefore, they will be able to present around 25 groups, which means 100 students, during this time. Apart from that, individual/autonomous resolution of exercises and problems associated with one of the four practical cases, which represents also 10% of the total workload, are carried out by the student during the course. To sum up, the project work
assessment, in which all four workshops are considered equally, accounts for 40% of the final mark, with the other 60% based on an individual exam.

Students will be provided with useful guidelines for preparing successful oral presentations, such as the subject, the objective, the target audience and how the interlocutor should act (adaptation to the time available and the message to be transmitted). For the exhibition, recommendations will be defined (arrive on time and check the outfit you will use for the presentation, suitably dress for the occasion) and psychological preparation (sleep well the night before, anticipate questions and possible answers). And finally, the evaluation phase, where it is analyzed how the interlocutor feels and which things can be improved for the next time. These guidelines will also include recommendations to use the Pecha Kucha and the items susceptible to being evaluated by the teaching staff during the presentations and not related to the technical contents of the project work.

4 ASSESSMENT OF EXPERIENCE

The assessment of the experience has been structured in three parts. First part focuses on the student feelings before the oral presentation and their expectations prior to the oral presentation. The second part assesses the oral presentation itself, attending communication and oral skills separately from the technical content. Finally, the third part focused on the student perception of the experience.

4.1 Survey of students' expectations prior to the oral presentation

In order to know the strengths and weaknesses of the students in an oral presentation, a survey of around 10-15 questions will be distributed. It will be answered in a scale from 1 to 5, where 1 equals strongly disagree and 5 equals strongly agree. Among them, the aim is to find out if students, when it becomes the interlocutor of the presentation regard to the project work, feel frustrated, nervous or with sufficient capacity to face it. Similarly, it is questioned which audience feels more comfortable with the speaker, or which they would prefer to use as support in order to guide their presentation. On the other hand, it is useful to know, if they believe that the university/school itself collaborates in improving the students' abilities in oral exhibitions, for example through lectures and conferences on their own experiences and the advice of professionals, more practical classes in which students discuss their personal opinions, courses specialized in this field, a higher percentage of workload in group work, or providing prior documentation for students to serve as a brief guide to use.

- I think I have enough self-confidence to do a professional presentation.
- I prefer that the responsibility lies on another colleague in the group.
- I am usually intimidated, nervous, weak, and insecure before a presentation.
- I use lots of notes or I read the slides to give continuity to the presentation.
- I try to show more graphics and images, because I think the message to be transmitted is much more direct and dynamic.
- I prefer a close audience to feel more comfortable.
- I usually prepare the presentation by repetition the content rather than understanding the ideas to be conveyed.
- The university collaborates in specialized courses that promote these skills (discussion forums, competitions, etc.).
- The percentage of workload in project work and oral presentations, is very low for the work and dedication they require.
- I would improve my self-confidence if classes were encouraged where personal opinions are discussed and expressed more openly.

4.2 Evaluation of the oral presentation

For the evaluation of students, teachers choose to use a rating rubric in which certain evaluation criteria are set out, with scores from 1 to 5, being 1 defined as "Poor" and 5 as "Excellent". The points to be evaluated are the following:

- Speech and vocabulary: speak slowly and clearly, with appropriate vocabulary.
- Voice tone: a volume loud enough to be heard by everybody.
- Body posture and eye contact: look at all audience naturally.
- Self-confidence and reliability in the approaches described.
- Time use: perfectly the interlocutor adjusts to the time limit by presentation and group.
- Use of visual and/or technological resources: appropriate use to enrich the presentation.
- Quality of the presentation: it keeps the attention on the viewers and avoids just reading what is written in slides or notes.
- Dynamic presentation.
- Content control.
- Organization and sequence: a logical and orderly sequence is adopted between the different cases of study presented.
- Clarity and precision in the presentation: Non ambiguities.

4.3 Survey of students' perception after the oral presentation (final evaluation of the experience)

After the presentation of the project work, the students will carry out a post-presentation survey to know their experiences regarding the new methodology adopted. In this way it is possible to identify the differences with respect to the beginning of the course and whether they have found it really effective to adopt other methods to enhance their confidence in oral presentations.

- The oral presentation helped me to better understand the workshops.
- The oral presentation helped me to understand the subject better.
- I will spend less time on the final exam preparation because oral presentations have help me to understand the content of the exam.
- The oral presentation has developed my communication skills.
- I am now more prepared to present any project orally.
- I will use Pecha Kucha in the oral presentations of other courses.
- I will use Pecha Kucha in my professional career.
- Pecha Kucha requires more preparation than traditional Power Point.
5 CONCLUSIONS

Literature has shown the need and benefits of including learning tools to train “soft skills” in Engineering Education. Oral presentations are one these tools, although engineering students are not used to work with oral presentations in the majority of the courses of the degrees. This paper describes a methodology to assess a pilot experience of implementing students’ oral presentations in a course of “Roads” at UPM (Technical University of Madrid). Although this pilot experience will be carried out during the next academic year (2018-2019), the paper describes the content of the questionnaires that will be distributed to students before and after the oral presentation as well as the items that the faculty staff will use to evaluate the oral and communication skills of the students during the presentation itself.

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MAY BE GEOTECHNICAL ENGINEERING LEARNING FUN?

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Key words: Teaching innovation, higher education, active methodology, formative assessment, flips teaching.

Abstract. Geotechnical Engineering, its technics and methods, are usually an awkward topic for many students of civil engineering degrees who are often more focused on getting the “final number” of a given problem than in the process, using the engineering thinking, conducted to plan first and later arrive to the solution. This issue is especially significant when teaching “advance topics” of Geotechnical Engineering such as Tunneling or Ground Improvement. Those topics are normally taught in the last years of the degrees and in many cases students are used to the classical teaching in higher education. All of this normally results in a low motivation of students, mainly interested in obtaining the Degree itself, more than in learning. In this article we show an active learning methodology based on autolearning, which with the help of the teacher and a series seminars and workshops, leads to involving the engineering students in those advanced geotechnical engineering topics, even enjoying with them. The core activity of the learning methodology is the preparation of a part of the subject by the own students, who work in groups and have to give a “real” lecture to their colleagues. The learning methodology presented follows several previous works conducted by the authors [1,2] and other researches [3], and aims the student to build knowledge, fostering their motivation as well as the responsibility of their own learning [4]. Assessment of the activities carried out by the students is conducted taking into account the evaluation of both the teachers and the students themselves.
1 INTRODUCTION

Typical students of civil engineering degrees usually give more importance to the result obtained of a problem, i.e. the “final number”, than to the process followed to obtain it. This lack on the use of the “engineering thinking” causes that topics like Geotechnics and Geotechnical Engineering often result to be difficult and even uncomfortable subjects for them. Besides, students are accustomed to the classical teaching of higher education, a regulated education fundamentally based on the transmission of great theoretical and technical knowledge. Both issues cause that in the last years of the degrees, when advanced topics of Geotechnical Engineering such as Tunneling or Ground Improvement are taught, students are barely motivated. Many of them commonly decide not to attend classes, and some of them are mainly interested in obtaining the Degree in itself, rather than in learning.

Active learning methodologies to involve students are therefore necessary. Those methodologies should also consider the inherent pragmatism characteristic of the Civil Engineer profession, and why not, they may also be developed in a way that students can even enjoy learning. Based on those ideas, this communication presents a learning methodology that intends to achieve a greater motivation of the students towards a subject and its related field, while providing students a certain control over their own learning. The subject object of the innovation belongs to the thematic field of Geotechnical Engineering and is part of the last year (4th year) of the Civil Engineering Degree taught at Civil Engineering School of Universitat Politècnica de València (UPV). The subject is taught since the academic course 2012-2013, when Bologna Plan was implemented.

The innovation presented addresses two basic aspects: (i) implementing a continuous assessment, based on a pragmatic approach to the subject, as opposed to the traditional formula of one or two unique exams; and (ii) proposing activities of an active nature, which makes it easy for all students following the subject, increases their motivation and involves them in learning.

Students are offered the opportunity to pass the subject through a continuous assessment throughout the semester. For doing this, and as the core activity of the learning process, students have to develop a part of the subject by groups, having to make partial deliveries (with subsequent feedback) to the teacher in charge of mentoring the group, as well as a final presentation to the rest of their classmates, teaching a real lecture. The topics developed by the students are eminently practical, and they are encouraged to teach them as actively and interactively as possible, even in a playful way, allowing being possible to “learn by having fun”.

The innovation follows the work developed by the teachers both inside and outside the teaching activity as well as in several previous teaching experiences [1-3,5,6], encourages students’ motivation and responsibility for their own learning [4,7] and fundamentally combines four types of learning methodologies: master lesson, cooperative learning, autonomous learning and flip teaching.

All in all, the following objectives are sought to be achieved with the innovation proposed:
- Involving students in the subject and awaken their interest in it.
- Involving students in their own learning and evaluation.
- Developing the student’s capacity for self-criticism regarding their own knowledge.
- Fostering team-working.
2 INNOVATION DEVELOPMENT

2.1 Subject planning

The subject is divided into two parts, a first one more regulated and conducted by the teachers, in which the master lesson and cooperative and autonomous learning are combined, and a second part, almost exclusively based on the flip teaching methodology. In this second part the student is the central character of the learning process, being students themselves who give the lectures (in groups) to their classmates.

Table 1 shows the subject planning followed during the last academic year (2017-2018), which, with small variations, is similar to that proposed since 2013. In addition to these classroom classes, the subject also includes some laboratory sessions and a field session, in which students are guided in the learning process by one or several teachers.

<table>
<thead>
<tr>
<th>Date</th>
<th>Topic</th>
<th>Learning methodology</th>
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<tr>
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<td>Master lesson</td>
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<tr>
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<td>Geotechnical investigation planning</td>
<td>Cooperative and autonomous learning</td>
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<td>Cooperative and autonomous learning</td>
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<td>Master lesson</td>
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<td>03/10/2017</td>
<td>Rock masses deformability</td>
<td>Master lesson</td>
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<td>04/10/2017</td>
<td>Case Studies on rock masses</td>
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<td>29/11/2017</td>
<td>Case Studies on ground improvement I</td>
<td>Flipped classroom</td>
</tr>
<tr>
<td>05/12/2017</td>
<td>Case Studies on ground improvement II</td>
<td>Flipped classroom</td>
</tr>
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This planning is known by the students from the beginning of the course, so, besides syllabus distribution, students know the teaching methodology to follow on each session. As learning terminology is generally unknown by students, the first class of the subject is used to briefly explain each one of the learning methodologies to be used throughout the course.
Thanks to this, students become aware of what is expected of them in each session and what can they expect from the teacher. This makes it easy that each student acquire control over their own learning.

2.2 Subject development

The first part of the subject is similar to the classical theoretical lectures, being the teacher who guides the classes, structures the content to be discussed and fixes to a certain extent the rhythm of learning. However, it is sought that the teacher does not have the complete leadership. Thus, the teacher gives some guidelines of basic points that will be worked on activities proposed to the students. The aim of this is students play a role as active as possible, developing the classes in an interactive way. For doing this, techniques such as the use of expert panels, viewing some fragments of documentary videos obtained directly from the internet (through the platform “Youtube”), presentation of real cases and performing simple tests using the computer application “Kahoot” are conducted. This is intended to both motivate the student and capture their interest, showing different alternatives to the typical masterclass, a methodology that is usually associated by students with what a lecture is.

The second part of the subject is developed with the flip teaching methodology and its development is based, as indicated above, on the fact that the students themselves teach the lectures. Through this flip teaching methodology, the student become the central character and the responsible of their own learning [8,9]. The first day of class, after informing the students about the operation of the course, the learning methodology and the evaluation system, they are asked to freely form ten groups of 3-5 people (depending on the total number of students) and communicate to teachers before one week what people will form each of the groups.

Approximately two weeks after the start of the course, each group is summoned to entrust them with the part of the subject that they must prepare and about which they must give a 2-hour lecture. Thus, each group is aware to see that they will be responsible for one of the lectures of the second part of the subject, so they will take the “teacher’s role”. To prepare the class, students have the help of one of the teachers of the subject, who tutors the group and controls the pace of work through more or less periodic meetings in which feedback is provided to students. However, the role of this tutor is a minor one.

After having assigned to each group the topic to be taught, in order to “focus” them on their learning development, the tutor instructs students to prepare the lecture. There is no restriction in the way students can give the lecture, and they have to decide how to do it, as well as the documentation to provide to “their students” (i.e. their classmates). Everything is entirely their responsibility. This creates, in a first moment, bewilderment, fear and disbelief in the students.

After this first “stage” and once the group begins to sketch a first idea of the contents of the lecture, the tutor reminds the group the importance of practical aspects in civil engineering and encourages them to prepare the lecture to be interactive, dynamic and playful, trying that everyone “learn by having fun”. This is sometimes followed with the following sentence: “Give the lecture as if it were the ideal lecture that you would have liked to receive in your life”.

This ensures that students prepare really interesting and fun activities. Thus, in Figure 1 we
can see the students of the group responsible for teaching the class doing a “Kahoot” to their classmates, in which as a prize the winner was given a chocolate tablet.

![Image](image1.jpg)

**Figure 1**: Students giving the lecture “Geotechnical-Structural calculation of a tunnel” corresponding to the 18th session of the subject

In Figure 2 we can see learning the topic “dynamic soil compaction” through a real simulation prepared by the students of the group responsible of teaching the lecture so that their classmates could understand by “playing” the basics of this technique and the effects that it brings when it is applied on a real ground.

This type of activities, together with the reality that their own classmates are who are teaching (Figure 3), leads to a notable participation of the students as well as a great involvement when compared to what was observed before implementing this methodology. Students usually finish overcoming their “stage fright” to speak in public and in some lectures there are debates and discussions on the subject taught with a very high participation.

Furthermore, it is interesting to note that this “change” in the behavior of students begins to occur in the first part of the subject in which the methodologies used are the masterclass and the cooperative and autonomous learning. This is because of at that time they have been working for weeks to prepare “their lecture” and that give them some security in class and predisposes them to collaborate in it.
2.3 Resources used for the subject preparation

Resources used as material for students to achieve the success of the innovation can be summarized as follows:

- Information to develop autonomous work: students are provided with plenty of material available at the webpage of the subject from the beginning of the course, both written material and videos that may be used as a starting point and approach to the subject.

- Theoretical material: this material is the basis for the development of the regular sessions of the first part of the subject and it provides feedback to students learning; all the material discussed in class is available at the webpage of the subject.

- Theoretical-practical material: this material, also available at the webpage of the subject, can be used by students to carry out cooperative learning and team-working.

- Bibliographic resources: at the beginning of the course and during the preparation of lectures by students (second part of the subject), a broad list of bibliographic references, both generic and specific, is provided; all bibliographic references are available at the University Library.
2.4 Evaluation

Students who follow the proposed innovation methodology are mainly evaluated according to the two parts in which the subject is divided as indicated above:

- The first part of the subject, which focuses on more theoretical aspects, is evaluated by means of an open answer written test, where the student must solve a series of questions similar to those made at class. This test represents 40% of the final grade.
- The second part, corresponding to the lectures given by the students in groups, represents 40% of the final grade and is assessed by co-evaluation based on three items with the same weight (one third each): (i) peer evaluation conducted by those classmates who were present in the lecture given by the student group; (ii) peer evaluation conducted by each of the students of the group that has given the lecture, of the other components of the group; and (iii) evaluation by the teacher who has supervised the group.

It is important to note that both peer evaluations are anonymous and are performed once the class is finished (there is a time limit of one week to do it). In addition, laboratory sessions represent 10% of the final grade and are evaluated by a written report done individually by each student.

As can be seen, an important weight is given to the peer evaluation based on the preparation of a part of the subject syllabus by the students and the later lecture giving to their classmates. Since the innovation is addressed to 4th year students who are on the verge of becoming civil engineering practitioners, it is intended to promote the capacity of students to technically select and present the information that they consider interesting for their target audience (in this case the rest of classmates), as well as their ability to technically discuss the engineering work carried out by themselves or by another practitioner.

Likewise, it is important to say that from the beginning of the course students are aware of the evaluation system, and they are given the opportunity to be evaluated both by following the mentioned methodology and through the traditional formula consisting of two exams. In the latter case, the first exam is identical to the test of the first part of the innovation, while the second exam is an open answer written test which deals with the topics related to the second part of the subject.

3 RESULTS

Figure 4 displays the academic results of the students on the subject from 2012-2013 academic course up to the present one (2017-2018). During the first year (2012-2013) a more traditional methodology was followed, based almost exclusively on the use of the masterclass during the whole academic period and the evaluation through two exams. In 2013-2014 the methodology described in this communication began to be implemented, and it has undergone little variation from that point, although it has been improving and polishing little by little over time.

Results show that the change on the learning methodology led to a clear and drastic decrease in the number of students who abandon the course, being less than 5%. Besides, the implementation of the teaching innovation has led to a general increase in the percentage of both pass (D) and average (C) grades, although there is no significant increase in the number of higher grades (A and B).
This indicates that the new methodology manages to improve the academic performance of the “average students”, who increase their grades. On the other hand, students who were already excellent still are. It is also interesting to note that of the total number of students who have been enrolled in the course since 2013, when innovation was launched, of the 543 students who decided to follow the new learning methodology almost all of them have passed, only 9 failed.

Regarding those aspects related to the level of involvement and motivation of the students and their assessment of the subject and the innovation, Table 2 shows the results of a survey carried out by the Education Institute Center (ICE) of the UPV in the last academic course with the aim of assessing the implementation of the flipped class methodology. It should be noted that there is no data from previous years, so it is not possible to make any objective comparisons. However, from a qualitative point of view, it was already observed from 2013-2014 that the innovation significantly increased the degree of involvement and motivation of the students.

The analysis of Table 2 shows that the active methodology proposed in the innovation achieves the objectives of fostering team-working and increasing the level of involvement in the subject. The latter seems to have a side effect, because it motivates the student to attend the class and work on it, helping the student to some extent to arrive better prepared to the exams.

Moreover, what students value most, besides the material given by teachers, is the possibility of learning together with their classmates both inside and outside the classroom. As expected, the creation of a good social environment fosters the learning process and it also
makes the learning experience more enjoyable. The evaluation system of the subject is also positively valued by the students, who appreciate the possibility of passing the subject by a continuous evaluation and not by one or two “independent” exams.

Finally, it is important to point out that the great majority of the students liked the teaching methodology followed and would recommend their colleges to enroll on it.

Table 2: Survey students results about the learning methodology used (course 2017-2018)

<table>
<thead>
<tr>
<th>Issue</th>
<th>Value scale*</th>
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</thead>
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<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Enjoyable and good experience</td>
<td>8%</td>
</tr>
<tr>
<td>Recommended experience</td>
<td>0%</td>
</tr>
<tr>
<td>Raising implication in the subject</td>
<td>8%</td>
</tr>
<tr>
<td>Facilitating relationship with the teacher</td>
<td>0%</td>
</tr>
<tr>
<td>Cooperative work (with colleagues) development</td>
<td>0%</td>
</tr>
<tr>
<td>Evaluation system</td>
<td>8%</td>
</tr>
<tr>
<td>Material given by teachers</td>
<td>8%</td>
</tr>
<tr>
<td>Work class activities</td>
<td>0%</td>
</tr>
<tr>
<td>Work in groups with colleagues experience</td>
<td>8%</td>
</tr>
</tbody>
</table>

* Value scale ranges from 1 (“negative”, “dislike”, “not interesting”, “disagree”) to 5 (“positive”, “like”, “interesting”, “agree”)

4 CONCLUSIONS

After five courses applying the new active methodology based on self-learning and the use of flip teaching, its implementation has undoubtedly managed to increase the motivation of students as well as their willingness to participate actively in the subject.

Innovation has allowed students to transform, at least to some extent, their typical vision of memorizing “strange” theories and “systematizing” the resolution of problems, classic approach of civil engineering students towards a theoretical-practical subject like Geotechnical Engineering, to a new framework in which they are the ones who learn continuously, day by day, guided and accompanied by the teachers who help them to face the “obstacles”. Students are the true central characters of lectures, even being themselves who teach to the rest of their classmates. And all this with a focus on practical and interactive aspects, even in a playful way in some cases, which clearly seeks that the student “learn by doing” as well as “learn by having fun”.

Thus, the implemented learning methodology has enhanced the formative evaluation of students, has improved their academic performance, especially that of the “average students”, and has ostensibly reduced the “academic absenteeism”, with a very low or even null student failing rate figures.

Finally, it is interesting to note that this innovation has been the outcome of the cooperative work of all the teachers of the subject, who have collaborated to a greater or lesser extent in the innovation and helped in the successfully implementation of it throughout these five academic courses. Team-working and shared reflections, as indicated by Santos et al. [3], have enabled to overcome the insecurities generated by doing something different and innovative.
REFERENCES


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