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New Trends and Challenges in Civil Engineering Education

Edited by
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Venue
University of Patras
Conference and Cultural Centre

Jean Berlamont
President EUCEET Association
Chairman of the Scientific Committee

Dear participant,

Welcome to the first conference organized by the EUCEET association. Through the four consecutive EU supported projects between 1998 and 2010, the EUCEET partners have acquired considerable expertise in civil engineering education and training. The EUCEET association wants to continue along the same track and contribute to the implementation of new learning methods and the development of new and better educational programs in civil engineering, taking into account the changing environment and boundary conditions.

The implementation of the Bologna, two-tier track has caused in many places profound changes in the (traditional) curricula, many of which have not yet reached a new equilibrium state. The role of research in universities and companies becomes more prominent, which implies the formation of researchers through adequate doctoral programs and relevant research. New subjects as there are: energy conservation, durability, limited use of natural resources, respect for the environment, cost effectiveness, effects of global climate change, … emerge and should find their way into the curricula, courses and project work.

Construction companies face huge challenges in the globalizing economy and open market. High quality work and the introduction of innovative technologies and techniques are indispensable in a competitive environment. Therefore the link between construction companies and higher education institutions becomes more important since companies need relevant research and competent and innovative civil engineers.

To respond to these changes, EUCEET has chosen as the theme for this conference "New trends and challenges in civil engineering education". We received a good number of interesting and qualitative papers and found enthusiastic key note lecturers, who are acknowledged specialists in their fields. Therefore, we hope that you will find this conference interesting and rewarding and that it may inspire you in your educational task at your own institution.

We hope that this first EUCEET conference may be the first one of a successful series of conferences dedicated to civil engineering education.

Stephanos Dritsos
Chairman of the Organizing Committee

Dear Participant,

In the globalised world that we live in, our social, economic and even human and natural environment are changing rapidly. However, one source of stability can be recognised that has lasted throughout the ages. It is education. In the Greek language, the word for education is "paideia" (παιδεία), which has a deeper meaning encompassing the concepts of culture, perfection and excellence. Indeed, the state of the populations' education in a country is the critical indicator of the quality of peoples' lives in that country. When considering how to educate civil engineers, the following questions naturally arise:

How should education respond to social needs?

Are broader social needs and market priorities in balance?

Is economic progress the leading parameter for education?

Is it the education of the people that governs the markets or do the markets govern the peoples' education?

Finally, which is the best way to educate civil engineers?

When the Civil Engineering Department of the University of Patras accepted the EUCEET Association's invitation to co-organise its first conference, it was intended that these questions should be discussed. Possible answers to the questions may be discussed better within a scientific conference. To this end, the general theme of the conference "New trends and challenges in civil engineering education" was chosen. Naturally arising within this general theme are the sub-themes of: Teaching and Learning, Civil Engineering Curricula: Old and New, Bologna Implementation and Concerns, PhD Studies and Qualification, Accreditation, Assessment. It will be seen in the following volume of abstracts and the accompanying full paper CD of the proceedings that the Conference theme and sub-themes have attracted a wide variety of high quality papers and participation from well recognised educational institutions throughout Europe and its environs. It has to be noted that all submitted papers were subjected to a rigorous review process.

It was a pleasure and an honour to serve in the organisation of this event. I am thankful to the members of the Scientific and Organising Committees, all authors, participants and sponsors. It is certain that the quality of the event will be considerably enhanced by the crucial matters covered by the invited keynote speakers, who are all distinguished and highly respected specialists in the field of civil engineering education. In particular, I would like to express my deepest gratitude to Prof. Marina Pantazidou and Ms Eftychia Apostolidi, secretaries of the Scientific and Organizing Committees respectively, as it is certain that none of this would have been possible without their unstinting efforts while working behind the scenes. It is with great pleasure and intense pride that the Civil Engineering Department of the University of Patras has the honour of hosting the EUCEET

Association's first conference. Furthermore, the Civil Engineering Department of the University of Patras offers a very warm welcome to delegates attending this conference and wishes the EUCEET Association every success with its first and subsequent conferences as well as with the broader work that the Association performs.

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Session 1: Teaching and Learning Page

Session 2: Civil Engineering Curricula: Old and New

Session 3: Bologna Implementation and Concerns

INFORMATION TECHNOLOGIES IN STRUCTURAL ENGINEERING: A PAPERLESS COURSE

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EXTENDED ABSTRACT

This paper presents the structure of an undergraduate course entitled “Programming Techniques and use of specialised software for Structural Engineering” which is offered to the 5th year students of the Civil Engineering Department of Aristotle University Thessaloniki in Greece. The aim of this course is to demonstrate the use of new Information Technologies in the field of Structural Engineering and to teach modern programming and finite element simulation techniques that the students can in turn apply in both research and everyday design.

Apart from demonstrating the programming and simulation techniques and tools currently available, the course focuses on the physical interpretation of structural engineering problems as they are discussed in class, in a way that the students become familiar with the concept of computational tools without losing perspective from the engineering problem studied. For this purpose, a wide variety of structural engineering problems are studied in class, involving problem solving related to structural statics and dynamics, earthquake engineering, design of reinforced concrete and steel structures as well as data and information management.

The main novelty of the course is that it is taught and examined solely in the computer laboratory ensuring that each student can accomplish the prescribed hands-on exercises on a dedicated computer, strictly on a 1:1 student over hardware ratio. Significant effort has been put so that modern educational techniques and tools are utilised in order to offer the course in an essentially *paperless* mode. This involves electronic educational material, student information in real time and exams given electronically through an ad-hoc developed, personalised, electronic system. The feedback received from the students, also in the form of an automatically processed web-based questionnaire, reveals that the educational digital media used and the structure of the course itself, meet the main course objective to familiarize the students with modern technologies without losing focus to the physical engineering problem studied.

KEYWORDS
Computer applications; Engineering education; E-learning; Programming techniques; Finite elements; Structural engineering; Information technologies.

1. INTRODUCTION

Major advancements have been made during the last decades primarily due to the revolution in Information and Communication Technologies (ICTs) that resulted from the rapid increase of computational power and internet speed and have drastically reformed the way engineers are educated and trained [1]. Educators on the other hand, are faced with an ongoing challenge of creating engaging, student-centered learning situations that can relate problems presented in the class to the tools developed for their solution. This transition from traditional educational means and processes to the use of modern Information and Communication technologies has not only reformed the educational experience but also drastically changed the educational objectives themselves: the students and now required to study both the physical problems *and* the tools currently available for their study. During the last few years, the above ICTs are widely used in the field of structural engineering education, primarily for [2]: (a) improving the visualization and demonstration equipment in class, (b) developing interactive educational tools and software for distant and life-long learning related to structural and earthquake engineering applications [3-9], (c) utilizing "hands-on" experiments for demonstrating basic concepts in structural dynamics and earthquake engineering, (d) setting up and executing bench-scale shaking tables at a lower scale, and (e) training students through "virtual" experiments in a self-learning environment [10].

An important role in the education of structural and earthquake engineering through ICTs is also being played by the Network for Earthquake Engineering Simulation (NEES) Academy for Education and Training which is a web-based, open university to students, teachers, researchers and professionals. This Academy utilizes cyber-technology for delivering NEES-related, primarily to the graduate level, resources such as complex computational simulations, learning modules, visualizations, multimedia presentations, video resources and interactive games, all serving the purpose of knowledge dissemination to the structural engineering educational and professional community [11-12] and thus providing a continuous link between the students, educators and researchers.

From an academic perspective, numerous courses are currently offered worldwide within the context of their respective university curricula, in a variety of structural engineering fields, utilizing modern technologies to assist students visualize, comprehend and solve complex physical problems in a completely new way. In many cases, these courses are offered in a so-called, "paperless" mode; however, quite typically, "paperless" is essentially limited to the replacement of hardcopy material by educational tools which are provided in various electronic forms (i.e., documents, spreadsheets, presentations) and delivered primarily through the web or even through new hardware devices such as tablet PCs and ipads.

To this end, the scope of this paper is to present the effort made at the Department of Civil Engineering of Aristotle University of Thessaloniki in Greece to offer to the undergraduate students a comprehensive experience of an entirely paperless course on structural informatics, that not only involves hands-on training and a set of electronic visualization and educational tools, but also a novel structure for conducting the final examinations and evaluation within the computer laboratory. To the best of the author's knowledge, the particular course must be the only one currently provided within the Departments of Civil Engineering in Greece and most probably elsewhere in Europe in a purely electronic manner, for a large group of enrolled students which typically exceed 100. The course structure, syllabus and main features of this course are presented in the following.

2. COURSE STRUCTURE

"Programming Techniques and use of specialized software for Structural Engineering" is an optional course offered to the fifth year undergraduate students of the Civil Engineering Department of Aristotle University Thessaloniki in Greece since the academic year 2004-2005. It is aimed to promote the use of new Information Technologies in the field of Structural Engineering and to teach modern programming and Finite Element simulation techniques that the students can apply both in research and design. The course curriculum is structured in two main parts:

(a) software and application development for structural engineering problems with the implementation of visual programming (Visual Basic.NET and Matlab). Utilization of the fundamental programming skills developed for the management of database systems (MS Access), spreadsheets (MS Excel) and drawings (Autodesk Autocad) using built-in programming languages such as Visual Basic for Applications (VBA).

(b) Implementation of widely used commercial finite element (FE) packages for the simulation and analysis of structural engineering problems. Emphasis is given in the fundamentals of FE simulation, while specific cases of structural non-linearity and 3D simulation are also demonstrated. Applications are performed using the FE program ANSYS utilizing both the Graphical User's Interface and the Ansys Programming Design Language.

An important component of the course is the distinction between the problem studied and the tools used or developed for its solution. Therefore, the course focuses on the physical interpretation of structural engineering problems discussed in class, so that the students become familiar with the concept of computational tools without losing perspective of the engineering problem studied each time.

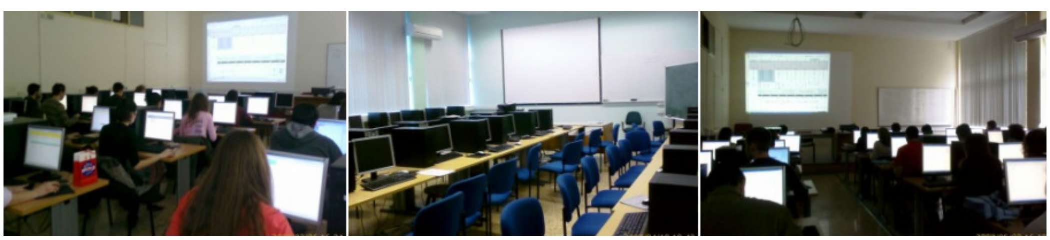

Figure 1: Overview of the computer laboratory

2. COURSE SYLLABUS

The course syllabus is divided into thirteen classes of three hours duration which are in turn split to an hour of theoretical background and two hours of step-by-step hands-on exercise during which the students reproduce what is demonstrated (projected) on board. As already mentioned, emphasis is also given in explaining the theoretical background behind the engineering problem studied each time, in order to ensure that the students comprehend the fundamental aspects of the physical problem before implementing the specific programming techniques taught. A wide variety of structural engineering problems are studied in class, involving statics, structural dynamics, earthquake engineering, design of reinforced concrete and steel structures as well as information management. It is noted that since most of the students are enrolled to the Structural Engineering Division, they are already familiar to the fundamental concepts of the above courses.

The exact content taught in each class, the programming skills developed and the engineering problem solved are presented in Table 1.

Table 1: Summary of the course syllabus and physical problems studied

Lecture ID	Topic	Programming Skill	Physical problem
#1	Introduction	Accounts creation.	-
#2	Visual Basic	Introduction to Visual Basic structure and GUI	Area of reinforcement longitudinal bars and hoops
#3	Visual Basic	If-else statements and for-next, do-loop structures	Design of an RC beam to flexure
#4	Visual Basic	Matrices	Static analysis of a simply supported beam with varying point loads
#5	Visual Basic	I/O and string handling	Building evaluation through string handling of a SAP2000 input file
#6	Visual Basic	Functions and modules	Dynamic analysis of structures
#7	Visual Basic for Applications (VBA)	Optimization of Excel using VBA	Response spectrum resampling
#8	Visual Basic for Applications (VBA)	Optimization of Access using VBA	Pre-earthquake assessment of structures
#9	Visual Basic for Applications (VBA)	Optimization of Autocad using VBA	Design and drawing of RC slabs
#10	ANSYS	Introduction to finite elements and ANSYS	Static analysis of a steel truss
#11	ANSYS	Introduction to 3D modelling	Static and modal analysis of a steel beam-column joint
#12	ANSYS	Introduction to nonlinear analysis	Nonlinear static analysis of a concrete column
#13	Matlab	Introduction to Matlab	Dynamic response of flexibly supported buildings

Figure 2: Official Course Website: http://nisida.civil.auth.gr/tp

3. COURSE PAPERLESS MODE

A significant aspect of the particular course is that since its initial development in 2004, significant effort has been put so that modern educational techniques and information technologies resources are utilized in order offer the course in an essentially *paperless mode*. In particular, this is achieved by the following:

(a) Course consists of 13 interactive lectures all given in the Civil Engineering Computer Laboratory. Classes are organized in 2 or 3 groups of 30 students, which are obliged to log in using their personal accounts.

(b) All educational material (handbooks, notes, source code, solved examples, tutorials, presentations) is provided in electronic form.

(c) Additional educational material (Figure 3) is provided in the form of video tutorials (freely available at www.civil.auth.gr/tp,), which essentially act as a step-by-step guide of all the examples solved in class [9].

(d) Sample, fully functioning educational software developed and demonstrated in class is provided through the Virtual Laboratory Official Website (www.edusoft.civil.auth.gr) for motivation purposes (Figure 4).

(e) The course time table and schedule is available on-line through the Official Course Website (http://nisida.civil.auth.gr/tp) and is automatically updated using the Google Calendar Service. Students can subscribe to the service to receive notifications related to the course schedule.

(f) Announcements are published on the course website where the students can subscribe through RSS tools for immediate information. The students can also comment through the relevant blog.

(g) Students interested in Diploma Theses to be conducted in the framework of the course can refer to the subjects offered online and apply also online through an open call procedure which takes place twice a year.

(h) The examination takes place at the Computer Laboratory in a similar manner as the hands-on demonstration experiments. The students store their examination papers online using their personal accounts while the electronic papers are gathered using specific software developed for this purpose. All examination papers are automatically tagged with the students' IDs and are stored in the server for asynchronous evaluation by the tutor. The final assessment grades are sent to the administration using the web-based e-class system of the Department.

(i) Students' feedback and evaluation of the course is made electronically on a provisional basis right after the completion of the exams, through an online questionnaire which is available at the following address: (http://freeonlinesurveys.com/rendersurvey.asp?sid=n7f2e2ld99vahwd864628). All evaluation statistics are performed automatically and are officially submitted to the Civil Engineering Departmental Committee that is responsible for course evaluation. The evaluation results are published on the course website.

The entire structure of the course is illustrated in Figure 5. Additional information related to the evaluation of the course is provided in the following section.

4. STUDENTS' FEEDBACK

Upon accomplishment of the educational process, feedback from the students' experience is obtained regarding all aspects of the course. In particular, a detailed, anonymous, online questionnaire is completed on a provisional basis on the day of the course exams. Only students attending the exams are asked to fill-in the questionnaire. It is noted that the statistics of the evaluation is performed automatically by the web-based application and that it is impossible for the tutor to investigate or modify the response provided, hence ensuring confidentiality and credibility of the evaluation process. The results of this evaluation are publically displayed at the official course website immediately after the feedback deadline is expired.

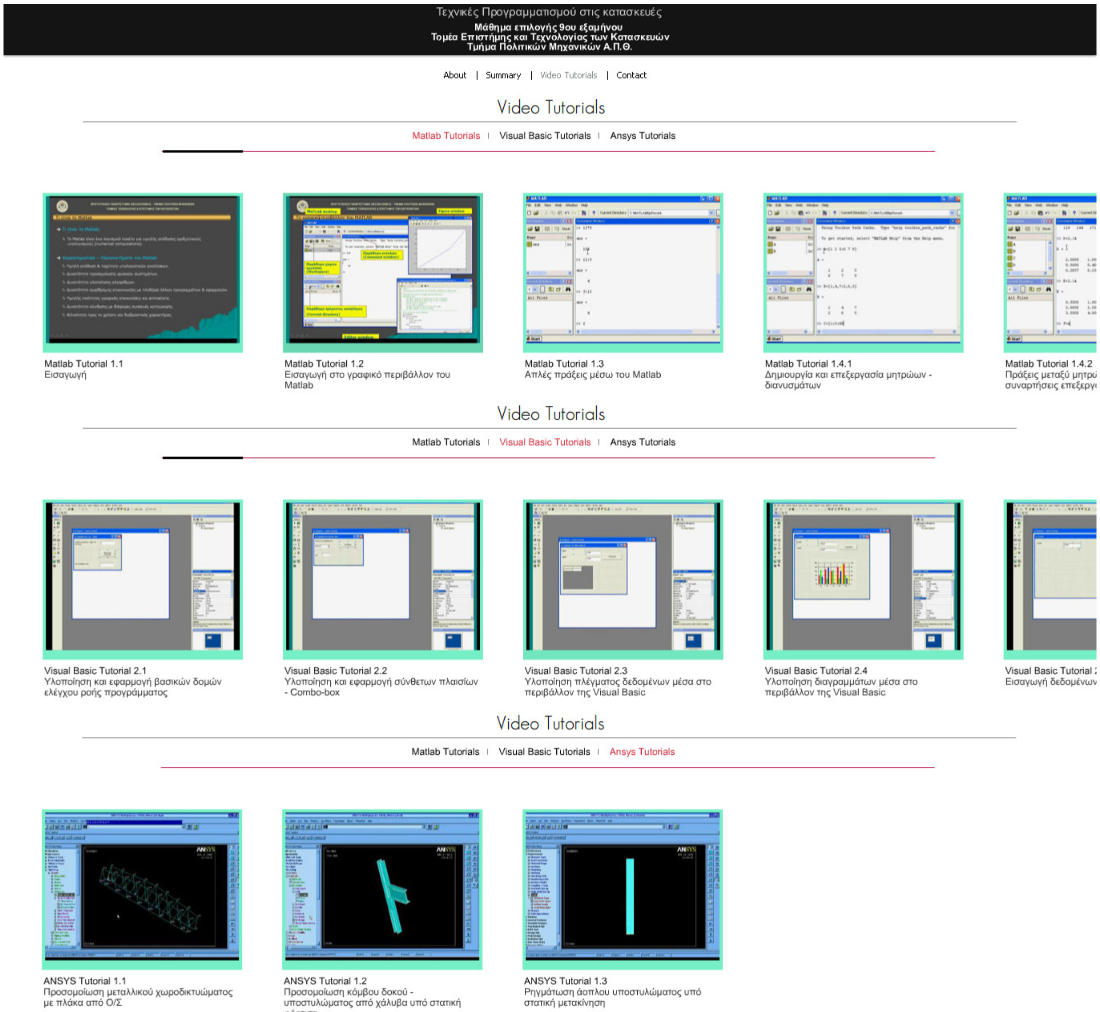

Figure 3: Online flash video tutorials of the course content (http://www.civil.auth.gr/tp)

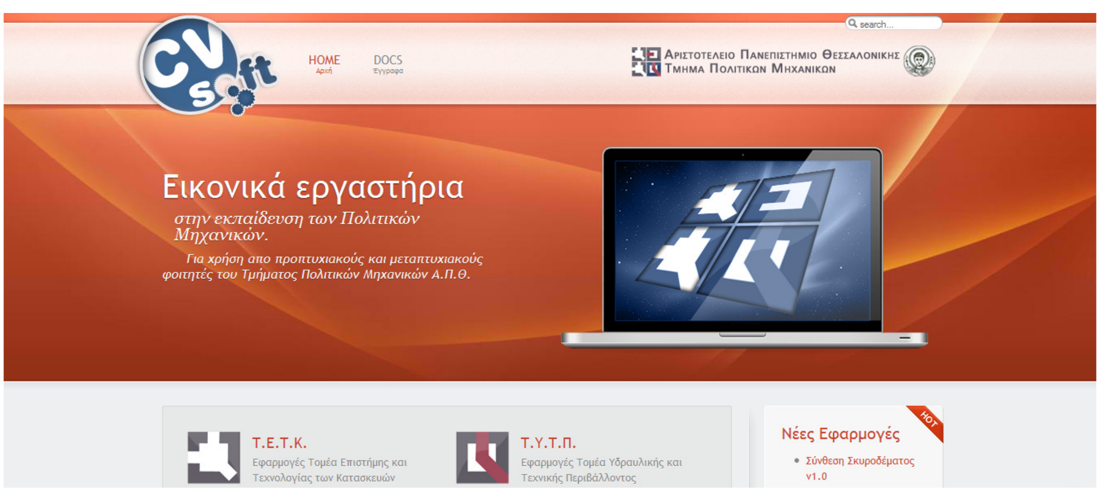

Figure 4: Educational freeware developed in class and released as freeware (http://it-structural-engineering.weebly.com/abel.html, http://cvsoft.civil.auth.gr/)

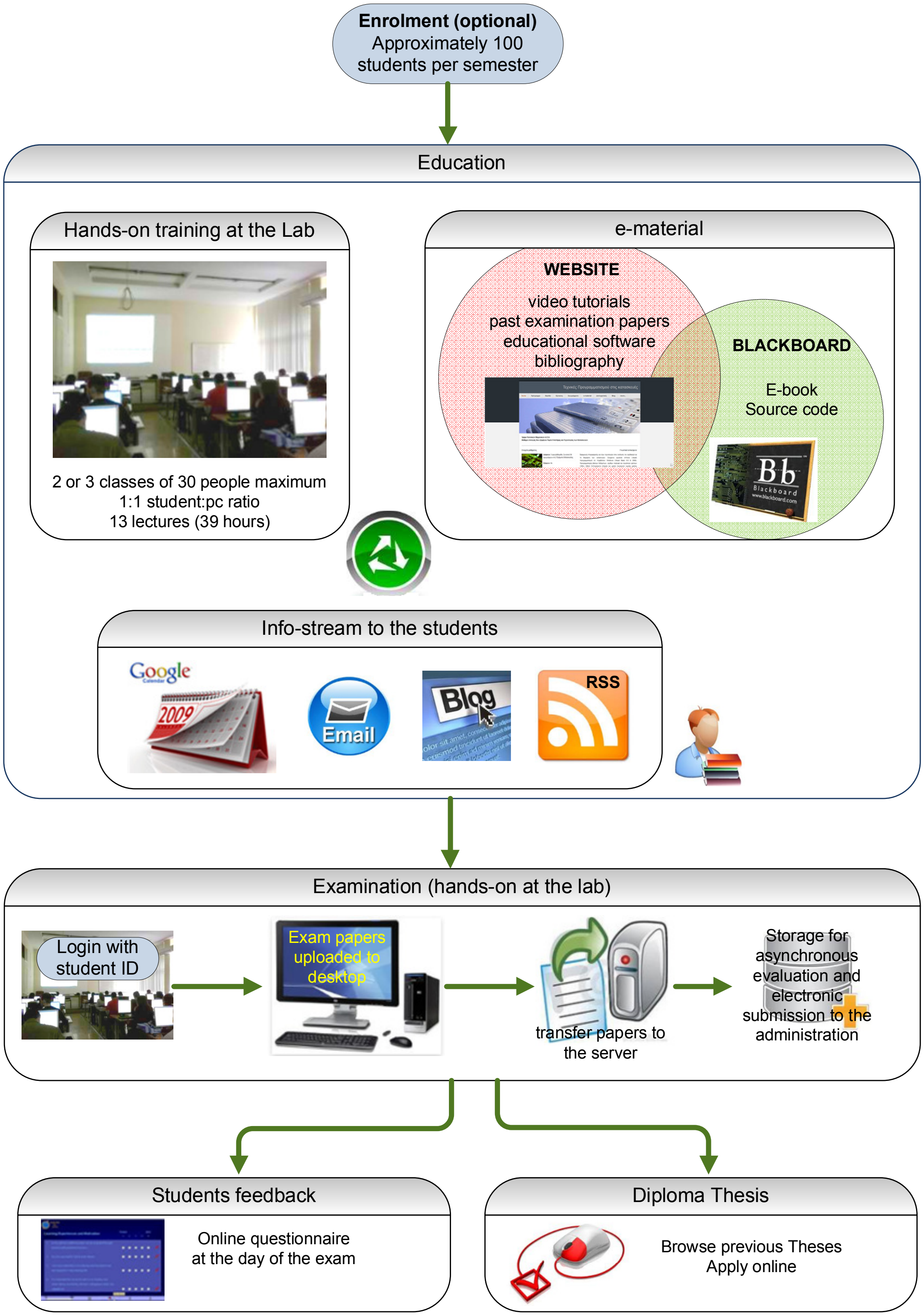

Figure 5: Structure of the course in a paperless mode

It is not the scope of this paper to reproduce any positive feedback that has been provided by the students. It can only be stated that in principle, the educational digital media used and the structure of the course itself seems to meet the main course objective to familiarize the students with modern technologies without losing focus to the physical engineering problem studied. It is also mentioned herein that some concern is often expressed that the time given for solving the examination problems is significantly reduced compared to the ample time span within which the problems are solved during demonstration. Some concern has also been expressed that despite the inherent interactive nature of the course and the fact that the students comprehend the problem studied and the tools developed, there are cases where they find it hard to take the initiative and immediately start programming another problem from scratch. From the tutor’s perspective, it is deemed that these concerns are valid and well spotted. However, these issues arise naturally due to the wide variety of the content covered and they are planned to be tackled through additional homework and hands-on exercise on dedicated computers during the course. Most importantly, the students are encouraged to break the ice of the “white” programming screen by repeating the commands projected on the wide screen but very soon, even within day one of the course, they are asked to deviate for the prescribed command lines and experiment with alternative programming structuring.

5. CONCLUDING REMARKS

This paper presents the structure of an undergraduate course offered at the Civil Engineering Department of Aristotle University Thessaloniki in Greece with the aim to demonstrate the use of new Information Technologies in the field of Structural Engineering for teaching modern programming and finite element simulation techniques to the last year undergraduate students. The above are taught using examples from a wide variety of structural engineering problems related to statics, structural dynamics, earthquake engineering, design of reinforced concrete and steel structures as well as data and information management.

The paper describes the modern educational techniques and tools that are utilised to offer the course in an essentially *paperless* mode, involving electronic educational material, student information in real time and exams given electronically through an ad-hoc developed, personalised, electronic system. It is believed that the particular course is a case study that demonstrates the significant potential for implementing the most modern information technologies in the educational process. It is also believed, based on the experience already gained in class, that the students are more than keen to obtain knowledge through new educational methods independently of the course content taught, apparently without underestimating the impact of a modern scientific topic in the first place. Therefore, ICT tools offer a number of advantages in terms of attracting the interest of the students and enhancing their deeper understanding of the problems studied. However, it has to be made clear to the students that although teaching and learning can be indeed made easy, the physical problems should not be perceived as easier than they really are. Effort has to be put by the tutor so that when the students become familiar with modern tools for teaching and solving engineering problems they don’t develop the false perception that the problems themselves can only be solved by magic, user-friendly interactive black boxes. On the contrary, it is the responsibility of the tutor to develop their ability to distinguish between the parameters involved in a physical problems, the fundamental concepts of their solution, the required mathematical background and, at the very end, of the necessary advanced electronic tools that can be adopted or developed to facilitate the above solution. Time will show at what extent this difficult balance will be eventually achieved by the future engineers between developing both their engineering judgement and computational skills.

6. ACKNOWLEDGEMENTS

The author would like to express his acknowledgements to the personnel of the Computer Laboratory of the Department of Civil Engineering of Aristotle University of Thessaloniki, Ioannis Papargyriou, Stylianos Xiros and Christos Macheras for their continuous technical and administrative support, as well as to Prof. Marios Vafeiadis, Chair of the Computer Laboratory Committee for his overall effort towards ensuring the fluid operational level of the above Lab.

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A TRAINING DEMONSTRATION PROJECT FOR CURRENT AND FUTURE WORKFORCE IN A COUPLED NATURAL HUMAN AGRICULTURAL ECOSYSTEM

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EXTENDED ABSTRACT

The primary objective of this paper is to train current and future "workforce" to develop effective cyberinfrastructure (CI) components to support observatories gathering data in agricultural ecosystems and policy pertinent to engineering curriculum. This project aims to transform/enhance an existing University of Iowa (UI) watershed educational project from being a local-scale project to a more generalizable CI-based project that can serve as a pathfinder to effective larger-scale activities on future observatories.

To achieve a generalizable CI model, an emphasis would be placed on developing an open, web-based CI framework and prototype for data collection and servicing of the data from hydrological/environmental sensor networks including market analysis. The web-based model facilitates easier access of the data, and deployment of the sensor data service. More specifically, the project intends to develop a web-based cyber-infrastructure model for sensor data collection, retrieval, and analysis based on the prototype of HIDE – Hydrological Integrated Data Environment.

The study has taken place in Clear Creek watershed. Clear Creek watershed has been experiencing severe surface erosion (the highest in Iowa) due to gully erosion and current land-use practices. The watershed, due to its close proximity to the UI campus, is ideally suited for performing CI demonstration projects, such as CI sensor deployment, data storage, data retrieval, modeling and visualization. The existence of conventional (e.g. computer networks) and emerging (e.g. network of sensors) CI components in Clear Creek and on the UI campus allows versatile use of these components for training purposes.

The hallmark of this educational program is an interdisciplinary effort that emphasizes agency training & public outreach and university/college training. The active participants are: The University of Iowa (UI) and IIHR-Hydroscience & Engineering, and the USDA-NRCS, and the Clear Creek Watershed Enhancement Project Group (CCWEPG).

The impact of this study is significant in reshaping the educational curriculum of engineering and science disciplines and in providing training and outreach material for other user categories. Specifically, the demonstration project will:

1. Develop an integrated curriculum that promotes across the discipline courses for future engineers and scientists. This will be of the first kind in this country.
2. Train workforce to design and maintain CI tools to address future societal needs related to environments and extensive urbanization and other land uses.
3. Train engineers and researchers to exploit CI tools to understand major regional-scale problems that have impacts on the national contaminated scale such as hypoxia problems.
4. Encourage agencies and universities to change the traditional approaches for studying earth surface processes and adopt the CI framework.

5. Develop a conceptual CI framework that can help agencies and universities to deal with huge amount of continuous data to better manage, store, analyze and present their received information.

KEYWORDS

Water, Biogeochemistry, Environment, Scaling

1. INTRODUCTION

Human activity is intricately linked to the quality and quantity of water resources. Although many studies have examined human-water dynamics, the complexity of such coupled systems is not well understood, largely because: (a) there are gaps in our understanding of water-centric bio-geochemical processes; (b) the analyses are still strongly disciplinary and inward-looking; and (c) appropriate tools and data for multidisciplinary studies do not exist. Additionally, most of our "natural" water systems are heavily engineered (e.g., tiled agricultural fields, channelized streams, dammed rivers), resulting in systems that are inherently unbalanced. In the absence of a full understanding of natural hydrologic and biogeochemical system behavior, there is a risk of unintended consequences. The impact of human activities is greatly magnified in the Mississippi River by flood and navigational control systems. For example, expansion of plant-based fuel production in the upper Midwest is expected to increase inputs of nitrogen and phosphorus. The unintended consequences of bio-fuel development may be serious hypoxia and fish kills. Similarly, as we have increased the efficiency of food production, animal feeding operations grow in size and become more localized. This is resulting in heavier use of veterinary pharmaceuticals and antibiotics, which are rapidly released to tributaries of the Mississippi. New approaches are needed for researchers to conceptualize and simultaneously address the complexity of water quality and quantity and provide tools that allow them to capture and model the water cycle and its interactions with the physical environment. Research and effective management of these systems in the 21st century necessitates development of a new paradigm in science and engineering education (Felder and Brent 2010).

Another obstacle in understanding water resources challenges is manifested in the "cultural" differences between environmental and hydraulic engineers. Traditionally, environmental engineers have focused on the biological and chemical constituents of the water, with historical emphasis on sanitary engineering. Hydraulic engineers generally study physical aspects of freshwater transport, and have a historic emphasis in flood control. Their segregation from each other and other disciplines creates a barrier that prevents innovative, systems-level environmental problem-solving. Now is the time to bring these disciplines together to take advantage of emerging high-tech sensor and communication technologies and numerical simulation capabilities to address pressing environmental issues.

2. MAJOR INTERDISCIPLINARY EDUCATIONAL EFFORTS

Students funded by the interdisciplinary program will work within three broad, but closely related themes. Regardless of which theme each trainee focuses on, each will have close interaction with all other students, faculty, and agency team members.

Theme 1: Inputs of water and biogeochemical constituents

Watershed evolution, with its interwoven biogeochemical systems (vegetation, terrain, and soils), is strongly governed by the feedback interaction of different earth surface processes that are driven by water through precipitation and surface-subsurface flows. Other interfacial processes may sequester pollutants and enhance or limit bioavailability, so that calculations for total pollutant concentration may not accurately reflect the risk of these chemicals to human and ecosystem health. Thus, a fundamental understanding of the different scale interactions between water and biogeochemical constituents found at the fabric of the earth surface is vital for 1) discovery, use, and conservation of natural resources; 2) characterization and mitigation of natural hazards; and 3) stewardship of the environment.

This theme will include use of cyberinfrastructure with real-time in-situ local and remote sensing data with multiple frequencies and spatial distributions to create an integrated, real-time watershed modeling system. This integrated system will be used to make direct inferences about sediment, contaminant, and nutrient yields from non-point sources and to identify improved best management practices that have the greatest effect on reducing nonpoint nutrient loads to the Upper Mississippi River Basin. Data obtained through sensors will enhance data collected from traditional sampling expeditions. Moreover, the technology will demonstrate to Trainees real-time, event-driven performance evaluation and optimization of sensor networks for studying nonpoint source pollution at appropriate spatial and temporal scales. These are key capabilities necessary to address inputs of water and biogeochemical constituents into large riverine and other freshwater ecosystems.

Theme 1 objectives:

1. *Explore how cyberinfrastructure technology can be configured to support real-time observations.* An important capability for the proposed environmental observatories will be adaptive monitoring of critical events, e.g. meteorological events that generate significant nonpoint source pollution including resuspension of pollutants [8].
2. *Improve understanding of complex, multiscale processes such as nonpoint source pollution.* The integrated, cyber-enabled, sensing - modeling systems will be used to address the following questions:
   - What are the physicochemical or other processes that determine the source of sediment and associated pollutants within a watershed? Do the models correctly estimate residence time or renewal time for sediments and pollutants? What is the effect of the residence time or renewal time in simulating sediment transport, nutrients, and water quality?
   - What is the effect of predicted climate change on nonpoint nutrient loads? Will the effects be more dramatic in agricultural or urban settings?
   - Are intense agricultural or urban systems more amenable to improvement with best management practices to control nonpoint sources of nutrients?
   - Can optimal spatial patterns of land management changes be identified via cyber-technology?

<u>*Theme 2: Transport of water and biogeochemical constituents*</u>

Most geophysical, physical, and biological systems are remarkably complex and nonlinear. They reside far from equilibrium and contain three generic features: geometric, dynamic and statistical fluctuations. Many of these systems span multiple scales of space and time, and contain dynamic parameters that are unobservable. Surprisingly, many also show the presence of statistical power laws, or statistical scaling, which represents scale invariance, a fundamental organizing principle underlying such complex systems. The scientific challenge is to develop a multi-scale dynamical understanding of statistical scaling relationships of floods, and other coupled biological processes in river networks.

Research within the last decade has shown that statistical power laws for floods are not built into hydrodynamic conservation equations governing river flows, but emerge as a consequence of the complex interaction of physical processes acting within the constraints of channel networks. The response of the sedimentary patterns on flow controls to a large degree the transport time of derived pollutants associated with sediments. Finally, it has been demonstrated that particulates and phytoplankton characterize historical samples and provide greater clarity of longer-term trends in a river. It is predicted that 1) phytoplankton production and particulates will be greatest in river regions with intermediate hydrologic retention time and connectivity; and 2) flooding will increase ecosystem connectivity and equalize conditions across the floodplain, but its spatial extent at a given moment will depend on amplitude, duration and frequency of flooding.

Understanding transport of water and biogeochemical constituents requires division of a river basin into a network of distributed channel and hillslopes as they naturally exist on the landscape. Partitioning of a landscape into hillslope – channel link pairs rise to three characteristic scales: a) watershed scale (~1,000 km); b) hillslope – channel link scale (~0.01 – 1 km); and c) hydrodynamic continuum (or Darcy) scale (~0.01 – 10 m). Two challenges in formulating multi-scale dynamics constitute theme 2 objectives:

1. *Up scale existing biogeochemical models to link hillslope – channel scales using different methods including probabilistic tools.* Related questions include:
   - How do flow and sediment transport change in terms of land use patterns and terrain characteristics?
   - To what degree and at what scale do different land use types affect residence times of pollutants? What is the effect of residence or renewal time in simulating sediment or nutrient transport and water quality?
   - What are the key biogeochemical processes that determine the transport of pollutants within a watershed?
2. *How do we address the challenge of dynamic parametric complexity that is introduced by the non-linear interaction of different processes.*

Theme 3: Transformation of water and biogeochemical constituents

The large river processes that drive the transformation of water and biogeochemical constituents, including the distribution and abundance of organisms, are largely unknown because of the temporal and spatial complexity of these systems. Within aquatic ecosystems, for example, there may exist stationary plants, slow-moving mussels, and fish that migrate great distances. The life cycle of these organisms may encompass a few hours or days to a century or more. It is very challenging to design studies that capture the long- and short-term changes (including those caused by chronic exposure to pollutants) that are caused by large- and small-scale changes in the river. Therefore, most studies address a small component and work within a narrow scientific discipline.

This theme's research goal is to create an overarching conceptual and mathematical framework that will enable both scientific research and discovery of natural systems and serve as a forecasting tool for natural resource managers. This new framework is based on an innovative evolution of three numerical modeling methods to integrate traditionally disparate system components. The proposal team recently demonstrated its success in coupling numerical methods by linking Eulerian hydrodynamic models with Lagrangian and Agent models of fish behavior and mussel life history. The objective of this theme is to couple the fish behavior and mussel life history models, and toxicity models and to include multiple system components (plants, nutrients, and/or other aquatic species) to simulate interactions between biological species and their physical and biogeochemical environment. This integration will result in "virtual realities" that consolidate and archive scientists' understanding of the natural world and systematically address the problems of pattern and scale in ecosystems. It will also forecast the impacts of different natural resource utilization strategies by society and serve as a platform for education and training (Theregowda et al., 2006).

Students will participate in development of numerical models for Navigation Pool 16 of the Upper Mississippi River Basin (UMRB). Models will feature a two-scale Eulerian module comprised of: 1) a high resolution computational fluid dynamics model (CFD) to characterize detailed, 3-D hydrodynamics for several hydrologic conditions; and 2) coarser scale water quality, toxicity, and biogeochemical models to characterize water quality and nutrient dynamics. These will be linked with Lagrangian- and Agent-based ecological models. Pool 16 has extensive existing data resources and embodies many of the challenges inherent in large-scale ecosystem restoration and environmental management. The field experience for this theme will be conducted from The University of Iowa's Lucille A. Carver Mississippi Riverside Environmental Research Station (LACMRERS), located along the Pool. This theme is innovative because it brings together an interdisciplinary team of biologists, ecologists, hydrologists, and engineers to share expertise and resources to address the fundamental challenges in modeling natural systems. This integration will result in a transformative new simulation-based discovery and design platform that can be used to generate hypotheses that guide ecosystem science, analysis, and restoration.

Theme 3 objectives:

1. *Develop an integrated scientific framework to simulate and study natural aquatic ecosystems*, while considering issues of spatial and temporal scaling, coupled physical and biological systems, and non-linear dynamic processes. Related questions include:
   - Can distribution of freshwater mussel assemblages be predicted using organic matter retention zones as a physical surrogate?
   - Can the mussel dynamics model accurately predict the pool-wide population and distribution of freshwater mussels in a navigation pool of the UMRS?
   - What impact does food competition with invasive zebra mussels and limited host fish availability have on the distribution of native, freshwater unionid mussel populations in pools of the UMRS?
   - Does habitat loss and floodplain fragmentation from flood control levees have a greater impact on species diversity and abundance than longitudinal connectivity impacts of navigation locks and dams?
2. *Significant redesign of existing numerical models to create an efficient and robust computational framework* using "hybrid" parallel computer architectures for application to long-term simulations of complex aquatic ecosystems.

3. EDUCATION AND TRAINING

Twenty-seven PhD students will enter this program in the first three years. Central to IGERT: Mighty Mississippi is the integration of engineers and scientists who represent all elements of natural water resources. This program will draw upon faculty from the UI College of Engineering and recruit students from many backgrounds. Graduate trainees may enter with either a B.S. or an M.S. degree and obtain a Ph.D. in 4 to 5.5 years, depending on their previous degree, in one of the departments listed in Figure 3. A trainee entering the program with a bachelor's degree will be expected to devote most of the first academic year to course work, the first summer to intensive research work, the second year to a mixture of course work and research, and subsequent years almost entirely to research. A trainee with a masters degree may require less formal course work, and thus will be involved intensively in research from an earlier stage.

A new curriculum will be developed centered around five new courses specifically designed to teach an integrated approach to water resources managements (Table 1). These courses will help students integrate our key three research themes by asking questions, posing and testing hypotheses, and by making interpretations. Seven additional classes will be required of the students to comprise the twelve required courses. The seven additional courses are core fundamental courses from both the hydraulics program (Fluids, Open Channel Flow, Stochastic Approaches) and the environmental program (Chemistry, Microbiology, Water Quality, Groundwater).

A unique aspect of this program is the opportunity for Trainees coming from a science background to become licensed as Professional Engineers (PE). Licensure requires taking a Fundamentals of Engineering (FE) Exam, followed by several years of experience working with a licensed PE. Depending on their background, they will be able to take a set of 3 to 5 undergraduate courses as pass/fail that will provide them the background to take the FE Exam, which normally requires an undergraduate degree in engineering. The CEE department has a long track record of students from a science background passing the exam and going on to become Professional Engineers.

Five New IGERT Courses	*Seven Fundamental Courses (already existing)*
Ecohydrology & Ecohydraulics (Civil & Environmental Engineering)	Fluid Mechanics (Hydraulics & Water Resources)
Wireless Sensor Technology (Electrical & Computer Engineering)	Open Channel Flow (Hydraulics & Water Resources)
Fate & Transport (Civil & Environmental Engineering)	Stochastic Approaches (Hydraulics & Water Resources)
Hydro-Informatics (Civil & Environmental Engineering)	Environmental Chemistry (Environmental Engineering and Science)
Ecology of Large Rivers (agency-taught)	Microbiology (Environmental Engineering and Science)
	Water Quality (Environmental Engineering and Science)
	Groundwater / Contaminant Hydrology (Environmental Engineering and Science)

Table 1. IGERT: Mighty Mississippi Curriculum

4. CONCLUDING REMARKS

This education and training program will advance discovery and understanding in other relevant fields where environmental and socioeconomic services of natural systems are impeded while promoting teaching, training, and learning. Results of this study will be disseminated through journal publications and conference presentations at meetings by the American Geophysical Union or Biogeochemistry Society, as well as integrated into course curriculums. Finally, this study will provide exciting training for students in this growth area and build connections between the cooperating universities, state/federal agencies, and local producers through innovative educational outreach (e.g., an investigator-student-run web page). This project provides many opportunities to integrate research and education, public outreach and education, and enhance collaboration among researchers from four disciplines, as well as increase interaction among students of these departments and universities.

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CURRICULUM DEVELOPMENT USING GRAPHS OF LEARNING OUTCOMES

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EXTENDED ABSTRACT

Students may not always have a clear picture of how courses in university studies are connected to each other and how they contribute to professional competences. For example, basic courses in the beginning of studies may be unmotivating because they seem abstract and unconnected to practice. The whole degree program may seem like a list of mandatory courses without much justification on why each topic must be studied.

To give students a more meaningful picture of how the courses in a university curriculum contribute to future courses and to higher-level goals, we propose a curriculum model that defines the connections between learning outcomes of different courses in detail. In our model, the learning outcomes of each course are identified, and prerequisite dependencies are specified between course outcomes instead of between whole courses. The instructor of each course specifies which topics from earlier courses must be known before the new topics can be learned. This way, the outcomes form a graph, or a network, which emphasizes the hierarchical nature of knowledge.

The outcome graph-based curriculum model offers advantages for both students and staff. Learning paths can be visualized to show students how each course contributes to the professional competences. We hypothesize that studying motivation is increased when learning outcomes are tied to higher-level goals. Students can also be given more freedom to construct a personal competence profile according to their own interests. The list of courses required to build the desired competences can be automatically calculated from the outcome graph. The dependency graph can also help staff to identify problems in the curriculum. It will reveal if a skill in a target competence cannot be developed from the available outcomes of existing courses or if a learning outcome of some course does not contribute to any professional competence or advanced course. Unnecessary overlaps or insufficient coverage of important topics can also be identified.

We are developing the outcome graph-based curriculum model in order to develop the Structural Engineering and Building Technology curriculum at the department of Civil and Structural Engineering at Aalto University. However, the proposed concept is generic and can be applied to any field where knowledge is hierarchical and courses have prerequisite connections. Our model is not in use by students yet. In this paper, we are reporting work in progress and discussing possible advantages and disadvantages of the concept.

KEYWORDS

Curriculum development, Learning outcome graph, Core curriculum analysis

1. INTRODUCTION

If university studies are to be motivating, students should have some freedom to choose courses according to their own interests. Indeed, university curricula often include elective courses, but in order to ensure a minimum level of knowledge, many mandatory courses are required. The first few years of engineering education typically have many basic courses such as mathematics and physics that students may find unmotivating because their connection to practice is not apparent [2]. It is also problematic if the curriculum is merely a list of courses that one needs to pass before graduating. That way, students do not have justification for why each course is necessary and how the skills learned from each course are going to be needed in future [1].

There is an ongoing process at the Department of Civil and Structural Engineering at Aalto University to reconstruct the Structural Engineering and Building Technology curriculum using the STOPS curriculum model developed by Paavola and Hartikainen [6]. We are currently developing a software that facilitates the implementation of the model and allows students to construct personal study plans.

In the STOPS model, the learning outcomes of each course are first identified, i.e. what a student knows after completing each course. Next, the prerequisite dependencies between the outcomes are identified, i.e. which skills from previous courses a student must acquire before entering an advanced course. Third, high-level competence areas are identified. In civil engineering, these include concrete structures, steel structures, construction economics, etc. The competence definitions consist of learning outcomes that students should have upon completion of their studies. Learning outcomes of the competences have prerequisite links to the outcomes of courses to indicate how each competence is built from skills taught on individual courses. The model is illustrated in Figure 1.

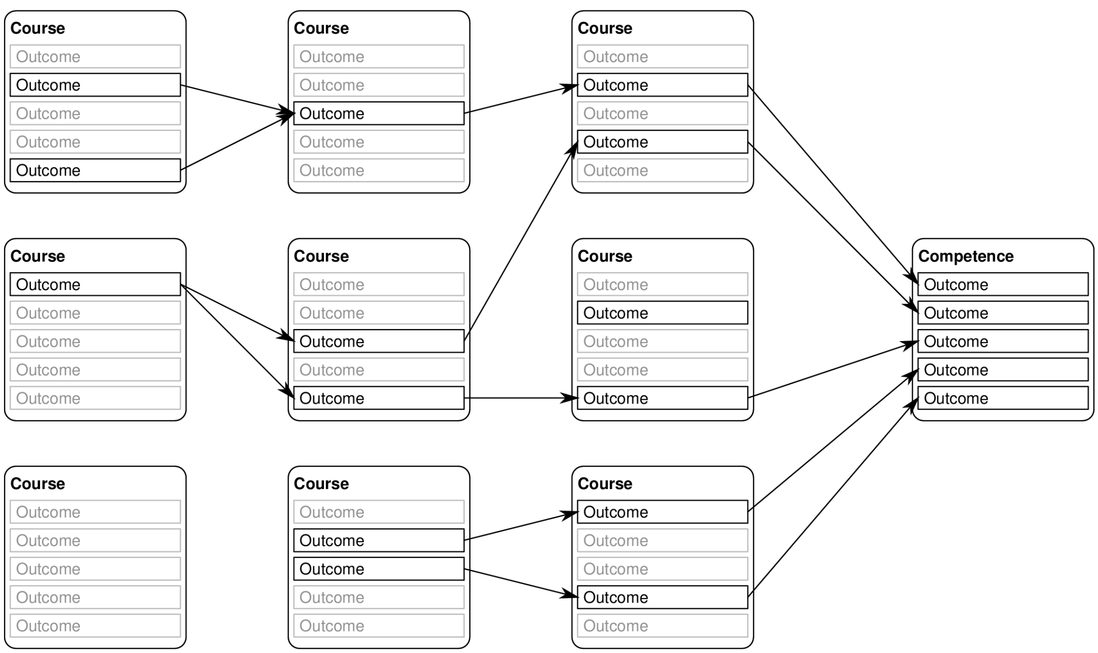

Figure 1: Example of the curriculum structure. A competence consists of outcomes that have prerequisite dependencies to course outcomes. Course outcomes can, in turn, depend on other course outcomes. From the graph, students can easily see how each course contributes to the competence.

Students can construct personal study plans by choosing competences according to their personal interests. The list of required courses is determined by following the prerequisite links from the selected competences all the way to basic courses. This way, the degree is no longer an arbitrary list of courses, but students can see how the skills taught on each course contribute to the desired competences.

The goal of this work is to increase study motivation by connecting the learning outcomes of each course to each professional goal. The model can also help instructors to improve the curriculum and courses by revealing problem areas. For example, prerequisite chains that are too long to make it impossible to graduate in a reasonable time can be identified.

2. RELATED WORK

2.1 Core curriculum analysis

Our curriculum model is inspired by a curriculum development method called *core curriculum analysis*. In core curriculum analysis, learning outcomes are categorized into content that every student *must know* in order to graduate, supplementary content that they *should know*, and specific content that is *nice to know* because it offers a deeper knowledge, but cannot be required from all students [9]. Categorization of content can typically be done by a panel consisting of experts from the industry and education.

Lindblom-Ylänne et al. [9] list numerous ways to use core curriculum information in curriculum design. For example, the "*must know"* content can be located in bachelor level studies and the supplementary content in different master's programs. The categorization can also be used in assessment. The "*must know"* core content can be required for passing a course, while supplementary and specific matter are required for higher grades.

Core curriculum analysis does not consider how courses are connected to each other. It can be helpful for determining what should be taught in courses but does not address the problem of conveying a meaningful picture of the structure of the curriculum to students. Also, core curriculum analysis does not take into account that different skills can be important for different students. Often, the importance of a skill depends on what the student is going to study in the future.

Core curriculum analysis should not be confused with outcome-based education (OBE). Spady describes OBE as an educational paradigm which ensures that every student achieves the same minimum outcomes but not necessarily at the same speed [14]. He specifically insists that OBE is not an existing curriculum with outcomes added on top [15]. A key idea in OBE is that students are not allowed to move forward before sufficient mastery is acquired, whereas in traditional education, it is possible to pass a course with a bad grade. Typically, OBE is associated with more flexibility in demonstrating the acquired mastery, and students can be given more time to improve if necessary. OBE began in pre-university education but has later been applied also in higher education, especially medical education [3]. OBE is suitable for fields where it is essential that students cannot be allowed to graduate before mastering a specific set of minimum skills.

OBE is more an assessment and instruction paradigm than curriculum design paradigm. Our curriculum model, on the other hand, does not define what educational practices should be used in courses. It is more a descriptive model that aims to help students to get a picture of the structure of their studies. In practice, defining the learning outcomes probably affects educational practices as well. The outcomes should, for example, be tied to what is being measured in exams.

2.2 *Intelligent tutoring systems*

Graph-based curriculum models have previously been used in intelligent tutoring systems (ITS). ITS are computer-based instructional systems that dynamically adapt the content that is delivered to students based on what they have already learned and where they have made mistakes [10]. They contain models of instructional content that allow learning material to be generated "on the fly" and give students more control over learning compared to static material such as books or web pages.

Nkambou et al. [11] have developed a subject-matter model and authoring tools for course and curriculum construction in intelligent tutoring systems. In their concept, a curriculum is represented by three models: capability model, instructional objectives model and pedagogical resources model. The capability model describes the domain knowledge, i.e. what content should be taught to students and what are the learning objectives. The instructional objectives model describes the behavior that the student must demonstrate following the learning process, i.e. the learning outcomes and assessment standards. It also defines the prerequisite relationships between capabilities. The pedagogical resources model connects instructional objectives to the learning resources necessary for acquiring the capabilities. Their ITS is designed to automatically guide students during the learning process. If the system notices that a student has trouble solving one type of exercise, it can offer more learning materials that are connected to that area of knowledge. On the other hand, if a student demonstrates good mastery of a topic, redundant material can be skipped.

Hwang [7] proposes a conceptual map model that describes how concepts and knowledge are accumulated to form higher level concepts. For example, multiplication and subtraction are required for someone to be able to understand division. Students are given tests, and by using an *item test relationship table*, it is possible to estimate which concepts a student has understood correctly. The system is able to give students a detailed list of subjects that require more practice. Hwang argues that traditional tests and exams that give student a numerical score are not equally helpful because multiple learning outcomes are assigned to the same grade.

Models aimed for intelligent tutoring systems must contain very detailed descriptions of the contents of a course so that learning materials can be automatically delivered to students. The objective of our system, however, is to describe a university curriculum on a higher level so that students can choose courses and plan studies. The aim is not to create an online learning environment but to leave implementation of individual courses up to the teacher of each course. Ideas from intelligent tutoring systems can, however, be adapted to curriculum design if the level of detail and granularity of the models are adjusted.

2.3 *Curriculum visualization tools*

Sommaruga and Catenazzi have made an application for the visualization of curricula as 3D graphics [13]. Departments, degree programs and semesters are rendered as regions in space and courses as boxes of different sizes. The user can navigate in the 3D space and zoom into details. Numerical properties of courses, such as credits and duration, determine the dimensions of the course boxes so that the user can easily discern the characteristics of different courses. The system focuses on the visualization of whole degree programs, without going into details such as learning outcomes of courses or the prerequisite relations between courses.

Gestwicki [5] has made the CurricViz application, which automatically generates visualizations of curricula as directed graphs. The study order of courses can easily be read from the graph. The system does not show details of the learning outcomes of the courses. The user can see that a course is a prerequisite of another course but not which outcomes specifically are important.

Zucker [16] has made the ViCurriAS application, which allows staff to construct a curriculum map, i.e. a graph of courses that are connected by prerequisite dependencies. The program allows instructors to examine how changes in courses affect the whole curriculum. The program can also be used for student counseling as it allows tracking their progress. Passed, current and upcoming courses are rendered in different colors so that the progress of studies can be easily seen. The program does not, however, show separate learning outcomes of the courses but deals with prerequisite dependencies at a course level.

Kabicher and Motschnig-Pitrik [8] have made a wiki-based curriculum planning tool that automatically creates visualizations of module dependencies. The application is meant for participatory curriculum design so that instructors can collaboratively plan how contents are divided between courses. However, the visualizations are not adapted for each student separately. Also, the application visualizes the dependencies of whole courses instead of separate learning outcomes.

In summary, it is common for existing curriculum visualization tools to show dependencies of whole courses instead of showing which learning outcomes specifically are connected. In this way, a student on a basic course does not know where is each skill going to be needed in future courses or how do skills contribute to professional competences. Also, the existing tools do not allow students to construct personal study plans. The visualizations are used as ways to improve current textual curriculum descriptions and course lists rather than providing new ways to design curricula.

3. OUTCOME GRAPH-BASED CURRICULUM MODEL

Paavola and Hartikainen [6] propose a curriculum model where the learning outcomes of each course are specified, and prerequisite dependencies are defined between the outcomes instead of whole courses. The outcomes form a directed acyclic graph where the vertices represent learning outcomes and the edges represent prerequisite dependencies between them. For a chosen outcome, it is possible to follow the prerequisite connections and collect the list of courses that are required to reach the outcome.

Figure 2 illustrates the learning outcomes and some of their dependencies in the *Bridges and Foundation Structures* course. It can be seen that the highlighted outcome "*Understands the dimensioning principles of pile foundations and can determine the forces on piles"* requires several tools from *Mathematics 1* and *Structural engineering* courses, and in turn, acts as a prerequisite for several outcomes of the *Bridges, General course*. Now, if a student is aiming to reach the outcome *"Can determine and sketch the principal dimensions for bridges and select suitable foundation types"*, it is possible to visualize how that outcome is built from the skills taught on earlier courses beginning from basic mathematics.

One of the goals in the new curriculum model is to offer students more freedom to construct personal study plans. The model contains professional competences for students to choose from and build their own competence profiles. Competences are divided into three levels (I, II, III), each consisting of outcomes that define what a student should know upon graduation. The competence outcomes, in turn, have prerequisite dependencies to course outcomes. Table 1 shows a working draft of the competences in the Structural Engineering and Building Technology curriculum.

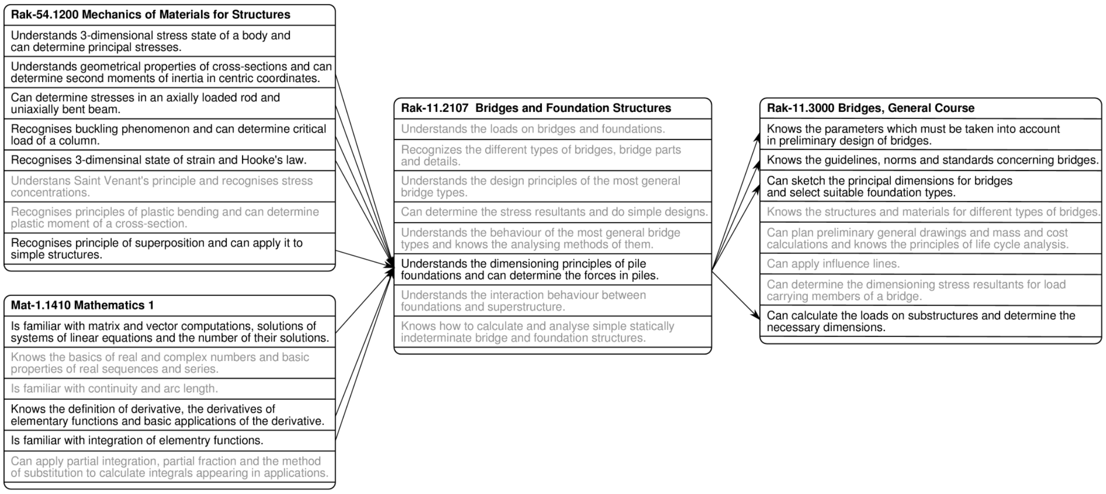

Figure 2: Connections from one outcome of the Bridges and Foundation Structures course to prerequisite and advanced courses.

Table 1: Example competences

Structural Analysis
Structural Engineering – Bridges and other Infrastructural Constructions
Structural Engineering – Concrete Structures Structural Engineering – Steel Structures
Structural Engineering – Timber Structures
Structural Engineering – Repair of Buildings
Building Materials Technology
Building Physics – Heat and Moisture Engineering
Construction Economics and Management
Building Services Engineering

The exact rules for choosing the competences are not finalized as of this writing, but the current idea is that level I is mandatory for all students and gives a basic understanding of the whole field. In addition, each student has to choose one or two level III competences and enough level II competences to reach 300 credit points.

When a student adds a competence goal to the study plan, the list of courses that are required to build the competence is calculated by following the prerequisite links. Figure 3 illustrates how the Bridges II competence consists of six outcomes that depend on the learning outcomes of three courses. These, in turn, depend on outcomes of other courses, which depend on other courses, etc. Now, each course has a justification for being part of the studies because it is possible to follow the learning path from the outcomes of each course all the way to the professional competence.

We have constructed a prototype of a web application that allows students to explore the curriculum model and build a personal study plan. The software has three main views: *competence profile view*, *course view* and *scheduling view*.

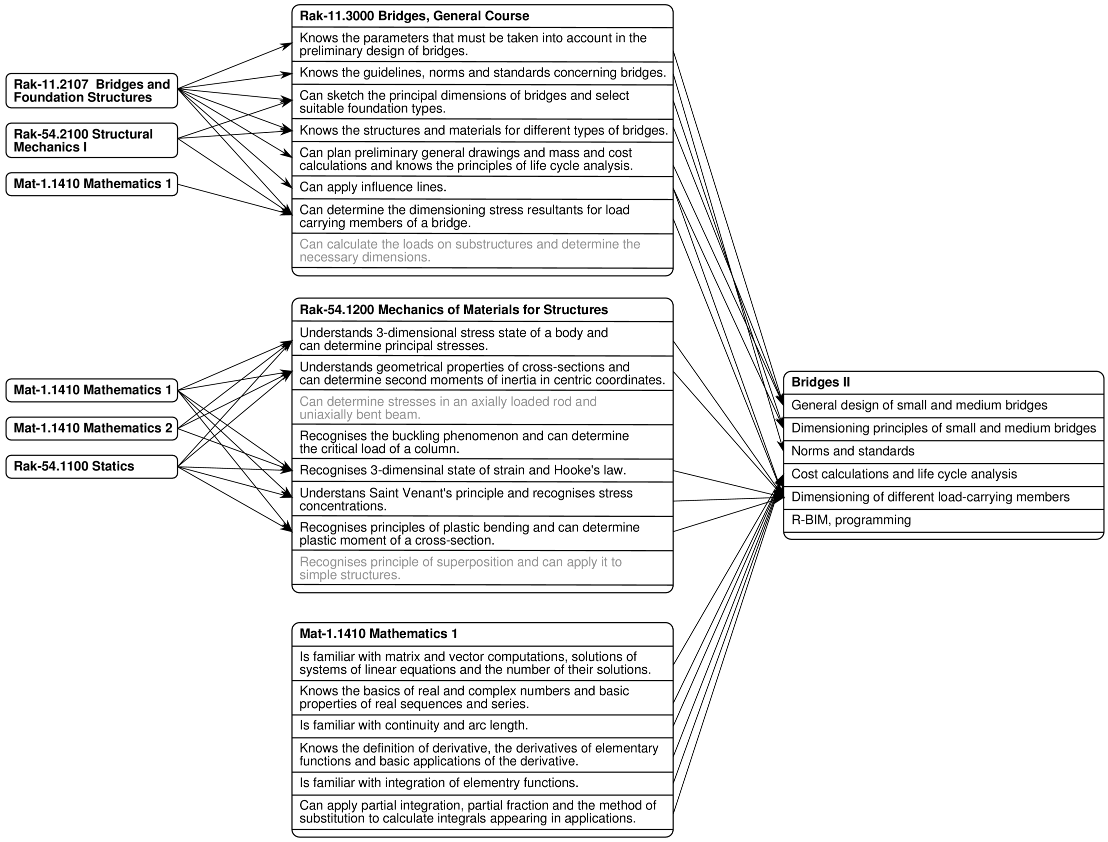

Figure 3: Some prerequisites of the Bridges II competence.

In the *competence profile view*, students are shown the available competences that can be selected as goals. A list of courses and the amount of credit points that are required to build the competence are also shown. Because some courses contribute to multiple competencies, the list of required courses depends on which other competences the student has previously selected. The dynamic course lists also make it easy to see how would changing the goals affect the list of remaining courses and graduation time in case a student wishes to alter the plan during studies.

In the *course view*, students can see how each course contributes to the selected competences. An example study path is shown in Figure 4. The course view also shows the learning outcomes and their connections to immediate prerequisite courses, as well as advanced courses for which each outcome acts as a prerequisite.

In *scheduling view*, students can arrange courses in semesters. An initial schedule is automatically calculated so that prerequisite courses come before advanced courses. When a student selects a course, its prerequisite courses and the courses for which the selected course is a prerequisite, are highlighted. This allows students to see if moving one courses to another semester requires other courses to be moved as well.

The prerequisite graph also makes it possible to automatically construct a personal core curriculum analysis for each student, based on which courses have been selected. For example in Figure 3, when the student has selected the competence *Bridges II*, the outcome "*Knows the structures for different types of bridges and materials"* of the *Bridges, General course* belongs to core curriculum of the student because there is a path from the outcome to the goal competence. The outcomes shown in gray are not core content for the *Bridges II* competence but can contribute to some other competences.

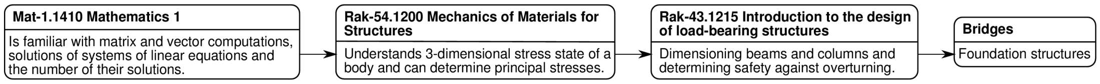

Figure 4: One of many study paths between the Mathematics 1 course and the Bridges competence. Each outcome requires the outcome on its left as a prerequisite.

To create the outcome graph in the first place, an adjacency matrix that defines the prerequisite relations between learning outcomes must be constructed. Each responsible teacher at the Department of Civil and Structural Engineering was first asked to list the learning outcomes of their own courses. A two-dimensional matrix was constructed with all outcomes of all courses on the first row and the first column. Each teacher then went through the outcomes of all other courses and marked the cells that represent a prerequisite to their own course. The task is labourious as every pair of outcomes must potentially be considered. However, the task is divided between multiple teachers, and they have prior knowledge of which courses should contain the relevant prerequisites. The competences have been defined by the professors of the department because at this point, the focus is on describing the current course offering. In the future, it could be fruitful to assemble a panel consisting of representatives from the industry and other interest groups.

4. DISCUSSION AND CONCLUSION

The goal of this work is to motivate students by giving them more freedom, and responsibility, in designing their own study plans. Instead of simply giving students a list of mandatory courses to study, the aim is to let students set personal competence goals and then show which skills must be learned in order to build the competence. A list of courses that produce the necessary skills is generated using the outcome graph. Our hypothesis is that studying motivation is increased when the learning outcomes of each course are linked to higher-level goals.

This approach introduces some challenges in the beginning of studies when students may not yet know where they want to focus. However, the model makes it possible to show to students where can the basic skills be used in in the future and that the basic skills do have practical applications. Constructing a personal core curriculum for each student could also have negative impacts on the learning style some students. Knowing which outcomes are not going to be important in the future, some students might be tempted to optimize the time used for studying by ignoring the less important topics. This could lead to a shallow learning style where they only study the minimum required skills without deepening their knowledge. On the other hand, the motivated students who aim for the best grades would still be required to master all topics on a course. Furthermore, current curricula also give students the freedom to choose whether they aim for the best grades or not.

Constructing the outcome graph can help teaching staff to identify problems in the curriculum. It may, for example, turn out that a competence is built from many separate outcomes of a large number courses, while most of the outcomes on those courses are irrelevant. This could indicate that there is a need for a new course that collects the relevant outcomes into a single course. It may also turn out that some necessary skills of the professional competences cannot be constructed from the available outcomes of existing courses, which indicates a need to add more content to existing courses or to create new courses.

The outcome graph also gives teachers a clear picture of what is taught on other courses, and what students can be expected to know when they enter a course. On one hand, unnecessary overlaps can be removed, and on the other hand, teachers cannot have false assumptions that topics are covered by other courses when they, in fact, are not. Also, when planning changes to courses, teachers can make sure that removing an outcome does not break important study paths. Having to specify the learning outcomes of each course can also help to improve teaching. Ecclestone notes that it gives teachers an opportunity to consider if the current teaching methods actually support the outcomes that the course is supposed to generate [4].

4.1 Future work

The new curriculum model and the software have not been used by students yet. More work is needed to ensure that the model does not produce degrees with too narrow set of competences and that students have a diverse enough basic knowledge of their field. In the future, we are going to let some students test the prototype to evaluate its usefulness and collect feedback. When the curriculum model and the application are mature enough, we plan to let a pilot group use the application in real life to create personal study plans, and evaluate whether it has an effect on their study motivation.

Some ideas from intelligent tutoring systems could also be integrated into the curriculum model. Nkambou et al. [12] maintain in their intelligent tutoring system a student model that represents the current knowledge of each student so that learning materials can be adapted accordingly. In the same way, if the study records would contain information of how well each student has learned each learning outcome, students could automatically be offered extra learning materials on later courses for filling missing prerequisites.

We are currently constructing a model that describes the existing curriculum in order to give students more tools for planning studies. However, the model could also be used for redesigning the whole course offering. After identifying the learning outcomes of courses and competences, the outcomes could be algorithmically arranged into a new set of courses in an optimum way.

5. ACKNOWLEDGEMENTS

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STUDENT PERSPECTIVES ON COMMUNICATION: A CASE STUDY ON DIFFERENT METHODS OF COMMUNICATION USED BY ENGINEERING STUDENTS

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EXTENDED ABSTRACT

The purpose of this paper is to provide insight into the different communication methods used by engineering students in order to improve engineering teaching and learning. As part of a second year Project Management module, engineering students participated in collaborative group work. This involved 320 engineering students, organised into 54 groups, competing in a simulated business environment. As part of their final group reports, students were asked to describe and assess the methods of communication used within their group and with members of staff. The student responses identify how online forms of communication were used alongside more traditional forms. The responses also highlighted the perceived advantages and disadvantages of different communication methods and offered valuable insights into student practice within a collaborative learning environment. This paper investigates how these findings can be used to improve teaching techniques within engineering and particularly in supporting large numbers of students in collaborative group projects.

There are two sections of analysis within this paper. The first investigates communication between students engaged in collaborative work; the second considers communication between student groups and teaching staff. Each section will present the methods used and the perceived advantages and disadvantages of each.

The case study results indicate that students utilise multiple means of communication and develop the skill of being able to assess the advantages and disadvantages of specific methods. They can adapt their communication to suit the different methods and will make use of one method to supplement the perceived deficiencies of another. The paper also describes how student perception of communication can be used to inform learning techniques and practices.

KEYWORDS

Engineering Education, Collaborative Learning, Student Communication, Multi-Modal Communication

1. INTRODUCTION

As part of a second year University of Manchester Project Management unit, engineering students participated in collaborative group work. This involved 320 engineering students, organized into 54 groups, competing in a simulated business environment. Students were all full-time, based at the University and in their second year of undergraduate studies. Students were organized into multidisciplinary groups of 5-6 students. Each group was asked to nominate a leader who would be the focus of correspondence with teaching staff. The business simulation used was April Training's 'Executive' simulation of the car industry [1]. Using this, students gained experience in developing a business plan, making investment decisions and competing with other teams in a volatile marketplace. Assessed coursework consisted of a business plan, a final report and a poster presentation.

The Learning Outcomes of this unit included:

1. to appreciate the wider multidisciplinary engineering context and its underlying principles;
2. to communicate information accurately and effectively;
3. to make effective use of IT facilities for information management and retrieval.

As part of their final group reports, students were asked to describe and assess the methods of communication used within their group and with members of teaching staff. The student responses identify how different forms of communication are used and indicated an awareness and achievement of the Learning Outcomes of the unit.

1.1 Collaborative Learning

Teaching and learning methods within engineering education have had to adapt to increasing class sizes and student populations. The use of blended learning (as recommended by the Higher Education Funding Council for England [2]) alongside the introduction of e-learning platforms has been crucial in forming a response [3]. Blended learning not only includes the mixing of different learning techniques, such as lecturing and collaborative group work, but also the incorporation of different web-based technologies into instruction [4, 5, 6].

Collaborative learning involves a 'strong commitment to joint aims' and 'mutual assistance' with 'little or no direction from someone in a position of power' [6]. Although typically done in small groups, this approach can effectively be deployed within large classes, as seen in this case study. In collaborative learning, both the student and the teacher take on more flexible roles. Students are able to take more responsibility for interpreting tasks and in developing problem solving skills [7]. Teaching staff take a less directive role and become more 'designers and managers' who facilitate learning [8]. Guidelines for good practice in undergraduate education indicate that 'good learning, like good work, is collaborative and social, not competitive and isolated' [9]. Collaborative group work also allows students to develop skills needed in the work place [10].

1.2 Multi-Modal communication

Students born after 1980 have been termed the 'net generation', for whom online interactions are a natural feature of both their social and learning environment [11]. Online activity is commonly used by students in research, peer-assessment, discussion and information gathering. Web-based platforms form part of a wider 'multi-modal' set of communication activities that integrate both online and offline forms of communication in education [3] The integration of web-based learning platforms within the educational environment allows learning to become more 'student oriented' while also reducing the time expended by the teacher [12]. This results in increased student responsibility for learning. Although studies have highlighted the benefits of this approach [12], face-to-face contact between students and teaching staff remains a priority among students [13, 14].

The increased variety of communication methods in the learning environment has led to the need for additional writing skills among students [14]. Use of emails, letters or short messaging service (SMS) require decisions about which method to use and the ability to communicate in a manner appropriate to the medium. Specific methods of communication have also been identified as having multiple functions. For example, Bangert [13] has identified student use of email for distributing announcements, clarifying assignments, providing individual explanations and addressing specific enquiries. Granić et al [17] have identified multiple purposes within e-learning platforms (such as Blackboard used in this case study) including reading forum messages, receiving direct feedback on work and receiving another perspective to a problem.

2. ANALYSIS OF COMMUNICATION METHODS

The final reports submitted by groups summarised their key learning points from the business simulation activity. This included a section where groups considered the effectiveness of their communication outside of group meetings and with teaching staff. These reports were analysed and the conclusions are presented in this paper. The communication methods used and the perceived advantages and disadvantages of each are presented.

2.1 Assessing Student-Student Communication.

Figure 1 presents a breakdown of the number of methods used by the 54 project groups to communicate outside of face-to-face meetings. Only five groups reported using a single method of communication (7%). 32 groups (51%) stated that they used two methods of communication – email and telephone. 16 groups (40%) stated that they used three methods, in most cases supplementing email and telephone communication with social networking sites. Only one group used four methods of communication. These results show clearly that students use multiple means of communication and supports Limniou and Smith's claim that student interaction is 'multi-modal' [3].

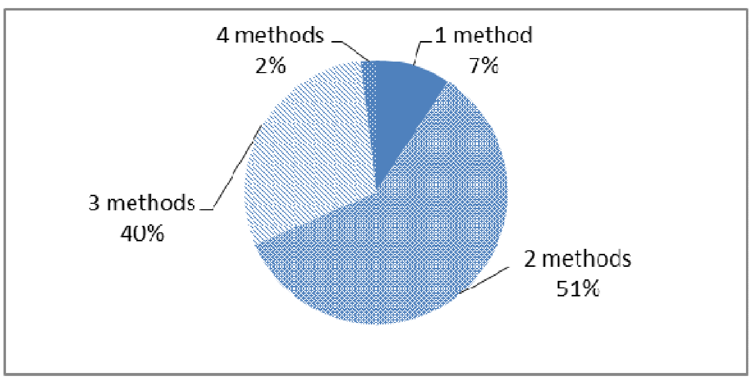

Figure 1: Summary of Communication methods used by student groups

As Figure 2 shows, a total of five different methods were used by students, although no single group used all five together. 53 groups (98%) reported using email and 50 groups (92%) used the telephone to communicate outside of meetings. 13 groups (24%) communicated on social network sites (SNS), two groups (4%) used instant messaging services (IMS) and one group used the web-based conference calling service, Skype. The following analysis will examine the most popular two methods individually and the remaining methods together.

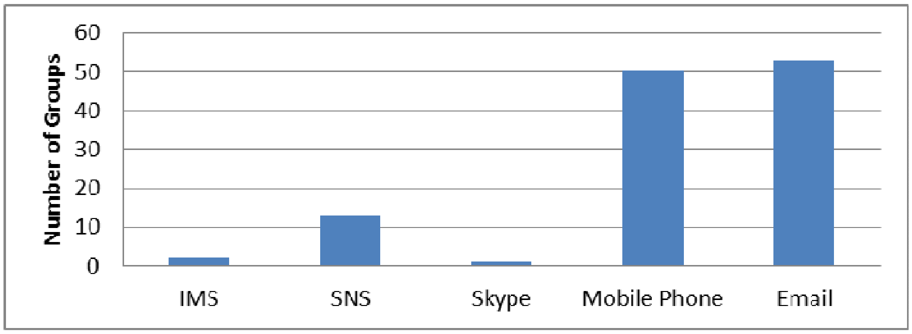

Figure 2: Summary of specific communication methods used within the student groups

2.1.4 Email

Email was used by almost all of the groups to communicate and was reported as being used to:

- arrange meetings;
- distribute documents and information to all group members, including absentees;
- distribute document drafts and receive feedback and suggestions;
- assign tasks to group members;
- circulate ideas and thoughts to all group members;

In summary, email was used for notification and information distribution. It was also identified as a medium through which all group members could communicate collectively, allowing documents to be produced. This supported the collaborative nature of the project work. However, email was also subject to the following criticisms:

- not all group members read emails regularly;
- it can take too long to receive replies or answers;
- it is not always accessible as it requires having access to the internet.

To be effective as a method of communication, email is reliant on group members regularly reading and responding to their email, with some groups indicating this was not always the case. One group also indicated that their use of email was not as effective as it could have been because members failed to use the 'reply all' function, leaving the majority of the group out of any continuing discussion.

2.1.5 Mobile Phones

Two distinct functions are included in the analysis of the mobile phone communication: voice calls and SMS. The following points summarise the functions and advantages identified by students about the use of the mobile phones:

- SMS used to notify group members of meetings and deadlines;
- SMS used to inform group of project results;
- SMS more likely to be read than emails;
- Voice calls were made to discuss changes and request information.

Although the mobile phone was a popular medium, the students also identified some disadvantages to its use:

- it does not allow affordable communication as a group; restricted to one-to-one conversations;
- difficult to contact people if phone was switched off or battery flat;
- use of phone has significant costs.

In summary, students used mobile phones as a quick and effective method of information distribution and notification. The restriction to one-to-one communication and short messages meant it was not suitable for the collective document distribution and production associated with email. However, as SMS and calls were more likely to be answered than email, the use of the telephone was able to compensate for the deficiencies associated with email. One group stated: "*emails were sent out by the group leader. These were then followed up by SMS alerting members to check their inboxes".*

2.1.6 Other Methods in Student-Student Communication.

This section briefly examines the remaining methods identified by students including Social Networking Sites (SNS), Instant Messaging Services (IMS) and Skype. Boyd and Ellison describe the functions of an SNS as holding semi-public profiles and articulated lists of connected users [16]. Other useful functions include: the creation of groups, IMS, and the use of email. SNS, exemplified by Facebook, are mainly used as social platforms rather than being associated with education. However, Facebook did present some groups with a space for undertaking group work. As one group stated '*everyone has a Facebook profile'*. Facebook use ranged from sending emails to group members identified through their Facebook profile, to the use of Facebook's IMS and the formation of their own 'Facebook group' to carry out project work. The diverse facilities within Facebook meant documents could be exchanged, important messages could be sent quickly and group discussion could take place. It also indicates that as the groups formed, members were likely to include each other in their online social network. One group identified the perceived lack of privacy in Facebook as an important issue, making them reticent to discuss project work on the site. Among the other methods, IMS and Skype allowed group discussion in a quick an easy format, although their use was limited as other methods also fulfilled these functions.

2.2 Student- Staff Communication Methods.

During collaborative group work, teaching staff take on the role of a facilitator and manager. Blackboard is a web-based e-learning platform used to supplement and support courses taught at the University of Manchester and includes content distribution and discussion board facilities. Information on the business simulation and the organization of teams was provided in lectures and supplemented by downloadable material in Blackboard. The main reasons for students to contact staff therefore centre on clarifying procedures, assessment issues and providing advice on group relations in the collaborative process.

Figure 4 indicates that the number of methods used to communicate with staff were significantly less than those used between students. Only 43 groups commented on communication with staff. Of these, five groups (12%) said that they used three methods of communication (email, Blackboard and Face-to-Face). 17 groups (40%) stated that they used two methods of communication. This was closely followed by 14 groups (35%) who stated they used only one method to communicate. Significantly, 6 groups (14%) said they did not actively communicate with teaching staff as they had all the required information already and did not have any need to communicate. There was a degree of under-reporting noted, with some groups who had face to face meetings and lengthy email correspondence failing to acknowledge this in their reports.

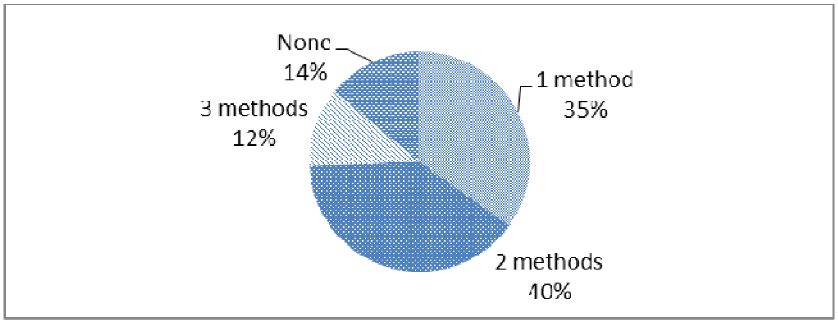

Figure 4: Summary of Communication methods used between groups and teaching staff

Four different communication methods were used to communicate with teaching staff (as shown in Figure 5). Email was the most popular method, 29 groups (46%) stated they used it. 24 groups (44%) stated they used Blackboard discussions and 14 groups (24%) also stated that they had face-to-face contact. Only two groups stated that they used the telephone to call the teaching staff. Significantly, the student groups also provided comments also on communication with the business simulation provider who took technical queries by email and telephone. This highlights the need for an integrated response to communication with the University staff and business simulation provider responding to student queries, keeping each other informed and referring issues appropriately.

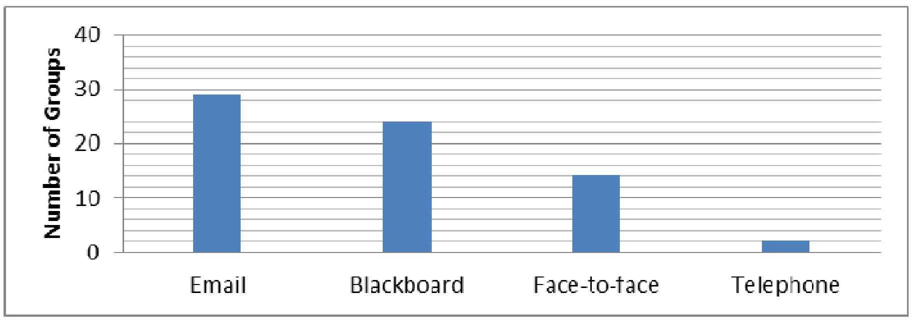

Figure 5: Summary of Communication methods used between groups and teaching staff

Generally, the students expressed satisfaction with the communication; comments such as ‘approachable’, ‘always available to answer questions’ and ‘friendly’ were used to describe the teaching staff involved in the course. Statements about electronic communication with the teaching staff and the business simulation provider were also appreciative. Comments on the responses to queries included: ‘prompt and useful’, ‘very helpful’, ‘efficient’ and ‘quick’. All queries were responded to within a few hours of receipt and this was clearly appreciated by the students.

This responsiveness demands that teaching staff monitor communication and respond to students using multiple methods. Information exchange is no longer confined to the classroom. The tutor also needs to be able to respond to queries by email, in the Blackboard e-learning system, face to face and occasionally over the telephone. It also highlights the importance of working with external training providers as an integrated team to respond effectively to student queries.

2.3 Different Communication methods with Teaching Staff

Email was also a popular method in student-staff communication. In the final reports, email was described as a quick and useful means for contacting staff when technical, procedural, group management and assessment issues needed to be raised. Compared to the discussion points, email queries tended to be more involved and sometimes contain confidential information about individual student performance. When relevant to a wider audience, teaching staff summarized responses to email queries in Blackboard discussion points. Two students made the transition from posting questions in emails to (subsequently) posting questions on Blackboard. This showed that they were learning about different ways to communicate with teaching staff.

Blackboard was identified as another very popular method for communication with teaching staff, with the discussion board the most popular feature used. In summary, the following benefits and uses were highlighted by students using Blackboard:

- quick and efficient communication with staff
- browse message threads as a source of information

63 separate discussion points regarding the business simulation appeared on Blackboard. In total, these were viewed 4359 times. This is an average of 69 views per item; the most popular item had 259 views. Only 21 students (6.5%) posed questions on the discussion board. These numbers indicate that Blackboard was primarily used to 'browse' for information with the majority of students taking a passive role.

Discussion items posted by students were typically short (1-2 sentence) requests for information. Most 'discussions' were limited to a student query and a response from teaching staff. It was only the final reports submitted by the groups that acknowledged the majority of groups had viewed the discussions on blackboard and found them helpful. As one group identified '*the points of discussion were the same issues that were raised amongst most of the other groups'.* This highlights a disadvantage of this method of communication since it was not clear to the teaching staff that the responses were reaching a wider audience. It also indicates that students primarily viewed Blackboard as a repository and the discussion points as a means of requesting further information.

Face to face meetings were sometimes arranged as a result of the email queries. The other opportunity for these was ad hoc enquiries after the lecture period. Students placed high value on face-to-face contact with staff and felt this was an effective means to address queries about the business simulation. There were comments in the reports indicating that students desired more face-to-face contact time and felt this would help to avoid problems. The requirements from this contact focused on the ability to ask specific questions and receive a direct response from staff, whether after a lecture, in an office meeting or tutorial.

3. DISCUSSION

In their Group Learning Reviews, each group was asked to identify three learning points resulting from the business simulation. The top three areas of learning for the students were Communication Skills (34 groups), the ability to work in a Team (32 groups) and Time Management /Planning (31 groups). The category 'Teamwork' included statements regarding group management, task allocation and the importance of discussion and compromise, while 'Communication' included statements on the ability to listen. The Learning Points indicate that both 'teamwork' and 'communication' are seen to be valuable skills and that students make a strong connection between the skills developed in group work and those needed in the professional environment. This recognition broadly supports the aims of higher education and collaborative work identified by various authors [8, 9]. It also indicates a connection between the students' learning points and the module learning outcome 'to appreciate the wider multi-disciplinary context of engineering'. Students recognised that interpersonal skills and the ability to work with colleagues and clients central to the future workplace.

Multi-modal communication has been defined as the integration of multiple offline and online methods of communication. This case study highlighted that engineering students used multi-modal communication and were able to integrate different methods according to the perceived advantages and disadvantages of each. Multi-modal communication can therefore be considered a skill that requires assessing and adopting appropriate methods of communication. As one group stated, this skill developed during the simulation: *'At the beginning of the simulation the team commented by email […] but as the simulation went on, the team started texting each other more and taking on the phone, which increased the understanding between each other'*. The analysis also indicated that while students deployed multiple methods, they also used a single medium for multiple purposes as was the case with email. This expands the definition of multi-modal communication to not only include multiple methods of offline and online communication, but also multi-functional uses of a single method.

The analysis of comments regarding student-teaching staff communication indicated that students valued speed of response and receiving answers to very specific questions. Concerning Blackboard, students not only regarded directly posing questions to staff as effective communication, but also the ability to browse existing discussions. The implication is that active use of the discussion boards by teaching staff allows communication with an increased number of students. This minimises the need for advice to be repeated to individuals or groups, while still being recognised as effective by students.

In the case study presented, email was revealed as the most common means of communication within the student group and with the University staff. Use of email allowed a co-ordinated response to queries by the external training provider and the University teaching staff. Regular communication between all those involved in the teaching was helpful to resolve any issues and to plan further work.

4. CONCLUSIONS

The analysis of communication methods used by students indicated their ability to assess the advantages and disadvantages of each method and to integrate them to support their learning. This indicates achievement of the learning outcomes 'to communicate information accurately and effectively' and to 'make effective use of IT facilities for information management and retrieval'. The analysis also indicated that that students not only made use of IT facilities to retrieve and manage information, but also to edit and produce documents.

Students engage in multi-modal communication and are able to adapt and integrate different methods of communication to support collaborative group work. This study suggests that multi-modal communication is a skill that is actively developed in the collaborative processes and that it is possible to expand the definition to not only include multiple methods of offline and online communication, but also multiple functions within a single medium.

This case study also suggests that students held a particularly defined view of effective communication with teaching staff, which centred on receiving answers to direct questions concerning technical, assessment and group management issues. Students considered both face-to-face contact and the use of Blackboard as effective. There was also a requirement for more tutorial contact outside of lecture periods. This highlights the position of the teacher as facilitator and manager within collaborative learning. It also demonstrates the need to balance face-to-face contact with the use of e-learning platforms. The extent of communication between student groups and staff emphasise the need for good communication skills on the part of teaching staff and a flexible approach to addressing student queries. Queries can also be summarized and used as teaching points in lecture periods. Involvement of external organisations to provide specialist business simulations can be very beneficial in supporting collaborative learning. In this case, the University staff and the training provider need to be able to work together to provide information an integrated and efficient response to student queries.

The paper describes the integrated use of multiple communication methods to support collaborative learning in engineering. Effective multi-modal communication can provide a means to address students' desire for increased face-to-face contact within the pressures and time-limitations of teaching large classes. Student support in this environment requires an integrated and collaborative response from University staff and external training providers.

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DEFINING A WORKPLACE EXPERIENCE FRAMEWORK: ANALYZING THE SOCIAL HEARTBEAT OF AALTO UNIVERSITY DESIGN FACTORY

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EXTENDED ABSTRACT

Organizations in both the public and private sectors are widely embracing new ways of working. A student-centred approach to learning is becoming more common and concepts such as “new learning”, “new learning environment” and “constructive learning environment” have emerged. Learning environments need to evolve with the change in students’ learning styles, aspirations and expectations. Today’s learning environments should facilitate meaningful, authentic activities that help the learner to construct understanding and develop skills relevant to problem solving. The use of university spaces is transforming. Formal learning, which has traditionally taken place in conventional classrooms, is becoming virtual thanks to internet-aided learning technologies, whereas the need for physical spaces intended for informal learning is increasing.

The aim of this research was to understand the purpose and importance of informal social face-to-face learning spaces for their users. The model of “6 dimensions of user experience” was applied as a data-gathering framework in this study. The research was conducted in Aalto University Design Factory and is related to the user experience of its common cafeteria, “Kafis”. Data were gathered by means of focused interviews among 16 users of Kafis, representing students, researchers, start-up entrepreneurs and staff members. The data were analysed by microanalysis by identifying repeating concepts from the data.

According to the results, it seems that the key function of Kafis is to offer a platform for socialization and sharing knowledge between its members. Furthermore, the metaphor “the social heart of the building” describes the importance of having this kind of place in the university environment. The social heart refers to a shared place that is welcoming to its users and has an open and cosy atmosphere. The research indicates that people create meaning for a place. Therefore, bringing people together is essential. However, to get the best outcome from these kinds of places, it is necessary to broaden the perception of work. In addition to individual work related activities, such as shortening the task list in front of one’s desk, work could also be understood as something that essentially includes collaboration between people, such as interaction and knowledge sharing.

The research provided evidence of the suitability of the model of “6 dimensions of user experience” as a starting point for a workplace experience research study. Future investigations relating to workplace experience research will focus on identifying workplace experience profiles of co-working spaces for learning, including informal social face-to-face learning spaces studied in this research. The next step would be to conduct a virtual survey research study. For future research purposes, the workplace experience framework was generated in the research.

KEYWORDS
Informal social face-to-face learning space, Co-working space, User experience, Co-working, University facilities, Higher education

1. INTRODUCTION

Organizations in both the public and private sectors are widely embracing new ways of working. New ways of working refers to work that is increasingly digital, loose, informal and mobile (van Meer, 2011). This has resulted in today's workplaces being e.g. more flexible in the use of time and space, more welcoming to their users regardless of their age, and well equipped from the viewpoint of knowledge interactions (Myerson *et al.,* 2010). Similar change is taking place in the educational sector. A student-centred approach to learning is becoming more common (Lea et al., 2003) and concepts such as "new learning" (Simons et al., 2000), "new learning environment" and "constructive learning environment" (Wilson, 1996; Loyens & Gijbels, 2008) have emerged. These concepts are mainly but not exclusively rooted in constructivist theory and claim to have the potential to improve the educational outcomes of students' in higher education (Lea et al., 2003).

The physical environment of an organization affects significantly its users' activities, such as teaching and learning processes and social practices (Jamienson, 2003; Oblinger, 2005). The traditional university campus facilities, like lecture theatres, have reinforced traditional narrowly defined roles by manifesting particular behaviouristic power relations between teacher and student (Jamienson, 2003). However, from the viewpoint of constructivist theory, the process of learning and teaching should be fundamentally student-centred (Lea et al., 2003). Therefore, new learning environments need to evolve with the change in students' learning styles, aspirations and expectations (Matthews et al., 2011). Today's learning environments should facilitate meaningful, authentic activities that help the learner to construct understanding and develop skills relevant to problem solving (Wilson, 1996).

Furthermore, the use of university spaces is transforming. Formal learning, which has traditionally taken place in conventional classrooms, is becoming virtual thanks to internet-aided learning technologies, whereas the need for physical spaces intended for informal learning is increasing (Brown & Lippincott, 2003; Brown & Long, 2006). For that reason, physical learning environments should include purpose-built informal social learning spaces. These spaces enhance the student experience and strengthen student engagement by fostering active learning, social interaction and belonging (Matthews et al., 2011).

Understanding the user experiences in these spaces and the factors causing them can help the university facility managers to develop and maintain spaces that support new learning activities. The aim of this research is to understand the meaning of informal social face-to-face learning spaces for its users: what purposes it is used for and why it is important to have one. The model of "6 dimensions of user experience" (Diller *et al.,* 2005) was applied as a data-gathering framework in this study. The research was conducted in Aalto University Design Factory (ADF) in Helsinki, Finland, studying the user experience of its common cafeteria called "Kafis".

This paper is divided into five chapters. After the introduction, the theoretical background for describing an academic learning environment is discussed. The process and structure of the data collection and analysis is described in the next chapter. In the fourth chapter, the results are presented and discussed. Finally, the conclusions are derived and the limitations and implications for future research and practice are considered.

2. INFORMAL SOCIAL FACE-TO-FACE LEARNING SPACES IN A NEW LEARNING ENVIRONMENT

The concept "new learning" is used to describe today's learning. It refers to "new learning outcomes, new kinds of learning processes and new instructional models that are both wanted by society and stressed in educational and psychological theory" (Simons et al., 2000; Loyens & Gijbels, 2008). The concept is characterized by features such as effective communication, thinking and reasoning, making accurate judgements of large volumes of information, solving complex problems, and working collaboratively in diverse teams (Pellegrino et al., 2001). Altogether, learning theory has undergone a widespread change of paradigm from objectivism to constructivism (or from behaviourism via cognitivism to constructivism). Objectivism holds that there is an objective reality that can be structured and modelled for the learner (Jonassen, 1991). Constructivism can be seen as an umbrella term grouping learning perspectives with a similar basic assumption: the understanding that the learner actively constructs the knowledge (see, for example Duffy & Cunningham, 1996; Harris & Alexander 1998; Mayer, 1999). Understanding the way in which people create meaning relates essentially to the constructivist learning theories (Loyens & Gijbels, 2008). Yet, objectivism and constructivism can be seen as compatible despite their contrary nature: they offer complementary perspectives to learning (Jonassen, 1999).

Phenomena such as constructivism, digital technology and a holistic view of learning activate the major learning space design trends: design based on learning principles, an emphasis on human-centred design, and increasing ownership of diverse devices that enrich learning (Brown & Long, 2006). Informal learning, as an opposite of formal learning, relates to learning space discussion. Informal learning emphasizes the social significance of learning from other people. It refers to learning that takes place in spaces surrounding more formal activities and events and in a much wider variety of settings than formal education or training (Eraut, 2004). In higher education, students spend the majority of their time learning in informal settings. These spaces act as a medium through which the social and academic aspects of university life can coincide (Matthews et al., 2011). So-called "activity magnet areas" can help to create informal learning spaces. They refer to different kinds of environmental features and amenities that attract people and encourage them to interact serendipitously. Passageways (e.g. elevator frontiers), service facilities (e.g. copy centres) or food suppliers (e.g. cafeterias) are such examples. (Becker & Steele, 1995).

The concept "learning spaces" is suggested to replace the traditional term "physical classrooms" in learning environment discussion (Brown & Lippincott, 2003; Oblinger, 2005). These learning spaces, also called new learning environments, make the students' learning the core issue (Lea et al., 2003). A new learning environment is "a place where learners may work together and support each other as they use a variety of tools and information resources in their guided pursuit of learning goals and problem-solving activities" (Wilson, 1996). The classification of new learning environments can be seen in Figure 1. This classification categorizes the learning environment according to the dimensions of formal – informal and face-to-face – virtual (Digenti, 2000).

	FORMAL	INFORMAL
FACE-TO-FACE	Courses Seminars Workshops	Networking events Team projects
VIRTUAL	Tele/videoconferences E-meetings Online courses	Web-based collaborative spaces

Figure 1: Four modes of learning (adapted from Digenti, 2000).

3. CASE: THE COMMON CAFETERIA “KAFIS” OF AALTO UNIVERSITY DESIGN FACTORY

“Kafis”, the common self-service cafeteria of ADF, is an example of an informal social face-to-face learning space. As seen in Figure 2, its 120m^2 are divided into five distinct functions: cafeteria, kitchen, dining room, living room and hallway. ADF was established in 2008 after a successfully conducted demo project called Future Lab of Product Design (Santamäki, 2008). It functions as a matrix unit that combines the expertise of Aalto University in the field of product development. The ADF building is a co-working space in an academic context of over 4000 square meters; it is designed to facilitate collaboration between academic teams, researchers, students, companies and communities. A number of academic courses, research projects and start-up companies are hosted in ADF. Prototyping spaces, rooms for lectures and seminars, teamwork spaces, and common areas (e.g. a lobby bar and cafeteria) are examples of ADF facilities. The physical spaces of ADF are designed to support easy modifiability of the spaces and interaction and collaboration between the users. In addition to traditional office hours, ADF is open for its users also during evenings and weekends. The ADF building is located in Otaniemi. Otaniemi is a part of the main city area of the capital, Helsinki, and one of the campus areas of Aalto University (ADF, 2010; ADF, 2011).

Figure 2: The five functions of Kafis.

4. METHODOLOGY AND DATA ANALYSIS

User experience can be seen as "a result of motivated action in a certain context" (Law et al., 2008). User experience has become relevant to many fields of research and industry due to its nature as a commonly understandable, holistic and all-encompassing concept that includes the user, the product and the context of use. User experience approaches can be divided into three categories: person, product and interaction centred approaches. Approaches relating to the first category relate to the idea that user experiences revolve around people's needs that products should satisfy, whereas approaches relating to the second category refer to the qualities of the design and their relationship to people's experiences and evaluations of them. Approaches relating to the third category examine the experience as a time related process (Battarbee, 2008). In this research, the concept of user experience is conceived broadly as a combination of all these three approaches.

The data was gathered by means of a qualitative research study, more closely "focused interviews" (or semi-structured interviews). Focused interviews include a sequence of themes and questions that should be covered with openness to changes in the sequence and forms of questions in order to follow up the answers given and the stories told by the subject (Kvale, 1996). A focused interview consists of certain attributes. Firstly, interviewees should be involved in a particular concrete situation. Secondly, the researcher should produce hypotheses relating to the situation. Thirdly, an interview guide or setting for the areas of inquiry should be created. Lastly, the interview itself should be focused on the subjective experiences of the informants (Merton & Kendal, 1946).

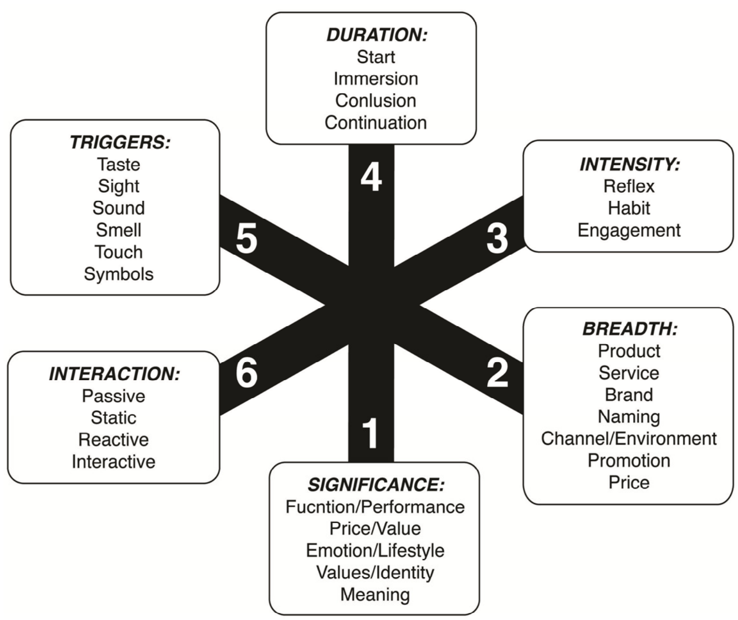

Figure 3: The model of "6 dimensions of user experience" (adapted from Diller et al., 2005).

The user experience of Kafis was the particular concrete situation in this research. The hypothesis of this research is related to identifying related to the framework of academic workplace experience. The interview guide of this study, which can be seen in Appendix 1, consisted of 48 questions in total. These questions were divided into three themes: questions relating to the background information, experiences of using ADF, and experience of using Kafis. The questions related to the last theme was further divided into six sub-themes according to the model "6 dimensions of user experience". As seen in Figure 2, the dimensions of this model are duration, intensity, interaction, breath, triggers, and significance (Diller et al., 2005). Three test interviews were conducted to develop the interview guide before the actual interviews.

The data collection took place during April-May 2011. 16 users of ADF participated in an approximately 45 minutes long, recorded, two-on-one interview. 11 of them were male and 5 female. The interviewees were born during 1950s to late 1980s with a mean age of 33,6 and a median age of 30,5. The users of Kafis were defined as anyone using Kafis and the ADF building in general more or less regularly. Among them, four user groups were identified. Thus, the sample included students attending product development courses (4), researchers (2), start-up entrepreneurs (4), and staff members (6). Half of the interviewees had an educational background in technology. The remaining interviewees had various backgrounds, e.g. design, economics or political science. The majority of the interviewees consisted equally of graduate students and people with the Master of Science (MSc) award. Also doctors of philosophy (PhD) and secondary level vocational school graduates were involved. The interviewees had various occupations, such as project coordinator, product development manager, research manager, managing director, course assistant, teacher, researcher, research assistant, intern, and student.
Microanalysis was used as the analysis method in the research. It is an analysis method of grounded theory, referring to a detailed line-by-line analysis that helps with generating initial categories and suggesting relationships among them (Strauss & Corbin, 2007). The analysis process consisted of two phases. In the first phase the transcribed interviews were read through, at the same time identifying repeating concepts. These concepts became the first order concepts. On the basis of these, second order themes and aggregate elements were identified. In the second phase of the analysis, the research material was read through again, this time verifying the data structure that can be seen in Table 1.

Table 1: Data structure.

FIRST ORDER CONCEPTS	***SECOND ORDER THEMES***	***AGGREGATE DIMENSIONS***
• Heart of the building • Easy access • No restrictions • Cosy atmosphere • Self-guiding usability	Open atmosphere	The social heart of the building
• Common area • People come to meet each other • Enhances possibilities of talking to strangers • Responsibility and freedom to use	Common place	
• People changes • Involves different activities • Users are individuals or small and big groups • Varying usage time	Evolving social environment	
• What is done in front of the desk • Forwarding job description related issues • Shortening the task list	Individual work	The perception of work
• Beneficial to oneself and to others • Interacting with people • Knowledge sharing	Collaborative work	
• Access through employment or a study place • Requires knowing the basics	Formal	Membership formation
• Access through knowing other members of the community • Requires participating in the common activities • Requires intensive presence	Informal	

5. RESULTS

5.1 General view

Most of the interviewees had consciously chosen to become ADF users. Students became ADF users accidentally or intentionally via course participation, researcher and staff members through employment, and entrepreneurs by comparing options for business premises and selecting the most attractive one. As one researcher stated, “I assumed during the second or third time I visited here that I might have possibility to work here because I am an employee of Aalto University”. Most of the interviewed researchers, start-up company representatives and staff members had used ADF previously as students. Interesting people, an inspiring atmosphere, an enabling culture and functional facilities (including connections, workspaces and devices) were the common selection criteria for all user groups. One start-up entrepreneur describes his feelings when visiting ADF the first time in the following way: “I got the feeling that you really are allowed to think freely here and do things“. Some differences in the selection criteria between the different user groups were identified. Moreover, students claimed that ADF is the only place available that includes everything they need for conducting their project work. One student pointed out that “no other place can offer the same kind of possibilities in one place”. According to another student, “there is everything that I need for working, such as access to telecommunications computers, machines and equipment and places where prototypes can be built. And places where other people can be met.” Later he continued, “there is no other place like this, this is the only option”. One student emphasized the importance of having the assistance of the workshop personnel available in prototype building: “one truly important thing is to have professional personnel in machine and electronic shops from whom you can ask help”. Researchers valued the synergy developed from the close vicinity of similarly oriented researchers. As one of them stated, “we knew that another researcher focusing on the same topic was coming here – there is synergy”. Start-up entrepreneurs preferred the innovative atmosphere of the place and the vicinity of the interdisciplinary students and described how “this is an innovation environment, there is thinking outside the box – thinking and students from design, engineering and business backgrounds.”

5.2 Kafis as the social heart of ADF

The users’ experiences were characterized by three specific themes relating to the origins of the conception of Kafis as the social heart of ADF building: (1) open atmosphere, (2) common place and (3) evolving social environment. According to the results, this conception emerged strongly from the data. For example, 11 of the 16 interviewees used the expression “the heart of the building” when describing the function of Kafis as a part of ADF. Others used concepts such as “our key place”, “nerve centre”, “community kitchen” and “meeting point”.

OPEN ATMOSPHERE. Kafis was considered to be the heart of the building. For example, as one start-up entrepreneur stated, “it is the heart of the whole building, where people come and meet”. Kafis was also considered easily accessible. According to one researcher, “it is easy to go there”, and one start-up entrepreneur pointed out that “it is nice to come here”. The atmosphere of Kafis was considered warm and cosy. For example, one researcher mentioned that, “it is warmer than many other places” and later called it a “homely space”. A staff member mentioned that “it doesn’t feel like an institution – it seems to be pleasant space for people to be – like homes are”. A student emphasized the importance of a cosy atmosphere by her comment, “I spend more time here than elsewhere so it is really important that it is homelike". According to the results, the cosiness of Kafis can be strengthened by easy usability. As one researcher mentioned, Kafis is a "self-guiding place where everything is clearly instructed so that you don't need a manual – like in my own kitchen".

COMMON PLACE. Kafis is the common area of ADF users. A researcher emphasized this by saying, "it [Kafis] is nobody's place in particular, and at the same time it is everybody's place". Maybe for that reason, as a staff member stated, "it feels like your own because you can use it freely". All in all, people come to Kafis to meet each other. One staff member emphasized that, "the people are the only reason why I go there". Another staff member pointed out, "you never know who you're going to meet there". A third staff member mentioned that, "people look at each other when they meet there, whereas elsewhere [outside ADF] people try to avoid eye contact". A start-up entrepreneur described the sharing culture of Kafis by saying that "people are open and come to chat and share ideas". Later he continued by saying "it is an area where it is acceptable to stop someone and ask what you are doing here". A researcher pointed out that "you can join any conversation group when you are there". The absence of restrictions or the permissive usage policy may be one factor in making Kafis a lively meeting point. As one researcher described, "it is not a closed space, you can go there and walk through or take coffee, whether there is an event going on or not". Another researcher noted that "you can be there a short time or a long time without a precise agenda". A student described the nature of the culture of Kafis as follows:

> Somebody comes to ask what you do and then you explain, and all of a sudden they say that it is similar to what we do or that a friend of mine has a company – and you get always interesting feedback, such as have you heard about this other project that does something similar or does the same thing in a different way – It offers a lot of possibilities to get good feedback and hear interesting things.

According to the results, the atmosphere of Kafis was seen to encourage talking with strangers. One researcher noted that, "Kafis is a natural place to talk to new people". Another researcher pointed out that "there is an unwritten rule that you should speak to strangers". A staff member mentioned that "they don't feel like strangers when they are there". The permissive usage policy is supported by the assumption that the users are responsible for taking care of the place and being considerate of the other users. "Here you get more freedom, but it goes hand in hand with a certain kind of responsibility", noted one researcher. Another claimed that "people must clear their own mess". To strengthen this behaviour, according to a start-up entrepreneur, "there [in Kafis] are different elements and signs that guide your action so that you empty the dishwasher, put the dirty dishes into the dishwasher, clean the tables and pay your coffee". Kafis was also considered to guide the users to greet and respect each other. As a staff member mentioned, "everybody always says hello and exchanges a few words together".

EVOLVING SOCIAL ENVIRONMENT. The other users of Kafis were considered one of the most important factors of Kafis. As a student pointed out, "the people make the place". The social environment of Kafis was seen as constantly evolving. Another student mentioned that "it [Kafis] changes quite a lot depending on who is there and what is done; this breaks the routine and conventionality". According to a staff member, "there are small meetings and groups of friends". One student pointed out that in Kafis, "start-up people, study course participants, staff members and everyone else come and end up talking together". However, although the social environment of Kafis transforms constantly, the atmosphere seems to stay invariable. As a researcher stated, "it [the atmosphere] never changes – I don't remember that it has ever been more formal". Kafis is used for different activities, such as for participating in the hosted breakfast, eating lunch, cooking, relaxing, joining planned or unplanned meetings and discussions, as a passageway, participating in different events and as the destination of ADF introduction tours. “Mainly my own coffee breaks and a few times I have had friends to whom I have shown Kafis as a part of the ADF introductions tour – I held one tutor meeting there – it has been a place for some nonspecific discussions” is how one researcher described the occasions when she has used Kafis. One staff member talked about the different use situations of Kafis as follows: “I have attended the breakfast multiple times – meeting-like discussion events – yesterday there was a French wine tasting event – one guy held a welcoming party for himself – all kinds of meetings – sometimes cooking”. A student said that, “sometimes during the weekends we have sat around the big table and worked”. The usage time of Kafis varies from a few minutes to several hours. “Breakfast is half an hour or 45 minutes, and usually later in the evening I go to cook there for 30 minutes – we have been there sometimes five to six hours”, explained one student. A start-up entrepreneur described his usage habits of Kafis in the following manner: “I spent an hour there when I go there to work on some offer or read the emails and five minutes when I go and get coffee”.

5.3 The perception of work

The users’ experiences were characterized by two specific themes relating to the origins of the perceptions of work. These contradictions occurred during discussions with four of the 16 interviewees. In these cases, the work was considered e.g. as things that are done in front of one’s desk. This kind of perception of work was named as (1) individual work. In the other 11 interviews, the interviewees thought that work also includes social interactions. e.g. talking with people was considered to be work. This kind of work perception was named as (2) a collaborative work.

INDIVIDUAL WORK. Individual work was related to conducting tasks such as forwarding job description related issues or shortening the task list. As a staff member stated, “maybe it is because of a generation difference that I think that work is what is done in front of the desk”. Another staff member claimed that, “work is checking off tasks from the task list”. These interviewees weren’t certain if e.g. talking with people can be seen as working. Relating to this, one researcher argued that “I don’t know if it [talking with people] is a part of my job description, whether I get paid for that or not”.

COLLABORATIVE WORK. Collaborative work is more than just shortening the task list. A researcher stated that, “all the time I spend here [in ADF] is work”. Moreover, work was considered something that is beneficial to one and to others. According to one researcher, “work is something that is beneficial and own kind”, and a student mentioned that “I always try to combine work and fun – I aim to do work that I’m really interested in”. Interacting with people was also associated with work. As a start-up entrepreneur stated, “work is communicating with people and exchanging ideas”. A researcher noted that “networking is part of any work”. Sharing knowledge was also closely related to the collaborative work. As a start-up entrepreneur summarized, “it [work] is being a member of the community, sharing knowledge, collecting knowledge and creating relationships”.

5.4 The process of becoming a member

The users’ experiences were characterized by three specific themes relating to the process of becoming a member: (1) formal membership and (2) informal membership.

FORMAL MEMBERSHIP. The formal membership is accessed automatically trough employment or a study place. As a student noted, “it was kind of an automatic membership when I was accepted to the course”. The formal membership requires knowing the basics, as one researcher explained that “first I had to clarify the basics such as where I sit and eat lunch – where are the dressing rooms”. However, this does not make you a full member of the community. As a start-up entrepreneur emphasized, “I am a constant user when I come here every day but I have not become acquainted with the people that much yet”.

INFORMAL MEMBERSHIP. Being part of the community requires knowing the other members. According to a student, “you need to know the people and how things are done”. A student who considered herself a full member of the ADF community said that “people know us [the project team] by name and we know everybody by name”. Participating in the common activities of ADF is also needed for acquiring the informal membership. A staff member noted that, “you get the membership via participation”. A student emphasized the same thing by explaining that, “I gained the membership because I was building this place”. Altogether, the results show that achieving the informal membership requires intensive presence in the community. As one student put it, “we [the project team] spent here more time than anybody and so intensively – so it feels like being a member of this community”.

6. CONCLUSION

Academic learning environments are in the middle of change. The challenge is meeting the needs of new ways of learning and teaching that emphasize interaction, collaboration and individual meaning making processes. To contribute to meeting this challenge, the aim of this research was to understand the meaning of informal social face-to-face learning spaces for its users: what purposes it is used for and why it is important to have one.

According to the results, it seems that the key function of Kafis, the informal social face-to-face learning space studied in this research, is to function as a platform for socialization and sharing knowledge between its members. It has other functions as well, such as being the place for relaxing or fulfilling basic needs such as eating or drinking. The metaphor “the social heart of the building”, which emerged from the interviews conducted in this research, describes the importance of having this kind of place in the university environment. The social heart refers to a shared place that is welcoming to its users and has an open and cosy atmosphere. The people make the place, so bringing people together is essential. According to the literature, there is some means to achieve this, such as designing an appropriate layout for the passageways vis-à-vis different places. Also offering events, nourishment and beverages (e.g. coffee) is effective (Becker & Steele, 1995). However, to get the best outcome from these kinds of places, it is necessary to broaden the perception of work. In addition to individual work related activities such as shortening the task list in front of one’s desk, work could also be understood as something that essentially includes collaboration between people such as interaction and knowledge sharing.

The model of “6 dimensions of user experience” (Diller *et al.,* 2005) was applied as a data-gathering framework in this study. The research provided evidence of its suitability as a starting point for a workplace experience research study. However, to be more universally applicable, it needs to be further tested and developed. The next step would be to conduct a virtual survey research. This would allow a greater number of respondents and produce more quantifiable findings. For future research purposes, the workplace experience framework was composed on the basis of the data collection phase of this research. It can be seen in Appendix 2.

Future investigations relating to workplace experience research could focus on identifying workplace experience profiles of co-working spaces for learning, including informal social face-to-face learning spaces studied in this research. For example, according to this research, it seems that the usage time (what period of time one has been a user of a place) and intensity of use (how often and how long times at once one has used a place) have an effect on the quality of the user experience. The users' attitude may also have an effect. It appears, for instance, that the more the user has invested his or her time and effort in a place, the more important the place is for him or her and the stronger the sense of belonging to a community. In addition to usage time and its intensity, the results also indicate that there are differences between the experiences of the different user groups. For example, students might value the acquiring of an informal membership more important than other user groups. On the other hand, it might be that the informal membership is valued among the students because they do not get it as easily as staff members. It also seems that different user groups have different needs, and therefore they experience the place differently. For example, it might be that students more often spend longer times in ADF and use it during the evening and weekends and therefore they value the cooking facilities and the cosy atmosphere of Kafis highly. Moreover, it would be interesting to investigate how the work is perceived among the different user groups. Based on this research, it seems that interaction and sharing seem to be a more indelible part of work than for the students and start-up entrepreneurs than for the staff members and researchers.

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APPENDIX 1: Interview guide.

BACKGROUND INFORMATION

1. Name
2. Year of birth
3. Education
4. Job description
5. Work assignments
6. Use of time

EXPERIENCES OF USING ADF

7. Why do you use ADF as a workplace?
8. How often (frequency and duration) do you use ADF?
9. How long have you been aware of ADF?
10. How did you get to know about ADF?
11. What was your first impression about ADF like?
12. What are the most important workspaces in ADF from the viewpoint of your work? Why?
13. How have you adapted to ADF?

EXPERIENCES OF USING KAFIS

14. What comes to your mind first when you think about Kafis?

Duration

15. Why do you use Kafis?
16. How often (frequency and duration) do you use Kafis?
17. Can Kafis be used for working?

Intensity

18. Who are the users of Kafis?
19. How do you use Kafis (e.g. by routine, intuition, habit)?
20. How does using Kafis feel like?
21. How did you learn to use Kafis?
22. What kinds of changes are happening in Kafis?
23. What do the changes feel like?

Interaction

24. How do you reach Kafis?
25. What would be the best location in the building for Kafis?
26. How does Kafis guide you to act?
27. For what kind of different purposes have you used Kafis?
28. How has Kafis supported these functions?
29. How do you solve the challenges relating to the use of Kafis?
30. In what kind of situations have you met new people in Kafis?
31. How do the other users of Kafis have an effect on your actions in Kafis?

Breath

32. How would you describe Kafis to outsiders?
33. What qualities of Kafis support your description?

Triggers

34. Does Kafis have a specific scent? What is the meaning of this scent for you?
35. Does Kafis have a specific voice landscape? What is the meaning of this voice landscape for you?
36. How does Kafis look like? What is the meaning of this looks for you?
37. How does Kafis feel like? What is the meaning of these feelings for you?
38. How does Kafis taste like? What is the meaning of this taste for you?
39. What features of Kafis do you not prefer? Why?

40. What features are missing in Kafis? Why?
41. What is the meaning of the “worm hole” and info screens?

Significance

42. Is the proportion of the spatial components of Kafis suitable: kitchen, dining room, cafeteria, lounge?
43. In what situations have you invested your resources (time, energy, money) in Kafis (e.g. emptied the dishwasher or bought coffee)? How have you felt about it?
44. What kind of effect does Kafis have on your work?
45. Is Kafis important to you? How?
46. What would you remember about Kafis after 30 years?
47. What is the role of Kafis as a part of Aalto University or Society?
48. How would you summarize Kafis?

APPENDIX 2: The workplace experience (WE) framework.

DURATION

- For what purpose is the space used?
- How often is the space used?
- How long times at once is the space used?
- How long times has the user used the space?

INTENSITY

- Who are the users of the space?
- How well has the user adapted to the space?
- How easy is the space to use?
- What are the problem solving strategies?
- How is the space changing and how is this change coped with?

INTERACTION

- How reachable is the space?
- What is the meaning of its location?
- What behavioural codes does the space support?
- How applicable is the space for different purposes of use?
- In what kind of situations are new and familiar people met in the space?
- What is the effect of a user of the space on other users' actions?

BREATH

- What are the first impressions of the space?
- How well does the space meet the expectations of the users?
- How is the space described to outsiders and which qualities of the space support this description?

TRIGGERS

- What is the specific scent, voice landscape, appearance, feeling or taste relating to the space and what is the meaning of these sense stimulations for the user?
- What does the space symbolize?
- What features of the space are preferred and why?
- Are the some features that are missing?

MEANING

- What are the most important features of the space?
- How does the space affect the actions taking place in the space?
- In what situations does the user invest his or her resources (time, money, energy) in the space and how are these investments experienced?

A CULTURAL DIVIDE?
DIFFERENT MODES OF TEACHING CONSTRUCTION MANAGEMENT

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EXTENDED ABSTRACT

The area addressed in this paper deals with the Teaching Modes most suitable to educate and train Students and Practitioners in Construction Management. It posits that Construction Management might be taught more often and more engagingly through a Project-Based Learning approach. As demonstrated at Imperial College London, Active-Learning Based Programmes and Modules can integrate Construction Management learning in modules that are studio-based (Creative Design), classroom-based (Energy and Infrastructure: Project Management) and field-trip based (Constructionarium). Another well-known and widely-used active-learning project is the Peri Construction Exercise.

This paper looks at both the Peri Construction Exercise and the Constructionarium, both of which ask students to cope with real engineering questions and both of which are used in multiple universities across a range of engineering and building degrees, for students of various levels. The two different educational programmes feature, and are affected by, quite different attitudes concerning the project scope, procedures, locations, resources, assessment and accessibility. However, both Educational Modules allow Students to be aware of the real pitfalls of construction, the behaviours required of engineers, the application of theoretical knowledge and practical know-how, and the management of purposeful engineering activity to requirements of time, cost, quality and safety.

The main findings that the authors present involve the difficulties and desirability of potential International Educational Joint Modules which might enhance a pan-European Approach to Active Learning in Construction Management. The advantages that can be gained can serve the interests of academic standards through enhanced knowledge-sharing whilst achieving a sensible response to difficulties in the economy through better utilisation and sharing of resources. The industry-centric focus of active-learning means that it can help with a better uptake of Building Information Management (BIM) approaches and a better understanding of what BIM means in different countries and different sub-disciplines of engineering and construction. All active learning using team-based projects leads to students having to communicate, and International Educational Joint Modules that have a focus on management and practice are expected to lead students (and staff) to a better understanding of management cultures in different countries, and improved preparedness of engineers for more open markets in construction.

KEYWORDS
Project-Based Learning, Construction Management, Building Information Modelling and Management, Active Learning

1. INTRODUCTION

The paper aims to deal with Teaching and Learning Modes concerning Construction Management, through a ‘comparison’ between the so-called Constructionarium, conceived by Prof. Chris Wise and Dr. Ed McCann, on behalf of Imperial College, London, in 2003, and the well-known Peri Construction Exercise, an International Competition for Students which is particularly popular in German-speaking Technical Universities and Universities of Applied Sciences, established in the late 1990s. Both of these Special Programmes are practical in nature and have advantages and disadvantages pedagogically, administratively and financially. However, the aim is to make students more ‘industry-ready’ as future Graduates, trying to enhance their experience. The comparative analysis seeks to investigate and analyse each scheme and identify transferable elements.

1.1 The Peri Construction Exercise

The Peri Construction Exercise is an industry-sponsored competition, where student teams are given plans and specifications. The Exercise requires that the students submit their own Construction Site Management Plan dealing with formworks. They must respond to the Project-Based Case Study that is provided. They have to work in small groups in order to do it, without any field testing, prior to submitting their work to a Jury.

The Peri Construction Exercise defines the time to complete the concrete part of the structure: 12 weeks, and the average working time per week: 40 hours. Students are told that all excavation and drainage work will be done by Sub-Contractors: it has been agreed to allow a 2-week period for the excavation and drainage of the building site. This adds up to a total construction time for building site equipment, excavation, drainage and structural work of 14 weeks.

The Peri Construction Exercise has been conceived by Peri, a large German manufacturer of formworking systems, in order to improve the skills to be taught to the students in Construction Management. It is an exercise where students need to be able to ‘think ahead’ and visualize the processes and resources needed to achieve a project. The students do not actually construct the project but have to be able think as designers and managers. Time needed to complete the Exercise is estimated to be about 75 hours per person (for a team of five), depending on the team’s background knowledge.

The Eighth Peri Construction Exercise 2011 involved a host of Universities all over the world, as this Project-Based learning activity has become popular quickly. In 2009 almost 400 information folders containing assignment details for the Institutes and Faculties were distributed, according to Peri itself, resulting in a total of 36 entries that were received from Germany, Austria, Italy as well as Malaysia and USA.

As an indicator of the strong German take-up, it can be noted that in 2005 the Competitors were ranked as follows:
Winner: Technical University Braunschweig
Second: University of Applied Sciences, Munich
Third: University of Dortmund
Fourth: University of Applied Sciences, Kaiserslautern
Fifth: University of Cooperative Education, Mosbach

In 2007 the Higher Education Institutions were assessed and ranked as follows:
Winner: University of Applied Sciences, Munich
Second: University of Applied Sciences, Wiesbaden

Third: Technical University, Graz
Fourth: University of Stuttgart
Fifth: University of Applied Sciences, Zittau/Görlitz

German interest shone again in 2009, when the Exercise prize was awarded to the Hochschule München whilst the Technische Universität München came fifth. The other main competitors were: Technische Universität Graz, Hochschule Zittau/Görlitz, Fachhochschule Kärnten, Fachhochschule Erfurt, Fachhochschule II Kaiserslautern, Hochschule für Technik Stuttgart, Technische Universität Braunschweig IBB. The highest-ranked non-German-speaking universities have been Università degli Studi di Brescia (from Italy) and Roger Williams University School of Engineering Computing and Construction Management (from USA).

Whereas the Peri Construction Exercise focuses on the planning and visualization of construction, with the construction management plan being judged, the Constructionarium presents students with completed designs and an obligation to construct them in 5 working days on site. The two events are highly complementary with one focusing on the ability to plan and the other on the ability to execute plans. Both require teams of students to work together, thus requiring them to practise team management. Both activities require student teams to think deeply about construction management and how to make construction choices under pressure of time.

1.2 The Constructionarium

Since 2003, the Constructionarium, pioneered by Imperial College London, has spread rapidly amongst built environment schools in UK Universities (mainly in England and Scotland), because it immerses students in the responsibilities of engineers: technical, managerial, financial and legal, whilst giving them a realistic site experience. On a genuine commercial construction site, it would be illegal, and/or a breach of contract, to permit students to take so much responsibility for actual construction. Hence, the Constructionarium takes place on an ‘academic site’.

A number of universities in the UK use or have used Constructionarium already, and more have expressed interest. Universities which have used constructionarium include:

- University of Greenwich with Atkins;
- University of East London with Atkins and P J Carey;
- University of Liverpool with Mott MacDonald and A J Morrisroe;
- University of Salford with United Utilities and William Pye Ltd;
- University of Birmingham with Birse Rail;
- University of Southampton with Aecom and Laing O'Rourke;
- University of Westminster with Robert Bird Associates and Byrne Bros;
- University of Cambridge with Ramboll and Laing O'Rourke;
- University of Nottingham with Walsh Associates and Sir Robert MacAlpine;
- Imperial College London with Expedition Engineering and John Doyle Construction;
- University College London with Watermans and Laing O'Rourke.

University of Northumbria was an early adopter of Constructionarium and events have been held in Scotland and discussions have occurred in Wales about future events. There is an expansion of interest into the nuclear power station sector with Further Education Colleges looking at introducing this model of learning, particularly near new-build nuclear power stations such as Bridgwater College for the Hinckley Point C station in Somerset.

The Constructionarium was created because Imperial College London found that classroom-scale practicals on the undergraduate MEng Programme in Civil Engineering could not instil the behavioural and practical skills and attitudes acquired through site-scale construction. Using dedicated land at the National Construction College, the Constructionarium tries to replicate UK site conditions as authentically as possible, whilst accelerating the time span: students move from ‘breaking ground’ to ‘topping out’ a sizeable structure in 5 working days.

Each structure has a team of 20 students for Construction Management (managing Time, Cost, Quality, Safety, Personnel, Training, Media Relations, Client Liaison and Evaluation). Students face the physical consequences of their management decisions as they build their structure. Thus, it differs from work experience because Constructionarium student teams take all roles including Managers and Chartered Engineers, Specialist Trained Operatives and General Operatives. The exception is skilled work where the law requires operatives to be licensed (e.g. scaffolding and crane driving): students then work with the licensed operatives. By taking a designer’s drawings and translating them into physical reality, students learn the meaning of ‘constructability’.

Based on the above, both Constructionarium and Peri Construction Exercise involve either the leading Technical Universities (Imperial College London, University of Cambridge, UCL, ETH Zurich, TU Munich, Uni Stuttgart) or the former Polytechnics and the Colleges in the UK and the Universities of Applied Sciences in Austria and Germany (and may include Switzerland, too). Some students of the University of Brescia (School of Engineering) were involved in both of these Educational Programmes: this provides a basis for comparison of the student experiences whilst discussions between teaching teams from the Peri Exercise and Constructionarium enable analysis from ‘expert educational witnesses’.

The authors investigate how such Educational Programmes might be integrated and assess how Project-based Learning or Active Learning could be improved by accommodating different ways of thinking, managing and educating whilst recognising the impact of differences in local ‘construction management culture’.

2. CONSTRUCTION MANAGEMENT AND ACTIVE LEARNING

At Imperial College, according to Prof. Julian Bommer, “visiting professors from industry have also been used significantly in the Department of Civil and Environmental Engineering to help understand and address industry needs. The first appointment (Professor Chris Wise, with sponsorship from the Arup Foundation) addressed feedback from accreditation bodies that there was not enough practical design in the course and this led to a number of changes, including the development of the Constructionarium”. The partners available to fund and to support the Constructionarium came from Engineering Consultancies (Arup, Buro Happold, Ramboll, WS Atkins, etc.) and the Construction Industry (John Doyle, Laing O’ Rourke, Morrisroe, etc.), whilst, as it has been reported, the Peri Construction Exercise is wholly managed by the German Manufacturer. However, a similar event has been seen with the Doka Exercise (Doka being the main Austrian Competitor of Peri). Clearly, industry sees benefit in having students rehearse the skills and knowledge required, and it exposes students to the existence of the companies.

Clearly, any University can use both concepts, - the Constructionarium and the Peri Construction Exercise, - according to its own needs and goals. A comparison allows the authors to investigate any sort of cultural divide that could exist between the approaches to education in Project & Construction Management: the British approach and the Continental (in this case, German-Speaking) one.

The British approach, as used at Imperial, is experiential learning-based: the Students are forced to respond to practical challenges of matching theoretical knowledge and vacation work experience to the engineering task they have been set. It picks up on team-work skills learned in group-based classroom activities, such as Creative Design classes. The Constructionarium grew from the need to introduce "constructability" to students, so that their design work would be more realistic and pragmatic from a contractor's point of view. The universities came to realise that the hands-on construction education was valid in its own right, not only to serve design classes but to help students synthesise many engineering concepts and construction management.

The Constructionarium concept was invented for Imperial College by two industry partners, John Doyle Construction Ltd (Engineering Contractors) and Expedition Engineering (Consulting Engineers). This triangular partnership was created to allow the construction industry to have a more direct impact on student learning at Imperial College, helping to address the balance between the teaching of theory, design and construction. Imperial College has a long tradition of excellence in teaching theory and technical design. From 1997, Chris Wise, then of Arup and latterly a founder-director of Expedition Engineering, brought in Creative Design teaching as compulsory element of the first three years of Imperial's four year undergraduate degree in civil engineering. He was joined by Expedition's Ed McCann as co-teacher and they realised student understanding of design was undermined by students' lack of hands-on experience with issues such as Site-working practices, Client realities, Budget realities, Safety realities, Time pressure, Physical limits of people and materials and general 'know-how'.

While the Constructionarium can address learning objectives relating to Time and Cost through the experiential learning process, it is perceived as less suited to addressing longer-term quality issues, as the students know that no one is truly purchasing their end product. The students can afford to 'fail' on quality because there is no genuine client who will create a legal dispute. However, they do face the immutable 5-day time limit (see Table 1). Also, the financial costings aspect forces students to think very hard about the financial implications of their engineering decisions on site.

Table 1: Timeline for students on a Constructionarium

Thursday	**Friday and Saturday**	**Sunday**	**Monday and Tuesday**	**Wednesday and Thursday**	**Friday**
Day 1	**Days 2&3**	**Day 4**	**Days 5&6**	**Days 7&8**	**Day 9**
Brief Students on projects and safety, allocate student teams	Two days off before intensive field trip	Arrive at CITB campus Site safety talks	Meet client. Contract negotiation and finalisation; Break ground.	Works. Deal with contract manager on claims And variations	Finish works Final Accounts Depart

The Constructionarium entails a course designed to generate an atmosphere that is as close as possible to the experience of running a real engineering project. During the Project, students use their own initiative and engineering knowledge gained during the first three years of the MEng course, and are guided by experienced Contractors and Engineers. The emphasis is on the experiential learning of applied design and construction: students gain experience of Team-working and Communication, Management, Engineering Judgement, Creativity and Problem-solving.

Likewise, according to the Peri Construction Exercise's rules, an exercise submitted must concentrate on the specified tasks only. Any extra tasks provided by the participants will not be evaluated. Students are faced with the reality that, unlike school where they might try to do 'extra' to please their examiner, an industrial client will not pay extra (or give extra reward) for things the client did not request. Peri Exercise lays down a reality that the specification/brief must be adhered to, with precision.

Constructionarium requires that the student teams take on all roles from Chartered Engineer and Project Manager down to General Labourers (this distinguishes a Constructionarium from ordinary work experience where students only function as a student labourer or student engineer).

The Peri Construction Exercise asks the students to generate the most suitable option, compelling them to show how they solved the given question/challenge. Indeed, Peri envisages that, should there be more than one solution for a given exercise, an explanation for the selection of a particular solution should be documented in an easily understandable way. The work must be based on the given layout.

The main purposes of the Constructionarium could be summarised as:

- to bring industry and academia together in educational setting where industry's strengths dominate, but mesh with academic objectives in engineering education.
- to provide students with shared points of reference for reflective learning that draws on a wide body of technical, practical and academic knowledge;
- to keep academic staff in touch with construction site reality, practices and culture;
- to provide a safe way for large groups to gain site experience together;
- to simulate working for a client, but to actually experience physical construction and decision-making.

The Peri Construction Exercise simulates that a consortium of companies will carry out the construction work. An agreement has been reached that all required equipment will be rented. The equipment costs should be acquired from the corresponding documentation, for example RS Means. Rental rates for the formwork materials are given in the task. Students are told that a Sub-Contractor will do the reinforcement work. But, just like the Constructionarium, the students must exercise engineering decision-making. They must commit resources and price work, using engineering knowledge to identify the work and make predictions about time, safety, quality and cost.

The Constructionarium entails that students must schedule the tasks and have to quantify materials, equipment, manpower resources, and predict when they will need concrete delivered, etc. They have briefing days and chances to work as teams before going to site but most of their time together is during the actual construction task.

During Constructionarium the students discuss the choices they made together with the representatives from Consultancies and Companies: for example it is left to the student group to resolve issues such as Project Management, Economics of a Project, Time Management and Materials delivered on time. Members of the teaching team are available for on-site consultation to develop the brief so that students receive immediate feedback as to their progress. Teachers report that students struggle with the idea that there can be multiple correct choices or a variety of ways to approach a task: they tend to want a single correct answer. If three staff give three different opinions, the students can get stressed.

The Peri Construction Exercise requires that missing information must be carefully selected. Reasons should be explained in a short paragraph and include the source. The Peri Exercise necessarily requires students to consider the information they have available and the justification for the decisions they make.

Constructionarium gives commercial organisations the opportunity to encourage young people to enter the construction industry by showing them what it is like to work on real Construction Projects.The Peri Construction Exercise has a focus on the students doing work to meet a brief: the deliverables by students on the Peri Exercise are documentation of the following:

- Building site equipment, including all necessary specific values, all necessary equipment items, a plan of the construction site setup.
- Bid documents for concrete and reinforcement work, including a list with all positions titled concrete and reinforced concrete with hourly estimates and material costs with reference statements, a bid for the concrete and the reinforced concrete work.
- Choice of procedure / calculation, including comparison of slab formwork systems, comparison of wall formwork systems.
- Formwork solutions, including all necessary formwork solutions for the straight walls, for the slabs, and for a formwork solution for the round wall found in the basement.
- Details of construction implementation.
- Construction development plan.

In contrast, Constructionarium students do not design what they build. For the Constructionarium the students are given the drawings of their assigned project. They are organised into groups of 16 – 24 students: in the Peri Construction Exercise, chiefly groups of up to five students are accepted.

An essential objective of the Constructionarium is the self-management and organisation of students, where they take responsibility for allocating tasks within the separate teams. The student teams of 16 or 24 acted as contracting companies and had to deliver their projects to time and budget within the five day on site period (although the event runs for 6 days, the first day is arriving and induction, with no site work). The site teams were required to do all the work, establish a programme for the works and provide a schedule of costs. To be involved in the Peri Construction Exercise, groups of up to five students are accepted. They, too, self-organise. The Exercise is based on a real project that has actually been completed. The geometry of the building and the basic conditions have been modified to simplify the Exercise.

The Constructionarium originally formed the first part a five-week main Design Project, which potentially contributes up to 16% of their 3rd year degree marks but, at Imperial, Constructionarium has now been separated from the Design Project and made into its own module in its own right. The design course is held after the summer examinations so that there are no other academic distractions: the Constructionarium originally 'merely' informed the students about constructability so that their design projects were more realistic about processes and resources required: like Peri, the Imperial design project is mostly document based but, at the end of each week, the Imperial design teams make a milestone presentation of their work for discussion with a critical panel of the academic Project Supervisors and invited industry critics. On site at Constructionarium, each project team will have their own portacabin, where they can plan work, report to tutors, and use for lunch breaks and wet weather shelter. There will also be a manned store with all the necessary equipment and materials to carry out the scale constructions. In contrast, the Peri submitted Exercise is document-based, and must not exceed 100 pages including all layouts and plans (A4 or letter format, font 10, font 8 only for charts). Exceeding the page limit will result in a deduction of points in the evaluation. There is, necessarily, an emphasis on communicating, on paper, as engineers.

Constructionarium can monitor projects against the pre-agreed programme and time and measures taken to ensure timely completion. The project is a demanding exercise in terms of personnel, within the student teams and for staff supervising student teams. Peri also involves serious application of effort but has the advantage of not requiring actual site infrastructure.

Table 2. Comparison summary of the two educational modules.

	Constructionarium	**Peri Construction Exercise**
Experience	Yes	No
Theory	No (partially)	Yes
Tailorability	Yes	No
Role playing	Yes	Yes (partially)
Scope	Widened	Narrowed
Design	No	Yes
Construction	Yes	No
Specialism	Low	High
Compulsoriness	Mandatory	Elective
Competitiveness	High	High
Size of the Team	20 persons	5 persons
Duration	10 days	6 months

3. CONSTRUCTIONARIUM: DIFFERENT POINT OF VIEWS

The University of Cambridge adopted the Constructionarium learning module within a larger work module, defined as it follows:

- Week 1: Monday and Tuesday. Introduction to Constructionarium. Lectures from Consultant and Contractors about planning and safety issues. Planning of work to be done and assignment of roles. Brief preliminary report handed in by Friday. Two days on Structural Modelling Project
- Week 2: On Constructionarium site
- Week 3: Two days to write individual final report. Three days on Structural Modelling Project
- Week 4: Structural Modelling Project

Students choose, or are allocated, a role within the team. The team then has to work together to decide how the structure is to be built and to fabricate the necessary elements. Some equipment will be available on site. Engineers from the Contractor and the Consultant will assist but it will be the responsibility of the students to produce a safe, workable and economic scheme, and then to put it into action.

The marking will be on an individual basis, primarily for a final report, but students will be awarded (or lose) marks depending on how well they contribute to the team effort (in contrast to Imperial where students receive team marks, not individual marks).

The University of Leeds defines the Constructionarium as Construction Site Field Course, where the students are pre-allocated into project teams (each of about 18 students). The students receive an individual assignment to research and have to write a report on the design and construction of a corresponding real (i.e. full-scale) project. The students only receive the briefing packs for their (scaled-down) project when they board the coach for the journey to the Constructionarium. These packs contain a description of the site and the required structure together with the necessary engineering drawings.

Finally, the University of Liverpool reckons that the Constructionarium initiative can be classified as the implement section of the conceive, design, implement, operate (CDIO) educational framework for civil engineering students. CDIO is an international learning and teaching initiative which is based on the principle of embedding active learning into engineering education at all levels. Students are required to follow the same professional and health and safety procedures that a construction contractor follows on a real construction project. Following their site week, Liverpool staff distributed a post-Constructionarium questionnaire, to assess the student perception of the learning outcomes. A de-brief meeting with the contractor and consultant was then held to report/ discuss student feedback and to help run the Constructionarium more effectively next year.

Students also gave helpful feedback and recommendations to improve future Constructionarium, which are selectively listed here as indicators of reflective practice:

a) Shorten the management meetings with academics and combine with the contractor meeting.
b) Installation of Autocad software onto the group laptops provided.
c) Use Constructionarium projects as part of the design coursework in other modules.
d) Election of the project manager or devise a better way than self-selection.
e) Create a new role of environmental manager.
f) Organise more team meetings during the Constructionarium Week.
g) Develop a better understanding of the project before the Constructionarium week and share views and personal previous construction experiences.
h) Provide more guidance on the preparation of a method statement.
i) Enable familiarisation with the team roles and responsibilities before the Constructionarium week.
j) After the Constructionarium, introduce a follow-up meeting with the contractor and consultant.

From this type of feedback, it can be seen that Constructionarium has students engaged in micro-tasks as well as big tasks. They identify their gaps in knowledge (e.g. method statements) and skills (how to form effective teams and manage individuals) and processes (fewer meetings, please) and resources (Autocad on our laptops please). The resource demands and attention required of lecturers is very high and onerous.

4. BIM(M)-BASED CONSTRUCTIONARIUM AND SUSTAINABLE CONSTRUCTION

The input data for both the Constructionarium and for the Peri Construction Exercise are provided with precision. But in the Constructionarium case, the students must then deal with the evolution of real situations and with representatives of Consultancies and Contractors, while the Peri Construction Exercise is only likely to require students to consider their selection by lecturers at the universities, as well as the Jury for the first five admitted to the final stage. The client input is more clearly defined for the Peri Exercise. In any case, the Constructionarium often belongs to a structured educational programme based on the experience learning, while Peri Construction Exercise is a task that can only be attended on a voluntarily basis.

Regarding the level of the internationalization, UK Universities have many international students and EU student numbers are also very high, so it can be assumed that the experience is multicultural, and in case of Construction Exercise origin of students is more homogeneous: however, the Exercise itself has several participating countries.

It is clear that the assessment’s criteria for the Peri Construction Exercise are based on the ability of the students to apply construction techniques to the case study through a detailed analysis of the constraints and to define in detail a logical way of solving the Exercise, also relying on a large body of technical literature. Peri Exercise requires students to have (or develop) information literacy skills, to find the right information.

The Constructionarium, based on the primacy of the Project Management-oriented principles and on the technical support coming from the professional and industrial partners, asks the students to cope with topics as Health & Safety Management, Environmental Management, or Financial Management: these are quite different from the Peri Construction Exercise.

It could be argued that to make a real comparison between the Constructionarium Programme and the Peri Construction Exercise does not make sense, since one is practical construction and one is design for constructors. Nevertheless, Construction Management is taught in a quite different ways from the various Universities throughout Europe. Both Constructionarium and Peri Exercise require students to make decisions as engineers, and to use engineering foresight. Construction management issues thread through each of these engineering challenges, but can be judged (assessed) differently. Thus it could be advisable to establish some Joint Educational Programmes (addressed to Graduate or Post Graduate Students) to allow the students to learn to cope with different ways of thinking and legal systems: to permit better understanding of how to make decisions in different engineering contexts and different engineering countries.

The imperative for such understanding grows. For instance, in 2011, the British Cabinet Office issued a Government Construction Strategy (2) that purports that a fully collaborative 3D environment must be needed, so that all Players and Stakeholders involved in a Project are working on a shared platform with reduced transaction costs and less opportunity for error. This will be a phased process working closely with industry groups, in order to allow time for industry to prepare for the development of new standards and for training. Moreover, Government will require fully collaborative 3D Building Information Modelling (with all project and asset information, documentation and data being electronic) as a minimum by 2016.

Imperial College London will take into account such a goal, through a step-by-step introduction of 3D BIM-Based Models. In June 2011, a first attempt, involving Università degli Studi di Brescia and Virginia Tech, was made to introduce the Building Information Modelling (and Management)-Based Automatic Recognition of the Progressed Works. Some students from the Università degli Studi di Brescia, who are preparing a MSc Thesis in Architectural Engineering about BIM(M), Laser Scanning, Augmented Reality and Automatic Tracking and Monitoring, worked with students from Imperial on their Constructionarium. The Italian students coached Imperial students on the collection of picture data from their construction project. The picture data was fed by the Italian students to 4D Models. This meant that they could superimpose on the photographs an image of what progress should have been made on the site if the Constructionarium project was on schedule. It generates a virtual-reconstructed scene using software models from Virginia Tech University in USA: the scene is generated using structural drawings and time plans (intended construction) compared against the pictures taken on the Construction Site (actual construction).

There would appear to be real benefits from introducing students, on exercises such as the Peri Exercise and the Constructionarium, to the use of Building Information Management tools, techniques, thinking, resources, assessments and evaluation. The Peri Exercise, with its design and resource focus, presents students with the type of task where they learn to persuade a jury (client) of the merits of their work in competition (tendering situation). Applying BIM principles will be essential: from 2016, the British Government will not give work to anyone who is not able to show that their designs are done with BIM management underpinning it and able to be used when the design is taken forward for construction.

Likewise, BIM can actually be seen in action on a Constructionarium site, but only if students have been taught about its purpose and how to make use of it. On a construction site, technology becomes an issue. That raises logistical and resource questions for the organizers of Constructionarium and it may be that each university will have to find its own resources for BIM to be seen in action on site. Currently, it is probably limited to quite old-fashioned approaches to bringing together the record-keeping and project management software on site. But the work done with Brescia University and Virginia Tech shows that undergraduate students can become quite excited about the possibilities of technology on a construction site. Indeed, for students who include computational methods and computing amongst the 'theory' subjects that they do, and who are interested in applied technology, the introduction of BIM into the Constructionarium practical exercise may raise its status. A 'wired up' approach to management on a construction site is in keeping with the 'go-anywhere' approach to information technology and breaks down the division between studio-office work by consultants and on-site management work by senior engineers working for contractors.

Further, the 4-D experiments conducted by Brescia students with Imperial students shows that advanced technology for BIM will enable all levels of workers to see or be shown their actual work against intended targets. Where the Peri Exercise challenges students to be able to foresee the requirements of construction and design for them, BIM could permit them to make visual models and introduce another form of communication to their client. For Constructionarium, a project manager (student team leader) would be able to show his/her (inexperienced) team-workers their progress. They would be able to show the specialist licensed operatives and their client (and supervising teachers) their progress against intended target and make explicit the scale of the challenge in front of them for the next day(s).

An outcome of both the Peri Exercise and the Constructionarium is increased confidence in the students, not least because they have engaged in intense, critical engineering thinking and submitted it for the judgement of a client/jury. From such experiences, students develop understanding, insight, and sow seeds for an identity as an engineer who can make engineering decisions. The use of BIM as part of that decision-making engineering thinking seems a logical development for the future of both of these practical exercises.

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THE ROLE OF EERI SEISMIC DESIGN COMPETITION IN IMPARTING TECHNICAL COMPETENCE AND PROFESSIONAL EXPOSURE IN THE UNDERGRADUATE CIVIL ENGINEERING CURRICULUM

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EXTENDED ABSTRACT

In today's world it is extremely essential that undergraduate civil engineering students have the ability to analyze and solve engineering problems by applying basic principles. In order to do so, it is very important to integrate various fundamental fields to understand the impact of civil engineering solutions in a global and societal context consistent with the principles of fundamental mechanics. At the same time, professional exposure is needed to steer them in the right direction with regards to choosing a suitable career.

A short description of existing international framework standards for the accreditation of engineering programs is provided with reference to: EUR-ACE, (European Accredited Engineering Programmes), Civil Engineering Body of Knowledge for the 21st Century (American Society of Civil Engineers), EUCEET (European University Civil Engineering Education and Training). It is acknowledged that these institutions and frameworks recognize common outcomes for accredited engineering degree programs. Specifically, EUR-ACE specifies six types of outcomes: knowledge and understanding, engineering analysis, engineering design, investigations, engineering practice, and transferable skills.

The Seismic Design Competition (SDC) is organized by the Earthquake Engineering Research Institute (EERI) Student Leadership Council (SLC) in the United States, in conjunction with the EERI Annual Meeting. The 2011 EERI Annual Meeting, with the theme "Earthquakes without Borders," hosted the 8th SDC in La Jolla, San Diego, California between February 9 and 11. The objectives of the SDC are: (a) to promote the study of earthquake engineering amongst undergraduate students, by providing them an opportunity to work on a hands-on project by designing and constructing a cost-effective frame structure to resist earthquake excitations, and (b) to build the awareness of the versatile activities at EERI among the civil engineering students and faculty as well as the general public (national and international).

KEYWORDS
Earthquake engineering, Undergraduate curriculum, Technical competence, Professional exposure

1. INTRODUCTION

1.1 The subject matter of earthquake engineering

The subject matter of earthquake engineering has rapidly evolved over the last few decades to become a science-based engineering discipline with a well defined body of knowledge. Earthquake engineering encompasses multidisciplinary efforts from various branches of science and engineering with the goal of reducing the seismic risks to socio-economical acceptable levels [1].

1.2 Earthquake engineering at the undergraduate level: possible outcomes and goals

At the undergraduate level, the study of earthquake engineering may be limited to the knowledge and understanding of the earthquake mechanism and the territory's seismicity, seismic response of buildings, underlying criteria for earthquake resistant design and new systems for seismic protection of buildings. The EERI Seismic Design Competition (SDC) provides an opportunity for undergraduate students to gain and accumulate knowledge and skills pertinent to the seismic response evaluation of structures with simple configurations and structural systems such as moment resistant frames and shear walls at the least.

Events such as the Seismic Design Competition (SDC) provide an excellent platform in order to meet the aforementioned objectives. The competition deals with undergraduate teams designing and constructing a multi storey balsa wood building frame structure, which will eventually be tested on a shake table during the event. SDC also requires the teams to offer response predictions in terms of roof accelerations and drifts together with anticipated failure modes.

This paper presents a comprehensive summary of the SDC, by highlighting several features such as the history of the event, its basic structure, scoring and financial aspects together with insights on how the event impart technical competence and professional exposure to the participating teams.

The SDC Project gives to students the opportunity to acquire the outcomes for Earthquake Engineering at high level of cognitive achievement asked by the international standards of accreditations for the "First cycle" graduates conforming EUR-ACE [2] respectively bachelor's degree conforming the BOK [3]. The outcomes acquired are: Experiment, Design, Project management, Communications, Globalization, Leadership and Teamwork.

The "Experiment" outcome is acquired at level L4: the students are familiar with purpose, procedures, equipment, and practical applications in the field of Earthquake engineering. They are able to conduct the experiments, report results, and analyze results in accordance with the applicable standards and across more than one technical area as architecture and socio-economical aspects. The students made reports with the results of laboratory studies, virtual experiments, and numerical simulations; they gained the ability to conduct the experiment, analyze and explain the resulting data. The outcome „experiment" is fulfilled by some participants at Master level due to the good synthesis of the results.

The outcome "Design" is accomplished at level L6 including analysis and synthesis for the activities of designing, predicting performance, building, testing and fostering creative knowledge of students. The "Project management" is accomplished at level 4: the SDC project is an undergraduate research in the frame of an extracurricular project; the students had accomplished the activities: initiate, plan, execute, monitor and control, and close the project.

The outcome "Communication" is also acquired by students at level L5, including synthesis; the students created graphics to explain the complex systems and processes of their technical solution, a documented report, and made team presentations. They wrote summaries of the work on posters and had conversations with technical audiences during the poster session. The outcomes "Leadership" and "Teamwork" are achieved by the students at L2 (comprehension) cognitive level and the "Globalization" is acquired at level 3, Application, in the context of theme "Earthquakes without Borders" and international ambiance of the event.

2. SHORT DESCRIPTION OF EXISTING INTERNATIONAL FRAMEWORK STANDARDS FOR THE ACCREDITATION OF ENGINEERING PROGRAMS

2.1 EUR-ACE Framework Standards for the Accreditation of Engineering Programs

The principal aim of the EUR-ACE [2] is to develop a framework for the accreditation of engineering degree programs in the European Higher Education Area (EHEA). The Framework Standards that have been developed, and the procedures for their implementation, are intended to be widely applicable, in order to reflect the diversity of engineering degree programs that provide the education necessary for entry to the engineering profession. The proposed framework affords a means for comparing educational qualifications in the EHEA, and thereby promoting the mobility of engineering graduates. In its current form the content of EUR-ACE is applicable to general engineering education, therefore it is not a difficult task to extend this application to Civil Engineering programs.

The six types of program outcomes of accredited engineering degree programs are: knowledge and understanding, engineering analysis, engineering design, investigations, and engineering practice.

2.2 Civil Engineering Body of Knowledge for the 21st Century

The American Society of Civil Engineers (ASCE) had produced a document titled "Civil Engineering Body of Knowledge for the 21st Century" [3]. This comprehensive document addresses the necessary educational response to the essential changes that are expected to occur in the practice of civil engineering in the 21st Century. Entry into the practice of civil engineering at the professional level requires fulfilling twenty four outcomes to the appropriate levels of achievement. The outcomes are classified into three main types and are listed below:

Foundational Outcomes: Mathematics, natural sciences, humanities, social sciences
Technical outcomes: Material sciences, mechanics, experiments, problem recognition and solving, design, sustainability, contemporary issues and historical perspectives, risk and uncertainty, project management, breadth in civil engineering areas, technical specialization;
Professional outcomes: communications, public policy, business and public administration, globalization, leadership, team work, attitudes, lifelong learning, professional and ethical responsibility.

Entry into the practice of civil engineering at the professional level requires the individual to demonstrate different levels of achievement, i.e. knowledge (L1), comprehension (L2), application (L3), analysis (4), synthesis (L5), and evaluation(L6), for the various outcomes. As an example for outcome “Design” the levels of achievement L5 is required, outcome “Materials Science” is sufficient to be at lower level L3.

2.3 Designing a curriculum

The thematic Networks EUCEET II and III have been involved in the TUNING [4] project for long. An exercise was conducted during EUCEET II to establish the generic and subject specific competences in civil engineering programs. Academic professionals and graduates were asked to express their views using a questionnaire.

To provide comprehensive guidance for the design of programs, the TUNING [4] project offers the guidance to design curricula asking questions for program design, delivery, maintenance and evaluation. The following table provides information on the items and key questions what should be considered for program delivery, maintenance and evaluation.

Table 1: Key questions what should be considered for program delivery, maintenance and evaluation

Actions	Questions
Monitoring	How is the quality of delivery of the programme and its components monitored? How is staff quality and motivation for the delivery of the programme monitored? Are there systems in place to evaluate the quality of the learning environment in work place learning/placements? Is the quality of class rooms and the equipment (including workplace environment required to deliver the programme sufficient? How is the entrance level of potential students monitored? How is student performance monitored in terms of quality of learning outcomes to be obtained / competences to be achieved and time required to complete the programme and its components? In what way is the employability of graduates monitored? How is the alumni database organized? Are data collected on the graduates' satisfaction with the programme?
Updating	How is the system for updating / revision of the degree programme organized? In what way can changes related to external developments in society be incorporated in the programme? How is staff development related to programme updating organized and guaranteed?

Sustainability and responsibility	How is the sustainability of the programme guaranteed? How is it guaranteed that the relevant bodies take responsibility for sustaining and updating of the programme?
Organisation and Information	How is the updating of information regarding the degree programme organized and guaranteed? How is the adequacy of the system of student support, advising and tutoring ensured? Is a Diploma Supplement issued to the students automatically and without charge in widely spoken European language?

3. THE EERI SEISMIC DESIGN COMPETITION (SDC)

The primary goal of the SDC is to introduce undergraduate civil engineering students, most of whom never had a course in earthquake engineering, to the principles of behavior and performance of structures during earthquakes. The SDC serves as a suitable platform to nurture a good proportion of technical objectives and professional experience in students ranging from their freshman to senior year in their undergraduate career. The main objectives of the competition are:

1. To promote the study of earthquake engineering amongst undergraduate civil engineering students,
2. To provide an opportunity to work on a hands-on project by designing and constructing a cost-effective building frame structure to resist earthquake excitations,
3. To build the awareness of the versatile activities at Earthquake Engineering Research Institute (EERI) among the civil engineering students and faculty as well as the general public and to encourage national and international participation in these activities.

3.1 Competition history

Ever since the first event in 2004, the SDC has broadened its scope and reach for eight years, with the latest event in 2011 taking place in conjunction with the 63rd EERI Annual Meeting in San Diego, California, USA [8]. The Student Leadership Council (SLC) of EERI is entrusted with the organization and conduct of the SDC every year. SLC is an umbrella organization composed of graduate students from EERI student chapters across the United States and Canada. As seen in Figure 1a, there has been a very steady increase in the number of participating teams and number of participants in general over the years, with 28 teams and over 200 participants in SDC 2011. This accounts for roughly 460% increase in the number of participating teams and is a measure of the success and commitment of the event (Figure 1).

Figure 2 shows the break-up of the year along the undergraduate career of the participants. Clearly, a very high majority of the students take part in the final year of their 4 year undergraduate career.

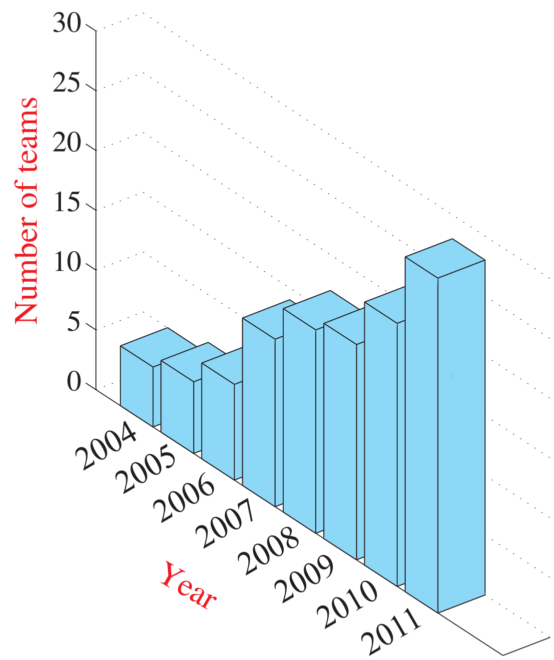


Figure 1: Evolution of the SDC – 2004 through 2011

This may be attributed to the fact that the major focus of structural engineering is inculcated in the third and fourth year in the form of analysis (static and dynamic) and design courses.

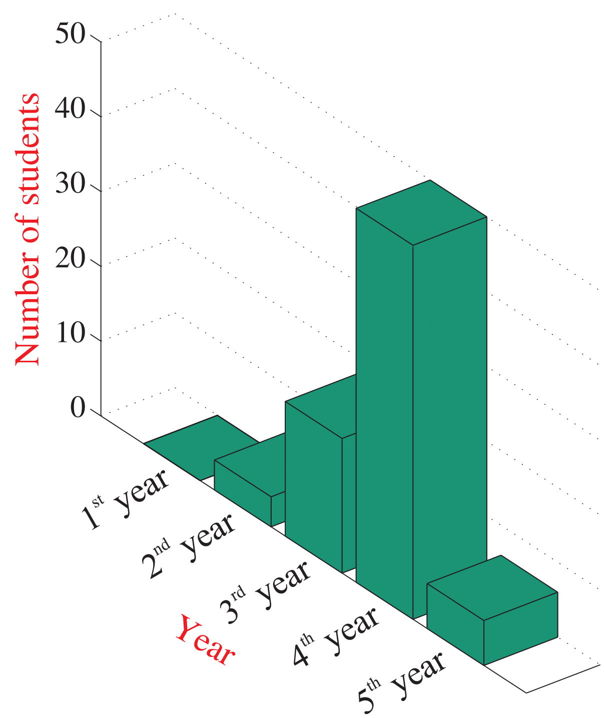


Figure 2: Demography of the participants in the SDC

3.2 SDC Structure

The fundamental premise behind the SDC is the design, analysis and conception of a multi storey balsa wood building frame that would eventually be tested on a shake table subjected to unidirectional ground motions. The SDC is a two day event comprising of several events. It begins with the teams giving short presentations about various aspects of their design, analysis predictions and unique aspects of their as-built structure including innovativeness. It continues with poster presentations highlighting yet again the significant contributions and important aspects of the structures constructed including details about the flow of forces, anticipated performance in terms of roof accelerations and drifts and some of the major constructability issues (Figure 3). The teams also come up with estimates for construction cost and revenue generated in terms of rentable space. The hallmark of the event involves testing of the structures to typically 2 or 3 ground motions, modified to push the structure to significant non-linear limits.

a) b)

Figure 3: a) Oral and b) poster presentation during SDC 2011, San Diego, California.

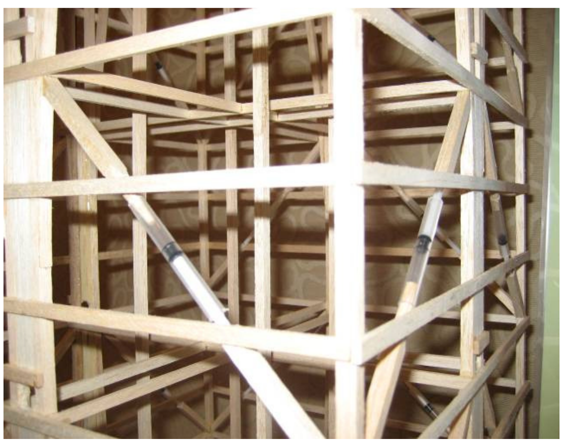
3.3 Scoring scheme

Participating teams are ranked based on their total score in the competition which is based on different components: oral and poster presentation, architectural design, seismic performance of the structure on the shake table, construction cost, and the annual revenue of the building. A panel of judges evaluates and scores the teams for oral and poster presentations as well as the architectural design. The judges are selected from the wide range of academic and industry professionals who attend the EERI Annual Meeting, which, in return, increases the interaction between the students and the professionals. The seismic performance of the building is calculated from the recorded roof acceleration and roof drift using the sensors that are attached to the structure. Each structure undergoes three historic earthquake motions simulated by the shake table, varying in severity from mild to extremely strong. The maximum acceleration and maximum drift are then converted into dollar values as seismic damage cost to the building. The other cost that is taken into account is the construction cost which is calculated based on the structure mass and the base footprint of the building. On the other hand, the annual revenue of the building is calculated using the rentable area times the average rental value of a square foot in an office building in the United States. The team that maximizes the annual revenue and minimizes the seismic and construction costs of the building is declared the winning team. Further details of the rules of the competition can be found in [6].

3.4 SDCs role in promoting technical competence and professional exposure

True to the title of the paper, this section explores the merit of the SDC in imbibing high level technical competence and professional exposure among undergraduate civil engineering students. The competition encourages the students to think about structural actions in terms of flow of forces and performance of the entire structure at the global and local member levels. The foremost of all the objectives in terms of technical competence is the exposure to the concept of structural dynamics and earthquake engineering which routinely tends to be a part of the graduate curriculum. SDC takes a leap by introducing participating students with the idea of ground motions, and response spectrum at the least. Emerging ideas of performance based earthquake engineering which involves design to meet specific performance objectives forms the forefront of the SDC. Finally, though not the least preferred, a lot of emphasis is placed on coming up with designs that are architecturally pleasing. SDC takes yet another step by encouraging the teams to come up with innovative damping systems. Figures 4a, 4b and 4c show examples of innovative damping devices adopted by select participating schools in previous SDC events.

In order to further the efforts in these lines, the SDC awards the *Egor Popov Award for Structural Innovation* and *Fazlur Rehman Khan Award for Architectural Design*. The former award is given to the team that makes the best use of technology and/or structural design to resist seismic excitations, while the latter one if conferred to the team whose building provides remarkable expression of architectural design and inherently integrates a sound structural design.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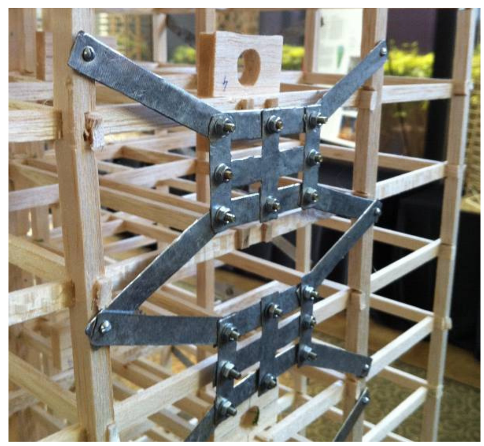
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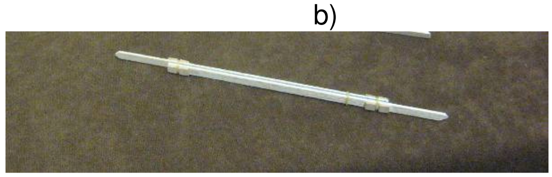
c)

Figure 4: a) A syringe viscous damper - Oregon State University, SDC 2009, Salt Lake City, Utah; b) Metallic friction damper, Technical University of Cluj-Napoca, Romania, SDC 2011, San Diego, California; and c) Friction damper, University of California Davis, SDC 2010, San Francisco, California.

SDC offers a wide range of professional exposure and benefits in addition to the sound technical competence mentioned in the initial part of this section. SDC provides tremendous exposure to the teams and the right forum to improve their oral presentation skills. It opens the doors to speak and interact with fellow undergraduate students from across United States and the world. Furthermore, the teams get a great opportunity to meet and interact with academicians and industry professionals due to its conduct in conjunction with the EERI Annual Meeting. This paves the way for their bright future, firstly in terms of molding them into full fledged professionals with the right amount of technical content and professional attitude and secondly opening their doors to graduate school or a fine industry experience that lies ahead. Above all, participation in the SDC inculcates team building exercise among peers and enhances their ability to work and interact in a competitive atmosphere. Thus, the SDC may be regarded to blend all the important aspects of structural engineering at the right stage in the undergraduate civil engineering curriculum.

3.5 Financial aspects

Costs associated with conducting the SDC include partial financial support for participating teams comprising of accommodation for teams, registration etc., and costs related to organizing the event itself. The latter comprises of costs associated with the venue and other logistics. The fiscal budget for the recently concluded SDC-2011 was about 50,000 USD for which the bulk of the funding came from the United States Federal Emergency Management Agency (FEMA) – Department of Homeland Security. Other sources of funding include sponsorships from the private sector. In addition to the partial funding provided by the competition, participating teams often tend to reach out to their respective departments in the schools they are associated with and/or local sponsors to secure funding for travel and procurement of construction material primarily. Further details about all aspects of the competition can be found at http://slc.eeri.org/seismic.htm.

4. CONCLUSIONS

The ultimate goal of an engineering program is to impart broad education and knowledge of contemporary issues necessary to understand the impact of civil engineering solutions in a global, societal, and environmental context. With tremendous boom in infrastructure around the world, it is extremely important that the current undergraduates who will shape the world in the future have the right mix of technical background and professional backing to design with minimal risk. Events such as the EERI Seismic Design Competition (SDC) provide the right platform by imparting these objectives at the right juncture in the civil engineering undergraduate program by integrating a wide array of disciplines. Apart from imparting technical knowledge in the areas of earthquake engineering and structural engineering in general, the competition offers a wide array of benefits in the form of personality development, project management and tremendous professional exposure, at the least. Several such programs must be designed and conducted at the regional and international level to steer the young minds in the right direction to build a sustainable future.

5. ACKNOWLEDGMENT

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EDUCATING CIVIL ENGINEERS ON HAZARD MITIGATION AND SUSTAINABILITY

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EXTENDED ABSTRACT

Sustainability and hazard mitigation are two of the rather new notions that attract increasing interest in civil engineering curricula. Sustainable development has been defined as “Development that meets the needs of the present generation without damaging the capacity of future generations to meet their own needs”. Therefore, sustainability is an important aspect of civil engineering projects. Hazard mitigation can be defined as any cost-effective action taken to eliminate or reduce the long-term risk to life and property from natural and technological hazards. So, it is relevant to design, construction and operation of small and large scale human projects that could be threatened by natural forces or by human errors and malicious activities.

In this paper it is argued that, together with the introduction of specific courses (usually elective) on sustainability and hazard mitigation, more attention should be paid to some underlying notions or principles, such as risk analysis, passive safety, carrying capacity, resilience, efficient use of locally available materials, respect of local environment, use of the simplest efficient technology for each task, consideration of non-structural measures for safety maximization. First the aforementioned notions are briefly outlined and then their integration in civil engineering curricula is discussed. The Department of Civil Engineering of Aristotle University of Thessaloniki has been used as an example, typical for Greek Universities. The official bulletin of the Department has served as basis, but informal author’s knowledge has also been taken into account. It has been concluded that sustainability and hazard mitigation are discussed in many courses, mainly elective. Nevertheless, they could be introduced in more compulsory courses, while an elective course, dedicated to them, would be very useful. More discussion of the underlying notions and principles would be useful, too. These results could be considered as indicative of Greek Civil Engineering Departments.

KEYWORDS
Sustainability, Hazard mitigation, Risk analysis, Passive safety, Resilience, Carrying capacity, Civil engineering curricula

1. INTRODUCTION

The scientific field of Civil Engineering is very large, some argue too large. Evolution of technology (e.g. production of new materials) offers new possibilities, but at the same time increases educational needs. The availability of computers and respective software has rendered traditional calculations trivial, but stricter regulations call for development of advanced computer skills. At the same time notions, such as sustainability and hazard mitigation, should find a proper place in civil engineering curricula (e.g. Chaw, 2007; Desha et al., 2009). As a result, conceptual understanding becomes more and more difficult (Montfort et al, 2009), in particular when the duration of engineering studies has been officially reduced.

This paper deals with the notions of sustainability and hazard mitigation and their integration in civil engineering curricula. The concept of sustainable development has been defined in the UN Document "Our common future" (1987) as "Development that meets the needs of the present generation without damaging the capacity of future generations to meet their own needs". It may be adapted to most scientific fields, including different branches of Civil Engineering. For instance, structure sustainability could be interpreted as achievement of the predefined goals (e.g. pleasant living space) with minimal consumption of raw materials and energy during the construction and the operation period and with minimal need for maintenance (e.g. Vazquez et al., 2011). Sustainable management of water resources on the other hand, aims at meeting water demand using renewable water reserves only.

Hazard mitigation can be defined as any cost-effective action taken to eliminate or reduce the long-term risk to life and property from natural and technological hazards. So, it is relevant to design, construction and operation of small and large scale human projects that could be threatened by natural forces or by human errors and malicious activities. In other words, it penetrates almost every aspect of Civil Engineering. Flood hazard mitigation is probably the most important issue (e.g. Schanze et al., 2006), but current research has focused also on very specific tasks, such as glazing hazard mitigation (Smith and Renfroe, 2010).

Understanding of sustainability and hazard mitigation presupposes grasping of certain closely related or underlying notions and principles, such as: risk analysis, passive safety, resilience, carrying capacity, efficient use of locally available materials, respect of local environment, use of the simplest efficient technology for each task, consideration of non-structural measures for safety maximization. These are briefly discussed in the following paragraphs.

2. THE UNDERLYING NOTIONS AND PRINCIPLES

Risk analysis includes assessment, characterization and management of risk, and also policies relating to risk. It can be considered as an interdisciplinary scientific topic per se (see for instance http://www.sra.org/, namely the web-site of the Society for Risk Analysis), closely related to hazard mitigation.

Passive safety is inversely proportional to the gravity of adverse effects, when technical measures fail. In landfills, for instance, it has to do with the extent and gravity of groundwater pollution in case of liner failure. It depends then on the natural permeability of underlying rocks and the depth of the local groundwater table, namely on landfill site selection. Another example is road construction, where passive safety is increased by using suitable street furniture (e.g. Passive Safety UK, 2010). In any case, passive safety is directly related to hazard mitigation.

In the framework of strength of materials, resilience can be defined as the capability of a strained body to recover its size and shape after deformation, caused especially by compressive stress, or as the property of a material to absorb energy when it is deformed elastically and then, upon unloading to have this energy recovered. Speaking about sustainability, though, resilience is defined as the ability to recover from or adjust easily to (adverse) change. By the way, this is a typical case of terminology problems, which are due to the extent of the scientific field of Civil Engineering.

The notion of carrying capacity has been initially introduced in Biology, where it can be defined as the maximum equilibrium number of organisms of a species that can be supported indefinitely in a given environment (that includes food, habitat, water and other necessary resources). In the framework of engineering, though, it can be defined as the upper bound of human interference or activities that an ecosystem or an area can sustain without permanent deterioration. For instance, carrying capacity of tourist destinations is a hot environmental topic for the Mediterranean countries (e.g. Tselentis et al., 2006; Christofakis et al., 2009). This interpretation of carrying capacity is easily understood by civil engineers, since it is a direct metaphor from statics.

Respect of local environment has to do with adaptation of human plans to locally available resources and climatic conditions. Construction of golf courts in arid Mediterranean regions, for instance, is a clear violation of this principle. Similarly, use of local building materials avoids unnecessary transport energy consumption, sometimes masked by low prices or ignored, due to abundance of funds. A discussion of the use of local materials and of other sustainability principles can be found in Glezos et al. (2000).

Technology offers undoubtedly new possibilities for sustainable development (e.g. water saving devices or new insulation materials that allow reduced energy consumption for the same living standards). While open to innovation, though, engineers should not be lured by the “high-tech temptation”, namely the use of over-sophisticated systems, if the same job can be achieved by simpler systems that could be locally constructed or repaired. Moreover, such systems are usually less vulnerable, users understand their function better, and their use may have positive impact on local economy.

Non-structural measures (e.g. adapting land use to flood hazards or regulating water demand) can play an important role in hazard mitigation and in sustainable development (e.g. Simonovic, 2002). Traditionally disregarded in construction-oriented curricula, non-structural measures are finding their proper place in modern education of Civil Engineers.

3. A CASE STUDY

The Department of Civil Engineering of Aristotle University of Thessaloniki is a rather typical example of Greek Departments, its peculiarity being that it offers the largest number of elective courses (around 100). It should be mentioned, though, that this number is going to be reduced.

Despite the large number of courses, the terms “sustainability” or “sustainable development” do not appear in any course title. Inside course curricula these terms appear in: a) the compulsory course of the 2nd semester: “Urban and regional planning and development”, with respect to traditional settlements and historic city centres and b) the elective course of the 9th semester “Environmental impact assessment”. One should not draw conclusions, though, based on direct references only. A closer look at courses curricula reveals that sustainability principles are presented at least in the following courses:

- Building Construction II (compulsory, 4th semester), with respect to energy conservation in buildings.
- Irrigation and stream mechanics (compulsory, 7th semester), with respect to water conservation.
- Special topics in building construction (elective, 8th semester), with respect to energy conservation in buildings.
- Energy-conscious design and use of solar energy in buildings (elective, 9th semester).
- Water resources management (elective, 9th semester).
- Geothermal energy (elective, 9th semester), with respect to sustainable use of renewable resources.
- Coastal structures (elective, 9th semester) with respect to development and protection of coastal zones.
- Solid waste management (elective, 10th semester).
- Environmental and energy policy in the European Union (elective, 10th semester)

The term “hazard mitigation” does not appear in any course title either. Nevertheless, the course “Fire protection in structures” (elective, 8th semester) is dedicated to the mitigation of fire hazard. Moreover, different aspects of hazards and mitigation measures are presented at least in the following courses:

- Groundwater hydraulics and hydrology (compulsory, 5th semester), with respect to floods and drought.
- Soil mechanics I (compulsory, 5th semester), with respect to ground subsidence and its impact on constructions.
- Engineering hydrology (elective, 7th semester), with respect to floods and drought.
- River engineering I (elective, 8th semester), with respect to erosion and sedimentation.
- Geotechnical earthquake engineering (elective, 8th semester), with respect to soil liquefaction.
- Wooden structures (elective, 9th semester), with respect to fire hazard.
- Hydroelectric works (elective, 9th semester), with respect to dam failure hazard.
- Environmental Engineering Geology” (elective, 9th semester) with respect to natural hazards.
- Landslides, earth cuts and fills (elective, 9th semester).

Regarding the underlying notions and principles, one elective course of the 8th semester is dedicated to risk analysis (Systems and risk analysis). The term appears in the curriculum of 4 more elective courses, namely “Engineering seismology and soil dynamics” (7th semester), “Environmental Engineering Geology” (9th semester), “Marine structures” (10th semester) and “Groundwater exploitation and protection” (10th semester).

The term “passive safety” appears in the course curriculum of the elective course “Road safety” (9th semester). It is also discussed at least in the elective course “Solid waste management” of the 10th semester, in relation to landfill site selection.

The notions of resilience and carrying capacity are discussed at least in the elective courses “Mathematical models of water ecosystems” (8th semester) and “Regional planning and development II” (9th semester), respectively. Finally, non structural measures are discussed in the framework of the compulsory course “Irrigation and stream mechanics” (7th semester).

The preceding overview shows that sustainability and hazard mitigation are discussed in many courses, mainly elective. Nevertheless, these notions could be introduced in more compulsory courses, such as “Environmental engineering”, which deals with sewage treatment. An excuse is that the respective course curricula are already too heavy. It is up to the tutors, though, to make room for these important notions. Introduction of a new course, dedicated to sustainable development and hazard mitigation, or rescheduling of an existing one (e.g. “Environmental impact assessment”), could fill gaps and could help students form an integrated picture.

Regarding the underlying notions and principles, risk analysis is covered in a satisfactory way, but more attention should be paid to the other ones.

Finally it should be mentioned that lack of direct reference to sustainability in course titles of the 5-year curriculum of studies, is counterbalanced in additional graduate studies. The Department of Civil Engineering of Aristotle University of Thessaloniki offers a Master's program in “Environmental protection and sustainable development”.

4. FINAL REMARK

The interest in sustainability, hazard mitigation and the related notions and principles discussed in this paper is increasing. Their integration in Civil Engineering curricula is already underway and will help to prepare our students for a basic future challenge: Safety and satisfactory quality of life for more people with reduced consumption of precious resources.

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SASICE: SAFETY AND SUSTAINABILITY IN CIVIL ENGINEERING

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EXTENDED ABSTRACT

The performance of the built environment and the construction sector are of major importance in Europe's long term goals of sustainable development in a changing climate. At the same time, the quality of life of all European citizens needs to be improved and the safety of the built environment with respect to man-made and natural hazards, such as flooding and earthquakes, needs to be ensured. Education has a central role to play in the transformation of a construction sector required to meet increasing demands with regard to safety and sustainability.

In this paper, work in progress of the SASICE (Safety And Sustainability In Civil Engineering) project is presented. The aim of this project is to promote the integration of safety and sustainability in civil engineering education. The project is organised in the context of the Lifelong Learning Programme, funded by the European Community. The coordinator organisation is the University of Bologna. Nine partner universities from different countries are involved in this transnational project. The universities participating to the project constitute a network of high level competences in the civil engineering area, with several opportunities to improve lifelong learning adopting different media: joint curricula, teaching modules and professor and student exchanges. As a response to the challenge regarding new educational methods in sustainable engineering, teaching modules are developed in 4 thematic areas: (1) Safety in construction, (2) Risk induced by Natural Hazards Assessment, (3) Sustainability in construction, and (4) Sustainability at the territorial level. The development of the teaching modules is based on an extensive analysis of the need for highly qualified education on Safety and Sustainability involving all relevant stakeholders (European and national authorities, companies, research institutes, professional organizations, and universities).

The main target is enabling students to introduce these advanced topics in their study plans and curricula and reach, at the end of their studies, a specific skill and expertise in safety and sustainability in Civil Engineering. With our natural resources fading away and our infrastructure in dire need of repair, new trends and challenges in civil engineering education in the concept of "Sustainable Development" are needed to be addressed.

KEYWORDS

Civil Engineering, Engineering education, Safety, Sustainability, Natural Hazards, Risk

1. INTRODUCTION

1.1 Need for Safety and Sustainability

The built environment is a vital part of any society. Since planning, designing and maintenance of the built environment (roads, bridges, dams, buildings and supply systems) are more or less related with human health and environmental protection, safety is an important aspect for engineers. In the past, communities focused on enforcement of structural design and related legislation for avoiding loss of life and property damage. For many years this thought was the priority in civil engineering projects. Recently, new approaches concerning risk prediction and mitigation are applied. These are known as risk-based approaches. The target is anticipating social-economic disruption and environmental degradation as well. Furthermore, in the last decades, the concept of sustainability came into focus. According to the Brundtland Report (Brundtland 1987) a broad definition of sustainability is to meet the needs of current generations without infringing upon the needs of future generations or compromising their abilities to maintain a similar standard of living with minimal environmental degradation (ASCE 2006; Institution of Civil Engineers 2006; The Hong Kong Institution of Engineers 2006). Due to the complexity of the concept of sustainable development, a multidisciplinary collaboration is required. The variety of interactions between all aspects of society and environment make the whole process really difficult.

Civil engineering, has to be sustainable by balancing the economical, social and environmental objectives. One of the factors that have most inpact on the levels of regional sustainability is education (Velasquez,1999). Sustainable Development should be addressed as a holistic issue but higher education is organised by disciplines which has led many academics to become “disciplincentric” (Velasquez and Munguia, 1999). One of the main problems, which must be overcome, is the assumption that environmental issues should be addressed by environmental specialists and not civil engineers (Cortese, 1997). Engineering students should enhance their environmental capability and integrate sustainability in designing and construction. The holistic approach comprises a wider knowledge base in the social, political, and life sciences in addition to physical sciences and mathematics. It has to furnish students with the ability to analyze, comprehend and understand the multi-dimensional aspects of sustainable development problems (Chau, 2007).

1.2 Related work

In the USA, very few programs and courses on sustainability engineering are provided. As the interest in integration of sustainability into civil engineering education was growing, more initiatives derived from interdisciplinary engineers and practitioners were financed. Most of them focused on the undergraduate curriculum. A special issue on “Sustainability in Civil and Environmental Engineering Education” was published in April 2011 by the American Society of Civil Engineers (ASCE) in the Journal of Professional Issues in Engineering Education and Practice, in order to compile many of these initiatives into a single issue. The special issue starts with a forum titled “Intelligent Sustainable Design: Integration of Carbon Accounting and Building Information Modelling,” by Stadel et al. (2011). It focuses on integrating life-cycle assessments and building information modelling through the example of a very difficult and important sustainability issue: carbon accounting. The issue then expands to a series of technical papers, each addressing the incorporation of specific sustainability topics into courses or evaluating sustainability learning techniques (Haselbach, 2011).

Safety and sustainability issues are on the top of interest in Europe, too. Sustainability has been addressed to varying degrees since the publication of the Bruntland Report

(1987). The European Civil Engineering Education and Training (EUCEET) Association contributes to implementing, improving and extending the curriculum by supporting activities such as new partnerships between universities and stakeholders, joint degrees at various levels, new learning techniques and multi-disciplinary programmes of education. In general, more and more initiatives aim to enable European engineering students to learn how engineers can contribute to the existence and sustainable development of society. The need for ensuring human and environmental health in an affordable and economically feasible way, intensifies the importance of providing funding to improve decision-making processes. For this purpose, the European Union sponsors a variety of Educational Programs such as the Lifelong Learning Programme (LLP).

1.3 The goal of the paper

This paper addresses the context and main activities of the Safety And Sustainability In Civil Engineering (SASICE) project which is funded by the EU within the framework of the European Lifelong Learning Programme in order to promote the integration of safety and sustainability in civil engineering education. The project is organised in five parts (a) the analysis of the needs in close consultation with all stakeholders, (b) the development of teaching moduli on safety and sustainability in civil engineering, (c) the integration of the teaching moduli in existing and new joint university curricula, (d) the pilot implementation of the moduli with an international exchange of professors between Universities and (e) the development of innovative Information and Communication Technologies (ICT)-based content and services.

The following sections present the content of the project and the way that students could benefit from the whole process. The students will be reached through the academic plans of the partner universities, with the main emphasis on current internationalization programs in the area of civil engineering. Within the framework of the project, it will also be verified how students with different backgrounds and formations are able to develop a specific knowledge on safety and sustainability. Students enrolled in existing programs at the partner universities will also be admitted to the courses to provide them with the opportunity of an “internationalisation-at-home” experience.

2. DESCRIPTION OF THE “SASICE” PROJECT

2.1 Members of the project

Nine partner universities from different countries are involved in this transnational project. Table 1 gives the participants and their countries of origin. The coordinator organisation is the University of Bologna in Italy. The project commenced in October 2010 and has a timeframe of 36 months. The universities participating to the project constitute a network of high level competences in the Civil Engineering area. The partner universities have been selected in order to meet at least two of the following three criteria: 1) a long tradition in internationalization activities; 2) a high number of students that will primarily benefit from the project results in their studies; 3) specific competences in more than one area of safety and sustainability in Civil Engineering.

Moreover, these universities are located in different countries, covering the different geographic and cultural areas of Europe. All the partner universities have the internationalization projects as a strategic priority, and some of them already have Master courses taught in English in collaboration with European or US partners, with very high level quality of education. The partner universities also have a long tradition in working together in different areas of Civil Engineering, as documented by the projects funded by the European Community where the partners are often involved.

Table 1: List of partner organisations

Partner no	Organisation Name	City	Country
P1	**UNIVERSITY OF BOLOGNA**	**BOLOGNA**	IT-ITALY
P2	**ARISTOTLE UNIVERSITY OF THESSALONIKI**	**THESSALONIKI**	GR-GREECE
P3	**INSTITUTO SUPERIOR TECHNICO**	**LISBON**	PT-PORTUGAL
P4	**KATHOLIEKE UNIVERSITEIT LEUVEN**	**LEUVEN**	BE-BELGIUM
P5	**UNIVERSIDAD DE CANTABRIA**	**SANTANDER**	ES-SPAIN
P6	**UNIVERSIDAD POLITECNICA DE VALENCIA**	**VALENCIA**	ES-SPAIN
P7	**UNIVERSITE JOSEPH FOURIER GRENOBLE**	**GRENOBLE**	FR-FRANCE
P8	**UNIVESTITY OF PAVIA**	**PAVIA**	IT-ITALY
P9	**UNIVERSITY OF SOUTHAMPTON**	**SOUTHAMPTON**	GB-UNITED KINGDOM

2.2 Aims and Objectives of the project

Society, institutions, employers, enterprises and organizations, recognize the need of a highly qualified education in the area of Safety and Sustainability in Civil Engineering developed at the European Community level. Several EC initiatives in education allow students to obtain experience in foreign universities, but often the different methods of teaching and performing of design activities necessary in civil engineering education do not allow full competence to be achieved in design methods in the foreign country. For this reason, some European universities have started joint educational programmes with bilateral agreements. However, collaboration between a larger number of universities, representing the different technical approaches to civil engineering is more desirable.

The present project starts from the real needs of higher education on safety and sustainability in civil engineering to develop teaching moduli making use of the high technical and teaching expertise of the partners. These moduli will be the starting point for a real joint curriculum where the technical contents can be taught in different Universities, adopting the same criteria for the evaluation of the students. It will then be possible to see how these moduli can consider the specific technical traditions of the universities, and to compare the performances of students in different countries. Very innovative ICT-based techniques will be also used to help the partner universities to share the contents of the teaching moduli and make them available to the students. Some universities (e.g. Bologna, Leuven and Southampton) have already started to use these media with exceptional results from the educational point of view.

The teaching moduli refer to four thematic areas: (1) Safety in construction, (2) Risk Assessment induced by Natural Hazards, (3) Sustainability in construction, and (4) Sustainability at the territorial level. Development of the teaching moduli is based on an analysis of the need for highly qualified education on Safety and Sustainability involving all relevant stakeholders (European and national authorities, companies, research institutes, professional organizations, and universities). Maximum use will be made of experience and know-how available in organizations such as the European Network for Building Research Institutes (ENBRI), the International Association of Bridge and Structural Engineering (IABSE) and the European Society for Engineering Education (SEFI) which has a task force dedicated to Sustainability in Engineering Education. During the course of the project, three different ways of implementing these teaching moduli will be examined. The first option refers to the introduction of the moduli into existing curricula of partner universities. The second option concerns the development of a joint engineering curriculum, and the last one involves double curricula leading to a double degree. In order to support the development of joint and double curricula, much emphasis will also be given to the development of appropriate ICT support.

3. WORK PACKAGES

The long term objective of achieving a more sustainable and safer built environment is reached through twelve work packages which support the SASICE project activities as given in table 2. Each partner is responsible for one or more Work Packages (WP) in collaboration with the other partners of the project. The first WP includes the initial planning, the management and the monitoring of the project. Bologna co-ordinates the whole project and shares with the partners the defined plan. Bologna will monitor also the activities that foresee multilateral co-operation among the partners and the creation of an open environment for discussion and decision making.

Table 2: Summary of Work Packages N°

Work package N°	Type of work package	Title of work package	Lead partner	Start	End	Total days
WP1	Management	Management of the project	P1	1	36	85
2	Dissemination	Dissemination of results during the project	P2	13	36	17
3	Exploitation	Exploitation of the project results	P6	19	36	18
4	Quality Plan	Quality Assurance programme	P5	13	36	20
5	Development	Needs in Europe of highly qualified education on Safety & Sustainability in Civil Engineering.	P4	1	6	24
6	Development	Teaching moduli: Safety in Construction	P9	7	24	15
7	Development	Teaching moduli: Natural Hazards and Management of Risk	P2	7	24	15
8	Development	Teaching moduli: Sustainability in construction	P1	7	24	15
9	Development	Teaching moduli: Sustainable Development and Environmental Protection	P7	7	24	15
10	Development	Development of innovative ICT-based content and services	P4	19	36	15
11	Development	Administration phase – Development of bilateral agreements	P3	13	24	26
12	Development	Teaching safety and sustainability: A pilot project	P8	25	36	18

The dissemination activity is part of the second WP, with a continuous diffusion of the results, supplemented by related workshops. The target groups that will benefit from that activity are: 1) the partner Universities involved in the project, 2) other Higher Education (HE) Institutions in Europe and Institution Associations, 3) Existing networks in which the partners are members, 4) Universities outside Europe, 5) public and private enterprises in the Civil Engineering area, 6) the students participating in exchange programmes. The dissemination mainly concerns: a) the analysis of the needs of HE with regard to Safety and Sustainability in civil engineering, b) the proposed teaching moduli and the joint curricula and c) the agreed criteria for the student grading. The aim of the dissemination activity is to inform these target groups of the need for new training methods on the emerging fields of safety and sustainability in civil engineering and the ongoing results of the project.

As far as the exploitation strategy is concerned, it will mainly take place during the last part of the project in the context of WP3. The fact that other universities could positively and freely exploit the results of the project is a key point of the project. Particular interest will be taken in opportunities to export the results outside Europe, with the possibility of proposing, in the future, joint curriculum programmes with US and Asian universities. The development of flexible moduli to be included in different learning paths and contexts would make it easier to exploit the results in a wide spectrum of HE institutions. The needs for legislative or technical changes to facilitate the development of joint programmes in higher education, to improve student or teacher exchange and services for international students will be submitted to the main actors of the process (University administrations, Ministries of Education and of Foreign Affairs) and other universities in Europe. Comments and suggestions will be included in the Final Exploitation Report. Finally, the project supports the creation of an international open community discussing the learning needs on Safety and Sustainability in Civil Engineering in a European context. This spontaneous community will promote new opportunities for further exploitations.

WP4 deals with the implementation of a quality control system (AQS) that will monitor the overall process of development of joint study programmes in civil engineering. The project partners will carry out an “intermediate evaluation” and a “final evaluation” of the project. The AQS strategy is based on the evaluation of all the project phases and in particular: 1) of the project management, 2) of the project activities, 3) of the overall results. The tools which will be used for the quality evaluation are specific evaluation grids (both quantitative, e.g. questionnaires and qualitative, e.g. interviews and focus groups) that will be prepared by 4 internal experts and validated by the quality board. It will be used by the local coordinator in charge of the evaluation activities in each university.

The main objective of WP5 is to define the needs for the integration of safety and sustainability in Civil Engineering education. Given the important economic and societal consequences, these topics must be developed at a European level. As for safety, the application of the Eurocodes for design and the complexity of the major civil engineering projects are creating opportunities for joint collaborations between companies in different European countries. Safety targets are very important also for existing structures (cultural heritage), which need to be established at a European level. With regard to sustainability, it is fully recognised that the application of energy saving techniques in construction often requires initial investments at government level, which must be co-ordinated at a National and European level to be sustainable from an economic point of view. Sustainable development and environmental protection are closely interrelated and European recommendations for the environment, water and coastal zones must be taken into account. The increasing demands with respect to safety and sustainability require a new class of specialized civil engineers with both technical and management competencies developed at the European level. It is particularly important in the Civil Engineering context, due to the Lisbon agreement of the recognition of the University degrees. The analysis will be carried out in close consultation with the professional world (construction companies, design offices, etc.). Quantitative (surveys and official statistics) and qualitative (personal interviews with leaders) data will be collected and analysed for the design of competences and university programmes. Maximum use will be made of know-how available in organizations such as ENBRI, IABSE, and SEFI. The final outcome of the needs analysis will be a general and detailed report on the needs and expectations that will serve as a guideline for the development of the teaching moduli in WP6-WP9.

Within WP6, the needs underlined in the analysis performed in WP5 are used as the starting point to develop a series of teaching moduli in the area of safety in construction, where the areas of Structural and Computational Mechanics, Structural Engineering and Geotechnics will mainly contribute. Presently, design codes require constructions to be designed in order to satisfy given levels of safety with respect to some performance criteria. For new constructions, these requirements are clearly stated in European codes for design (Eurocodes), whereas for existing constructions, the criteria for assessment and for design of strengthening interventions are not uniform across European countries. Existing constructions include residential and commercial buildings, bridges and retaining walls, and some are of historical and cultural importance. They can be very sensitive to actions such as earthquakes and to the effects of pollution and climate change if they have not been designed with respect to them. The modern sustainability agenda is leading to a drive to refurbish and extend the life of existing constructions rather than demolish and replace them. Hence, knowledge about the safety, assessment and strengthening of existing constructions should be shared across Europe and with the next generation of civil and structural engineers.

In WP7, a teaching module concerning Natural Hazards and Risk Management is to be prepared. Geological, hydrological and meteorological events such as volcanic eruptions, landslides, floods, tsunamis, earthquakes and snow avalanches cause loss of life and economic damage every year. To predict, manage and communicate the hazards associated with such geophysical events, a clear understanding of their physical nature is required. Explanation of disasters' causes and impact involves understanding not only of environmental hazards but also diverse social, economic, cultural, institutional and other factors which shape vulnerability. Theories of social vulnerability and protection, sustainable development and disaster risk management, the causes and consequences of natural disasters, and decision-making processes and interventions to reduce disaster risk will be presented. The linkages between hazards, vulnerability and disasters, and the factors affecting the governance of disaster risk management will be examined.

The module will be structured into two main categories: (a) Physical Processes and (b) Integrated Risk Management. The first covers the physical processes of extreme events. Basics from meteorology, hydrology, economics, engineering and planning sciences will be mapped out. The second deals with risk analysis (hazard determination, vulnerability determination and risk calculation), risk evaluation and mitigation within a system of an integrated risk management.

WP8 deals with the development of teaching moduli in the area of sustainability in the construction process, where the areas of structural engineering and infrastructure engineering will mainly contribute. Sustainability can be improved throughout the construction process, from the material production, to the impact of the construction techniques on the environment, to the energy efficiency of the final construction, to its durability during time. In the teaching moduli, these aspects will be considered, and quantitative techniques and protocols to quantify and certify the sustainability of a construction, such as the Athena or the ITACA protocols, or the LEED system of certification of the United States Green Building Council (USGBC) will be studied. Sustainability is a problem that cannot be faced at a national level only, because the positive consequences on the environment of a sustainable construction/technique often can be recognized at a very large scale (typically transnational).

Within WP9, teaching moduli in the area of Sustainable Development and Environmental Protection will be developed. The areas of hydraulics and hydrology, geotechnics, transportation and highway engineering will mainly contribute. The concept of sustainable development (SD) has rapidly emerged as an approach similarly advocated and criticised by local and international organisations, broadly described as an envisioning strategy to save the earth for future generations. A central concern of these moduli will be to give a critical understanding of the SD debate and practice, unveiling the political, social and economic forces underlying environmental conflicts and exploring concrete approaches to address their causes. The moduli will adopt a European and international comparative perspective, exploring the specific conditions for intervention in different contexts.

Some of the contents of the teaching moduli will be supported by the use of ICT-based contents and services, in order to facilitate the effectiveness of the teaching activities of the partner universities. This process is organised through WP10. The main support will be the recording and webcasting of lectures from selected teaching moduli. This may take the form of live webcasting, where particular lectures are recorded and broadcast live so that students from different universities across different time zones can participate simultaneously, or as a library of recorded lectures which can be browsed by the student retrospectively.

Several technologies already exist across the partner universities that could be used or adapted for the needs of WP10. The University of Southampton has a system for recording a lecture and making it available as a webcast with the lecture notes integrated. A range of electronic devices can access the material (PCs, smartphones, etc.). Southampton has also innovated in the use of interactive video as a teaching aid, in the context of health and safety awareness and road safety, in which students are asked to view video footage and select on the screen where health and safety risks are seen to occur (Hammond et al., 2011). The system has the advantage that immediate feedback can be given, and could be extended to the topic areas of structural safety and environmental sustainability. Another webcasting system already available at the University of Bologna (https://podcast.unibo.it/) and extensively used by leading universities in the world (Stanford Univ., Berkeley Univ, MIT, Cambridge Univ. etc) could also be used. Using any of these distribution media, videos of lectures in other partner universities will be made available to the students, who will then be able to participate in a virtual European class. Some of the recorded videos will also be distributed via social networks and other similar media (You Tube, Facebook, etc.), which are more and more used by leading universities to increase the diffusion of their media contents.

The regulation for degrees of civil engineering (CE) in the partner Universities will be studied in WP11 to work out the possible ways to introduce the teaching moduli the teaching moduli on safety and sustainability developed in WP6-WP9. Three ways of increasing level of integration will be analysed: a) the introduction of these moduli in the curricula offered by the partner universities, b) a joint CE curriculum, offered by some partner universities, along side the regular curricula, devoted to safety and sustainability problems, c) joint competences with development of double curricula between the partner universities, with final achievement of a double degree by the student. In case b), the teaching moduli will be interchangeable among the universities, and adapted to the student tracks according to the university traditions. In case c), the achievement of a joint degree will require the fulfilment of 60 ECTS points in each of the two universities to complete the Masters programme. The curricula may need to be submitted to national quality agencies for an external evaluation. WP11 also includes development of procedures for student selection, mobility rules, credit transfer and Diploma Supplement contents.

WP12 will be a pilot project developed in the final year of the SASICE project, where the universities involved in WP10 and WP11 will teach the moduli developed by the network in a co-ordinated manner. A teaching plan will be prepared, with professors going to give lectures in foreign universities. To this purpose, some moduli considered as key outputs of the project will be selected and taught at several universities. In the courses, mid-term tests, final exams and homework will be given to the students in the same manner, and evaluation criteria established and agreed by the partners will be applied to give the student scores. At the end of the courses, the quality assurance of the teaching level will be monitored with student questionnaires. Having foreign professors to teach the moduli in their own university will be a good opportunity also for the students that do not plan a mobility experience to have an interesting internationalization-at-home experience.

3. OUTPUTS AND RESULTS

The impact foreseen through the development of this project will be enhancement of higher education in the area of civil engineering in Europe, but should also have important consequences in other areas of engineering (Mechanical Engineering, Information and Communication Technology, etc.), where analogous methods of teaching and student mobility criteria can be adopted. The impact of the pilot projects where professors will go to teach the moduli in partner institution should be very high not only for the students following the educational program, but also for the entire Faculties of Engineering of the partner universities.

Moreover, these activities will enhance students and staff mobility, sharing of teaching learning experiences, conformity on joint competences and modules, assessment and evaluation criteria, and agreement on internal procedures for quality assurance. It is the reality of working together at a European level and according to European patterns.

Students should have the opportunity of achieving a joint Master degree on Civil engineering and improving their language skills and competence for intercultural relations. Departments should be able to enrich their teaching, research and management experience by sharing and debating during the development of the project. Multilateral relations among European partners could increase the formation of a common identity for European education by co-operation and collaborative work. The new generation of professional engineers which will be formed with deeper knowledge in safety and sustainability will then have a great impact on the society and the economy in the civil engineering sphere.

The partner universities presently have several partnerships in European research projects and all have a strong interest in collaboration in teaching activities. Once a solid base for the integration of safety and sustainability has been provided by this project, it will be easy to continue in the following years with professor exchanges to teach and refine the teaching moduli. Some of the partner universities are presently introducing joint curricula in their regulations, and these collaborations will help to arrive at a stable and durable collaboration between the universities. For five years after the end of the project, a series of workshops will be held annually at one of the partner universities, mainly involving students and stakeholders, to verify how a wide expertise on safety and sustainability topics in the civil engineering area may open new job opportunities and be an important resource for a actual integration of the different technical cultures of the member states.

4. CONCLUSIONS

The SASICE project which is part of the EC Lifelong Learning Programme will contribute to a more competitive Europe. The programme focuses on issues concerning education in civil engineering in different regions of the EU and how to form a new generation of civil engineers with a deep knowledge on safety and sustainability problems, assessment and design methods and guidelines adopted in different European countries, thus striving to achieve the Lisbon agenda goals. The consortium is formed by universities representing very different regions of the EU with diverse social models, so providing a unique experience for education and research for future students, as well as new employment possibilities after graduation.

The development of teaching moduli developed together by universities from different countries and with traditionally different methods (inductive vs deductive methods) has the goal of experimenting with novel techniques for academic teaching. Joint degrees contribute to putting into evidence university excellence and European competitiveness. The quality control guarantees excellence in teaching and research supervision, sharing their expert knowledge. The programme will contribute to the quality and visibility of European higher education through implementation of a well-defined joint curriculum offered jointly by some of the partners.

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ON THE ECONOMIC APPROACH TO NATURAL HAZARDS MANAGEMENT: WHAT ECONOMICS CAN ADD TO COMMON TECHNICAL KNOWLEDGE ON HAZARD-RISK BINOMIAL IN ENGINEERING DISCIPLINES

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EXTENDED ABSTRACT

Technical knowledge has been subject to a continuous adaptation process along the last 20 years, and a lot of new issues and problems have been attracted and included in Civil Engineering paradigm in this period. Environmental issues that were marginal subjects in the sixties are nowadays part of the core knowledge developed under the umbrella of the "Common Technical knowledge" of Civil engineers. One of the most characteristic issues that have followed this path is the subject of natural hazard -risk management. While societies have reached an increasing level of awareness about the challenge we face in this area, a broad set of approaches have been involved in knowledge development. These areas go from geographic sciences (focusing on physical sources of vulnerability and measures of natural events), social sciences (focusing on economic and social sources for vulnerability and resilience), and biological sciences focusing in environmental consequences both from natural events and for human induced changes. The fragmented origins of knowledge have produced an academic literature that shows a clear lack of consensus among basic concepts, measures and indicators.

Economic disciplines have been traditionally involved in engineering analysis, through the conventional CBA approach that traditionally played an auxiliary role for engineers when huge amounts of resources were mobilized in the construction of big infrastructures. Hence this paradigm was supposed to serve as overall framework for natural hazards related technical decisions. Nevertheless two specific issues have emerged in the process, which require some reflection: The unexpected high level of risk we face, and the need to adopt sustainable strategies. These issues need to be considered to develop a general framework, as far as they should serve as a robust basis for knowledge development and assignment criteria. Hence decisions in the field of risk adaptation or mitigation will be better implemented.

There is a continuously increasing perception of hazard exposures in our society that has attracted the attention towards this subject, and unveiled the unexpected relevance of involved decisions in these areas. On the other hand, sustainability issues have emerged in parallel with economic analysis, asking for new decisions criteria in order to approximate technical issues to intergenerational equity restrictions.

The aim of this paper is to investigate the existence of a common basic knowledge that helps to efficiently decide on resource assignment, by indexing the different approaches on the literature that may serve as a common knowledge for engineering learning. The paper is organized as follows. First, we review the different risk assessment frameworks in the existing literature. Then, we compare the different conceptual approaches and clarify the assumptions yielding behind each ones. Third, we review the contribution from economic approaches to the issue. And fourth, we derive some theoretical conclusions on the role played by the different multidisciplinary contributions.

KEYWORDS

Evolutionary, Institutional, Resilience, Vulnerability

1. INTRODUCTION

Analysis of the consequences derived from natural shocks and catastrophes has always been a central issue for human concern. Specifically the analytic approach on this issue can be tracked back on economics to the early seventies, when the US Administration first introduced the term vulnerability in normative and executive documents, (OEP-EOP, 1972). From that moment on a new network of concepts emerged in literature, attempting to introduce in the discussion a broad set of ideas that have been diversely applied.

In this line interesting concepts suggesting fruitful ideas have been imported to the literature from diverse origins. Concepts as exposure were imported from health safety discipline, resilience was developed under ecology paradigm, and others were gradually adopted according to specific approaches, on social sciences such as geography, on political sciences, and on economics, following the analytical focus trend that was pointing to increasingly complex problems, and searching for explanation and proposals for correction measures. A new jargon has emerged covering suffered damages and prevention measures (mitigation, adaptation…).

This approach showed some interesting characteristics. First it was the result of an interdisciplinary work, where economists, natural scientists (geologists, ecologists…) and social scientists faced the different pieces of the question, tried to apply their model and finally assumed the need for interdisciplinary exchange of ideas. Nevertheless, the results of this process did not provide a consistent framework capable of representing all the specific problems and questions analyzed and a global framework was needed to combine them. The aim of this paper is to review what economic analysis can offer to create a consistent model, where the different concepts and ideas taken into account by the analysts are seen as part of a broad map, and where interaction among them serve to model the complex interactions yielding behind natural phenomena.

Nevertheless, there is a parallel emerging literature that focuses on the conceptual dilemma between the consideration of “natural hazards” either as pure natural risk (e.g. derived from volcanism) or human induced risk both as new causal effects derived from environmental consequences from development [Martin (2007)], or as institutional weakness derived from the lack of resources to immediate response, carrying and recovering capacity and financial responses. [Benson and Clay (2004)].

Simultaneously, economic theory had evolved introducing new fresh trends challenging marginal paradigm. In 1989 Ecological Economics Society was founded and the Ecological Economics Journal started to be published, promoting a new approach to environmental problems, where interdisciplinary experiences were perfectly suitable.

The paper is organized as follows, first we will review the general approaches to environmental and climate change risks, then we will analyze the institutional framework produced by economics to explain the complex natural human system and attempt to identify the main questions under discussion and the sources of this lack of consensus, second we will review the main concepts that have been produced to capture the diverse implications of environmental risks on society. Then we combine the relevant works in the literature in this area. We finish with some conclusions on the result of the question.

2. INSTITUTIONAL APPROACH TO HUMAN-ECOLOGICAL SYSTEM

Environmental science has always lead the research in the field of climate change. The determination of the scenarios to be considered in climate change has required a systematic analysis of environmental variables and relations among them. Nevertheless, when sustainability emerged in social science debates as a central issue, both in theoretical analysis and in the political practice, institutional, evolutionary and complexity economics emerged as new actors in the show. At that point the evidence showed that complex problems as climate change require more than the analysis of the parts, that is the individual sub-models. When we are coping with nonlinear complex systems, their overall behaviour will result from the interaction among the pieces and not from the pieces themselves, and from the internal evolutionary mechanisms included in it.

According to Costanza et al (2001), a distinction has to be made between a) framework, that is, the inventory of basic elements included in the analysis, which serves as a reference for theoretical debates, b) theories, that identify and set priorities among relevant elements, that try to solve specific questions and that fix proposals for assumptions and, c) Specific models introduced to represent each case study. Furthermore hierarchy and scale have to be considered as basic explanations of the proposals, [O'Neill and Rust, 1979 and O'Neill et al 1989]. On one hand individuals affected by the pressure under study, considered as study subject per se, will show their individual behaviors, and on the other the overall ecosystem might initiate an evolutionary path that will drive the system to a different stable state that can be preferred even at the cost of individuals or species destruction. [Allen et al (1982)].The same is also true when social systems are under study.

Adopting Costanza´s scope, we can identify as basic elements in the theoretical framework:
1.- Stocks: They include any element that is susceptible of accumulation. Under this category different assets can be considered, human made capital be it physical (industrial equipment, infrastructure, human (knowledge and culture), or social or institutional capital capturing the value generated by the complex infrastructures created by societies in order to provide them regulations, buffers and protection [Coleman, (1988)]. On the other hand natural capital is also included in this category and again we can identify different families, in one group we can find assets assimilated to conventional economic capital as renewable and non renewable natural capital.

2.- Flows. Under this issue we include all the interactions among elements listed under the stock issue in the previous point. Several flow categories can again be identified, external flows, that arise from the sun, and interchange flows, that can be identified again as internal for each stock, when can be considered as pure exchange among assets under the same stock category, or inter-stock when a transfer between the two spheres can be observed. In the first group we can find the internal flows of biomass in the ecosystem, and the process of accumulation of human made capital, through physical investment, knowledge accumulation and learning and institutional strengthening. In this last case, all the institutional agreements developed on natural resources management play a key role in our framework. In the second group we can include all the extractive activities, from non renewable resources, and harvesting, in the broad sense, to the renewables; in both cases we found the externalities generated from socioeconomic activities as pollution or environmental protection and reconstruction, and finally any recreational services.

3.- Controls: The ecological-social system is equipped with a complex structure of limits, restrictions, and feedback loops. These elements represent per se a new issue to analyze in all the developments derived from our framework, to accurately represent the system. Under this category we include physical and biological laws that regulate first physical processes and biological behavior and second, ecological interaction both between individuals and aggregates, if focusing in internal nature controls, and another set of control rules when focusing on human societies. In this second group obviously we still find biological behavior, but also primary institutions as families, social aggregates and political institutions, and a set of rules adopted in order to clarify assignments and solve conflicts among different agents and assets.

4.- Attributes: these are the characteristics of the previous elements that have to be considered in the analysis for a comprehensive approach to the actual situation. A broad set of attributes can be included in this category of elements, but when sustainability is under analysis the main attributes are heterogeneity, decomposability, predictability, extent in space and time, resilience and productivity. All of them help to improve the accuracy of the approach. Heterogeneity focuses on the diversity of positions, interests and characteristics of the affected elements, decomposability focuses on our ability to break down study subjects and predictability clarifies the degree of uncertainty in each of the observed phenomena, extent of space and time puts a limit to the temporal or geographical unit of study needed, productivity relates to intrinsic wealth associated with assets and resilience is included as attribute to capture the ability to absorb shocks without changing to a different equilibrium state [Holling, (1973)]. When natural risks are under analysis a new broad set of attributes emerge: vulnerability, susceptibility, exposure to certain risks and again resilience. This attributes will be our subject of analysis further on in this paper.

Another approach for the analysis of the ecological social system is derived from complexity literature. Holling (1973) proposes a different framework based on the idea that the different elements of the system are subject to a never ending cycle of adaptation and creative destruction. For this school of thought the system should not be decomposed and rebuilt from the pieces according to a set of rules and conditions but to be divided in self-organized subsystems that, with a short set of rules and linkages, incorporate their own logic into the global explanation and facilitates mutual reinforce. These units created decomposing the global systems show three properties, wealth, internal controllability and adaptive capacity [Holling, (1973)]. The first one, wealth, quantifies the possible alternatives that can be reached by the system. The second one, internal controllability, focuses on the number and strength of internal connections and hence the susceptibility of the system when external pressures are present, its capacity for self-governing. The third, adaptive capacity, offers a view of the capacity of the system to absorb pressures without suffering irreparable damage, incorporating once again the elusive concepts of vulnerability and its contrary, resilience.

Following this path, systems evolve from an initial phase where at a certain point the process of exploitation of resources starts. In this phase an initial social group, be it human or strictly animals, after several attempts, discovers a path to growth and stability, strengthening system resilience. The Darwinian selection or the economic competition can both explain the launching of the process, and in any case an accumulation of resources starts, be it directed towards biological accumulation or economic capitalization. As the process matures, an increasing set of self-controlling measures are created in order to solve conflicts and avoid the less profitable horizons to happen. This phenomenon occurs at the prize of limiting the ability to survive, of limiting heterogeneity and diversity, and inexorably approaching destruction through a process of assets accumulation and limiting degrees of freedom, and hence lowering resilience (increasing vulnerability). When the process is mature enough in this new conservation phase, the system shows lack of capacity to cope with shocks, due to the rigidity generated in this process, and this generates an inexorably and sudden collapse. The accumulated resources are suddenly freed and a new release phase starts. In this situation the previous game seems to be over and new opportunities are opened to all the agents in an unpredictable way. A race starts to take control of the organization and the winner establishes himself reorganizing the system according to its interest and paths, creating a new reorganization phase. In this phase a continuous increase in stability allows to reproduce another cycle moving again to exploitation phase.

The third level of the analytical framework is manifested in individual models focusing on the specific issues to be covered selecting and quantifying variables (drivers) different models have been created around the different focus point of the project (DIVA for coasts…) [Hinkel and Klein, (2009)]. As a result of this review we have a clear view of two theoretical frameworks where we can integrate the existent proposal on vulnerability resilience and related concepts.

3. THE ACTUAL DEVELOPMENT USED IN POLICY AND STUDIES

Although at present a demand of order and internal consistence is generally accepted in literature, [Adger (2006)], there is a huge amount of rigorous work that has already been developed that will be better understood if we try to unveil and consistently structure the basic assumptions yielding behind it. With this purpose we present a parallel view of the practical developments following the same structure we have previously used to describe the theoretical proposals.

An interesting reflection on the semantic confusion built around the term vulnerability can be seen in Mc-Fadden et al (2007) that points to the role played by language as an instrument to categorize knowledge, and hence points to the exogenous origin of the different concepts built around colloquial terms. The concept behind the word vulnerability is built mixing several assumptions: weakness, exogenous attack, and subject suffering this attack, so natural thinking process drives to identify a receptor, a source, and to assume a balance between shock size and carrying capacity.

3.1 The general framework

At the first level the general framework is not discussed in depth because there is not discussion about it in the literature, nobody explicitly objects to the idea that climate models are complex, uncertain, and full of non-explicitly observed feedback loops that makes the process to respond dynamically. The same can be argued about evolutionary ideas, it is generally assumed that long term consequences drive the system to new states, and there is no reason to omit adaptation capacity and systemic evolution of our system.

Specifically two definitions can be observed: the first one following Costanza´s approach has provided an intellectual basis for the so called DPSIR (Drivers, Pressures, States, Impact, Responses) theoretical proposal emerging from environmental disciplines, and the second has given birth to the PSR (Pathway Source Receptor) emerging from risk analysis disciplines. There are basic differences among them and we can easily understand them according to the answer given to the four questions the model suggests: flows, stocks, controls and attributes. See Table 1.

About Flows and stocks clear difference exists between both approaches. The first one (DPSIR) focuses on: a) the different drivers that direct the elements of the system towards coping specific needs, b) pressures defined as the demands raised to the environment by the active agents in the system, c) states both as pollution externalities or harvesting of resources, and on the states or levels of services reached by the different elements whom the demands are raised, d) impacts as loss of quality states created by the shocks, and e) responses to capture the recombination of the system to adapt to the impacts, both environmental or social, these responses are then included in variables as adaptation, mitigation damage… The second one (PSR) offers a narrower view of the situation, the model assumes that a certain shock will exist, and then identifies the different pathways to be followed in order to determine the final consequences on each receptor. The quantitative and probabilistic aim in the model can easily be seen and no second step responses are internally considered.

Table 1 Comparative Frameworks for Risk Management (based on Costanza *et al.* (2001), and Wadekker *et al* (2009) Diaz Simal and Torres (2011)

	DPSIR		PSR
FLOWS	1.- Drivers: different drivers towards Specific needs 2.- Pressures: demands raised to the environment 3.- States: pollution externalities and levels of services reached 4.- Impacts: loss of quality		1.- Shock will exist 2.- Different pathways 3.-Final consequences on each receptor.
STOCKS	5.- Responses: recombination of the system		
CONTROLS	1.- General system of feedbacks 2.- Reassignment of resources and functions		1.-Physical process 2.-Probabilistic impact - response
ATTRIBUTES	1.- Heterogeneity 2.-Decomposability 3.- Predictability 4.- Extent in space and time 5.- Resilience-vulnerability 6.-Productivity	Resilience Vulnerability: 1.- Homeostasis 2.- Omnivory 3.- High Flux 4.- Flatness 5.- Buffering 6.- Redundancy	1.- Hazard – Exposure 2.- Susceptibility 3.- Vulnerability 4.- Resilience 5.- Adaptive capacity

About the controls that connect all the different elements, again both frameworks provide a different solution, the DPSIR approach includes a general system of feedbacks that allows all sort of realignment of paths, reassignment of resources and functions, and the second offers a more static view. The physical process analysis is the critical issue and there is only one final response to the probabilistic impact that has to be anchored in the real system in order to estimate the consequences of the shock for the different affected agents.

On the attributes we will find again a different family of concepts emerging in each of the parallel lines, on one hand on the DPSIR approach, we build the discourse based on attributes as previously stated: heterogeneity, decomposability, predictability, extent in space and time, resilience-vulnerability and productivity. A brief analysis has previously been made in this document, but it is important to review here the relevant issue of resilience [see Holling (1973)]. Although this concept is invoked in both frameworks as a relevant attribute its scope is clearly more adapted to DPSIR approach. Resillience has been in use for years by ecologists and social scientists in a continuous process of scope broadening, expanding from pure biological concepts to social behavior strength sources [Folke, (2006)] and has been recently parameterized by Wardekker et al (2010) around six explanation components that might guide the research for modeling resilient behavior systems. These components point to the relevant sources of resiliency where research has to focus, and so became a useful guideline in the applied field work. The set is formed by: a) Homeostasis that refers to the existence of control loops, previously defined as a component of the system, and suggests that a mature system gains resilience when multiple feedback loops generate stabilization processes helping to assume and survive to external shocks. b) Omnivory is again a multi-disciplinary concept suggesting that resilience is gained through the availability of alternatives to fulfill needs, and lost when we are playing with only one card be it as high as ace or a two. c) High flux has to do with the dynamic "speed" observed in the system, the abundance of resources for the agents to try new solutions in the adaptation process. As dynamic and rich as the system is, as quickly it can adopt new strategies, and thinking in terms of adaptive cycles, this ability to give quick response is a critical issue for survival. d) Flatness focuses on the hierarchical structure of the system. Again social environment with absence or excess of administrative levels producing institutional paralysis does not look very different from ecological systems, where new adaptive strategies can be adopted spontaneously by single species or through a global coordinated change adopted by all the species of the system. e) Buffering is another source to focus on that qualifies any social or environmental system, once again the abundance of resources, acting as safety ratios, produce different possibilities available and allows to qualify system´s strength. Typical buffers as aquifers, sand deposit, food deposits that help biological systems to survive to extreme conditions, can be mirrored in the socioeconomic systems through social guarantees, financial deposits, insurances… that should be considered as resilience sources. The final item f) redundancy introduces a new source of resilience that identifies systems where no critical resource or mechanism exists, as far as it can be substituted or reproduced. Examples for this can be seen from living organisms full of redundant genetic information, to advanced societies ready to replicate their institutional arrangements, or in a different sense in network structures where no one is critical and the destruction of any component is solved just by displacing the activity to the next available alternative.

Two additional comments have to be made, first vulnerability seen as a loss in resilience of a system can be decomposed in individual attributes as has been showed, and second all those attributes suit with Holling (1973) schema proposal for a system adaptive cycle: wealth, internal controllability and adaptive capacity.

On the other hand, the alternative SPR approach has developed different attributes according to the basic scope adopted: Hazard measuring the probability of a source to shock the system, exposure reflecting the probability that a shock consequence reaches a certain receptor, susceptibility and vulnerability to reflect the gravity of the consequences of such a phenomenon, extent of time and space, delimitating the receptor under analysis and resilience (also critical in DPSIR model) and adaptation acting as second step reaction by the system. [Adger, (2006)]

3.2 The Theoretical approaches

In this step it has already been clarified that two separate theories have been developed, the first one around DPSIR approach suggests a complex, multi-effect and multi-driver, evolutionary behavior, heavily compromised with non-linearity relations, and focusing in the adaptive reaction of the system, and the second one around SPR approach, suggests a single-causal single-driver and linear process.
Under the DPSIR approach, theories based on ecology, economic and social science have focused on different issues, as resilience, biodiversity and ecological services, social resilience and entitlement theories among others [Villagrán, (2006)]. Under the SPR framework, theories based on engineering knowledge applied to specific receptor have been the usual case.

4. A REVIEW OF THE DIFFERENT APPROACHES FOR MEASURING VULNERABILITY

As can be derived from the contents of this paper, vulnerability as a variable has attracted attention from different theoretical developments, under the umbrella of different conceptual frameworks derived from institutional agreements or from academic proposals. Adger (2006), Fussel (2007), Fussel and Klein (2006), Villagrán (2006) and Gallopín (2006), have developed a systematic analysis of the diverse contributions and solutions. As has been defined previously a broad set of origins have produced parallel paths to the concept. [Diaz Simal et Torres (2011)].

Institutional economics (a) have broadened the scope towards social and political contributions both to vulnerability and its opposite concept, resilience. Entitlement Theories (b) proposed by Amartya Sen (1979) have focused in the analysis of poverty as a key factor towards vulnerability seen from development and welfare economics schools. Evolutionary economics (c) disciplines have focused on the adaptive process that rules human and natural evolution as subject of the analysis. Ecological economics (d) have focused on the role of nature as provider of services as part of the available capital. In a different sense, from an opposite point of view from these global vulnerability schools, Risk management (e) and risk-hazard natural disaster analysis (f) disciplines have focused the analysis to quantification of risk.

As a conclusion of all this literature we can assume that again two parallel approaches can be identified subject to a different initial framework that might be misguiding the analysts, but that have to live together as they are essentially studying the same problem through different scopes. The first approach with a more systemic view groups Entitlement theory, Institutional Economics, Evolutionary Economics and Ecological Schools, and the second, with more quantitative focus is organized among risk theories and natural hazards analysis areas.

Essentially there is a set of questions that have to be answered together although they have received independent answers. The first question is about the sources of vulnerability we are facing, the second question is related with the scale and temporal path of the analysis, the third question is related with the available information to compare vulnerable situations and the fourth is related with the capacity to produce a synthetic indicator. (See Table 2)

On the first question related with the sources of vulnerability, we find different suggestions according with the diverse priorities across societies. Entitlement theory focuses on poverty as key issue (famine insecurity health…) pointing, first on the increasing exposure to hazard by poorer groups in societies, second on social dependence on critical assets, third on the lack of recovery capacity and finally on the contribution of poverty to new social and political hazards. Institutional economics focus on the low level of controls a society has, due to the weakness of the decision framework, the perception of the problems they face, and the quality of its governance structure: that on one hand deals with certain problems. And on the other omits the needed regulations for others, hence clearly defining specific incentives in both cases. Again the ability of societies to self-protect themselves, their capacity to experiment shocks with less critical damage, and their social recovery capacity are the key problems to characterize societies. [Birkmann (2006)].

The second question that has to be solved is related with the scale and temporal path of the analysis. Again there are different answers. In a first group, Entitlement Theories, Institutional Economics, and Evolutionary Economics schools have to combine a high scale resolution to identify vulnerable areas, with aggregate indicators that include global characteristics of a society, seen as a single complex individual, when facing a crisis, and of course they have to adopt a long term temporal scale. Nevertheless evolutionary schools need to focus on micro-scale to identify individual incentives and behaviors behind paths. The ecological schools are tied to the spatial distribution of ecosystems and individuals within them. And from a different view risk and hazards literature adapts its scale to their probability prediction, and so work in long term periods for capturing trends in natural events, and high space resolution to capture spatial differences.

Table 2 Theoretical contributions to the concept of vulnerability

	Evolutionary economics	Institutional economics	Entitlement theories	Ecological economics	Risk Management	Natural hazard and Catastrophes analysis
Sources of vulnerability	1. Evolutionary paths 2.- Long Term States	1.- Weakness of the decision framework 2.- Perception of the problems and risk 3.- Quality of the governance structure	1.- Poverty 2.- Ability to choose	1. Anthropic pressures. 2.-Carrying Capacity	1.- Risk management decisions (adaptation mitigation, assumed damage…)	1.- Risk hazard probability quantification. 2.-Expected damage
Scale and temporal path of the analysis	1.- Long Term scale 2.- Social micro-scale (Incentives)	1.- High scale resolution to identify vulnerable areas. 2.- Low scale indicators to include aggregate characteristics of a society 3.- Long term temporal scale.		1.- High scale resolution to identify ecosystem units	1.-Long term periods for capturing trends in natural events. 2.-High space resolution to capture spatial differences.	
Available information	Qualitative information on evolutionary and adaptive capacity.	1.- Aggregate economic data, 2.- Distributive equity, 3.- Governance and transparence, 4.- Quality of social and human capital		1.- Biodiversity 2.-Resilience 3.- Evolutionary 4.- Primary production	1.- Physical data on the present functions 2.- Previsions on path evolution of climate parameters	
Capacity to produce a synthetic indicator.	Projected trends	1.- GDP 2.- Wealth Distribution. 3.- Governance indicators 4.- HDI	1.- Sen´s Poverty Index	1.- National Accounts environmentally adjusted 2.- Happiness indexes	Expected damage ($)	Level of risk (probability)

For the third question related with the available information to compare vulnerable situations, again we have different scopes. A first group is formed with schools concerned on societies, human settlements, and wealth and hence the indicators produced focus on the measure and combination of attributes derived from aggregate economic data, equity in the distribution of wealth, governance and transparence, and quality of social and human capital, (education level, social security, retirement funds, assistance networks…). The ecological schools try to capture their own defined indicators as biodiversity, resilience, evolutionary paths, primary production… About the risk-hazard literature, there are two main sources of information, first physical data on the present functions of affected dynamics, and second previsions on path evolution of climate parameters behavior.

The fourth question is related with the quantification of the synthetic indicator to capture the information, and consequently builds a vulnerability function based on this data, and again different responses are available at this point. The first possibility is to keep different vulnerability sources separate and not trying to combine them in any expression, at a risk of describing the same problems several times, and the second is to move towards a single synthetic indicator.

Different attempts have been made in this area that require further explanation, in risk analysis, some work has been done trying to determine the expected damage derived from a hazard, combining hazard, exposure to it, fragility of the exposed assets and valuation of the damage, identifying probability of occurrence of an event with percentage of damage expected [Alexander, (2000)]. Other analysts have focused on the pure probability risk [Dilley et al (2005)]. Finally economic attributes of a society are based on conventional economic statistics (GDP) and equity comparative indexes as Gini Indexes on wealth distribution and Sen´s (1976) poverty indexes that compare the expected economic impact of the hazard with the poverty threshold and consequently weight-relative impacts on poor and rich. Hahn (2003) suggests a set of conditions to verify in order to obtain robust indexes: validity, verifying when it points to the core of the phenomena, sensitivity to the differences among them, availability of data in space and time at the needed scale, consistence along series of measures, and objectivity.

According to the answers to these questions we can justify a lot of different models according to Costanza´s proposal, each one justified by a different framework, and a different theoretical view. The problem at the moment is to select the one we need to solve our questions, and to be prepared to consistently merge different contributions.

5. CONCLUSIONS

There are different approaches to the problem of defining vulnerable situations each one pointing to a different factor of the problem of global change, and derived from different conceptual framework and theoretical approaches. To guarantee a solvent approach three layers have to be clearly stated: Framework, theoretical approaches that introduce parameters, priorities and behavioral assumptions for variables; and models. In any case, hazard quantifications are essential in any analysis, and have to be measured in probabilistic terms that compute both probability of events and value of affected assets. There is a binomial approach to the measure of vulnerability focusing on the potential losses through vulnerability measures itself, and the other focusing on the carrying capacity or resilience. These two concepts play different roles, the first one reviews the pressure and the second marks the threshold pressure that the system can assume, be it by natural factor of resilience, by economic wealth or by social strength.

There are at least six theoretical approaches from economics to the nature of vulnerability as a concept that contribute from different assumptions, at different scales and with different priorities. Evolutionary economics focus on adaptation mechanisms and their effects in the long term, trying to draw a future map of the situation. Institutional economics focus on the arrangements made in our societies as a condition and requirement to understand the distribution of effects of change. Development and welfare economics try to contextualize the effects in different social conditions. Ecological economics focus on our dependence on nature, an issue that we have pompously ignored in our monetized world. Risk management and Nature and Catastrophes analysis have focused on identifying sources of risk (pressures), drivers towards societies and quantification of effects both in terms of risk and expected damage. All of them have to be included in technical paradigm in order to create a common knowledge area.

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CIVIL ENGINEERING EDUCATION AND THE BOLOGNA DECLARATION: A GREEK RETROSPECTIVE

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EXTENDED ABSTRACT

Although the Bologna Declaration appears to be adopted almost throughout Europe and its environs, Greece strongly objects to its implementation. Some reasons (which may equally apply to the rest of Europe) are as follows: Education was founded in ancient times and represents a global way of thinking encompassing virtue, morals, ethics, etc. It is believed that multidisciplinary civil engineers with a broad education in many matters are required and engineers with strong personalities are needed that are able to take responsibility. Specifically, Greece is the most earthquake prone country of Europe and every civil engineer must have a strong structural engineering background in seismic design. While other European countries may consider earthquake engineering as a subject for specialisation, this complex topic is the core subject encompassing a whole section of studies. Much of the infrastructure in Greece is still to be built. Every structure, no matter how small, by law requires earthquake effects to be taken into consideration. The Greek individualistic nature demands that every building is different and manifests itself in the existence of very few large civil engineering companies. Rather, the norm is a single person or two or three persons working together in a small office. Greece has a particularly unskilled workforce in the construction industry. These reasons promote the need for all civil engineers to be highly educated and to be capable of dealing with all the various demands of civil engineering.

Amongst other things, the Bologna Declaration involves the implementation of a two-tier process in civil engineering. Before the Bologna Declaration, an integrated system existed throughout most of mainland Europe. For financial reasons, competition for university places in Greece is extremely high and only the best of the very best are accepted. The two-tier system essentially creates a second-class civil engineer with a three-year qualification. This may not be suitable for the best of the very best students. Any university education must be geared towards the projected demands of the workplace. A European wide standardized education is an attractive idea with many advantages but any individual country must firstly look after the needs of its own population. When considering the special needs of Greece, it is believed that a two-tier system is not capable of educating civil engineers to the appropriate levels of knowledge and expertise required.

This paper details the reasons for Greece's strong objection to the Bologna Declaration before going on to investigate if other European countries experience of the experiment has been successful or not. At first glance, it is found that the principles of the Bologna Declaration have been implemented in nearly all education systems throughout Europe. However, further investigation reveals that there is considerable concern over the application of the Bologna Declaration to civil engineering education. That is, relevant civil engineering education societies and associations as well as academics and students in many European countries are calling for a return to the integrated continental system for civil engineering education, if this has not already been instigated.

KEYWORDS
Bologna Declaration, Civil engineering education, Continental system, Two-tier system

1. INTRODUCTION

Greece's opinion on the Bologna Declaration can be summed up by the words of Prof. Themistocles Xanthopoulos stated during the opening session of the first General Assembly of EUCEET II in 2003: "*Any splitting of the existing structure into two cycles, the undergraduate and the postgraduate, de facto downgrades the undergraduate cycle to that of the Schools of Higher Professional or Vocational Training, given that it is not possible to equip with substantial professional skills in the short period of this cycle without at the same time the shrinkage of the background scientific knowledge, that is without the actual betrayal of the scientific substance of the University degree.*

It is, besides, at least unreasonable to claim that it is possible to decrease the duration of studies without downgrading their university nature, at a time of pressing demands, both from students and academic staff, for an increase of the duration of university studies due to the explosive increase of knowledge in the applied sciences and technology, as well as the recognition by the relevant professional bodies of the inadequacies of the Bachelor's degree, as a university diploma, in the labour market.

We reject explicitly the main objective of the Bologna Declaration, namely the compulsory and universal division of all University courses into two cycles..." (Manoliu, 2004). However, it is the authors' opinion that Prof. Xanthopoulos is incorrect to use the word "compulsory", as the Bologna Declaration is an intergovernmental agreement and participation is, therefore, voluntary (Wikipedia, 2011).

This is not just the opinion of Greek academics. During the period 2006 to 2007, steps were taken by the then Greek Government with opposition consent to implement the Bologna Declaration. The consequences were that the "*universities were taken over by the students, massive protests, police violence and riots*" (Wikipedia, 2011). The student protests in Greece resulted in the Greek Government abandoning its plans for Bologna Declaration style educational reform.

Greece's opinion on the Bologna Declaration remains today as: "*at the CLAIU-EU Conference "Engineering Master Degrees in Europe" hosted by the Royal Military Academy, Brussels, the new Rector of the university, Prof. Konstantinos Moutzuris, reiterated the same position*" (Manoliu, 2010).

As can be gathered from above, Greece objects to the main purpose of the Bologna Declaration, which is the adoption of a system essentially based on two main cycles. To recap, the Bologna Declaration advocated a move from the "continental" system to the "Anglo-Saxon" system for European university education. At the time, the "continental" system was prevalent in mainland Europe while the "Anglo-Saxon" system existed in the United Kingdom and Ireland. It is only fair to note that Estonia, Latvia, Lithuania and Turkey had "Anglo-Saxon" type educational systems at the time of the Bologna Declaration. The system was newly introduced in the first three countries in the wake of independence from Russia.

The Bologna Declaration dates from 1999. When considering the "continental" system, reasons for the Bologna Declaration and the desired shift from a "continental" system to an "Anglo-Saxon" system included international unattractiveness of courses, high drop out rates, excessive costs, considerable student overrun times, late entry on the labour market, etc. (Manoliu, 2004).

2. CIVIL ENGINEERING EDUCATION IN GREECE

Education in Greece was founded in ancient times. Many educational concepts developed thousands of years ago in Greece serve as the pattern for modern day education at every level throughout western civilisation and elsewhere. At the highest level, the Academy and Lyceum of Plato and his student Aristotle provided the model for today's modern universities. Quite simply, education in Greece is based on thousands of years of tradition.

The authors have given in detail the case for Greece's objection to the Bologna Declaration and a brief summary of the main points follows (Dritsos and Moseley, 2010):

Much of the infrastructure in Greece is still to be built. In addition, most of the serious earthquakes that occur in Europe occur in Greece. In this context, it is to be noted that the Fifth EUCEET Volume does not list earthquake engineering as a core subject (Majewski, 2006). Therefore, most European civil engineering students do not even study the topic. This could be considered as surprising as, if cost and fatalities are considered together, it is clear that earthquakes represent the greatest natural hazard known to humanity. In Greece, earthquake engineering is the core civil engineering topic and must be studied over and above the other civil engineering subjects. Furthermore, the complex topic of earthquake engineering encompasses a whole section of studies and does not only cover new construction. As relevant knowledge has increased, anti-seismic guidelines, codes and specifications have been continually upgraded, particularly in recent years. Consequently, the vast majority of the structures and building stock in Greece (and therefore, in other earthquake prone regions of the world) is inadequately designed and is in danger of experiencing serious damage or even collapse during a strong earthquake. Anti-seismic strengthening and/or repair are little known topics in Europe outside of a few earthquake prone countries. This problem is not going to go away and is only going to get worse as time goes on. A Greek civil engineer must be well acquainted with the subject of seismic retrofitting. This is because the design and planning of an intervention is infinitely more difficult and complex than that of designing a new construction. The subject of anti-seismic strengthening and/or repair represents a unique challenge to the civil engineering profession and requires a high degree of judgement and prudence.

There are very few large civil engineering companies in Greece and the norm is for one to three persons working together in an office. Here, specialisation is an exception as Greek civil engineers must be familiar with all aspects of the industry. Therefore, there is a need for highly educated civil engineers capable of dealing with all the demands of civil engineering.

In Greece, no two buildings are the same and the public demands something architecturally different for every structure or building. Therefore, all new construction starts from scratch and it is not just simply a matter of copying and adapting the last design. Greek law states that earthquake effects must be taken into consideration when designing a new project, no matter how small.

Greece has a highly unskilled workforce and constructional tradesmen receive no formal training. Although such workers may in time gain considerable experience, the basic technical background is always missing. The role of the civil engineer as supervisor in this situation is critical due to the need to keep standards high, particularly with regard to the high seismicity of the country.

Clearly, due to its peculiarities, Greece requires multidisciplinary civil engineers that have been broadly educated in many matters. This promotes the need for an integrated civil engineering education system. In other words, the two-tier system is opposed in Greece as a compulsory and universal division of all engineering university studies.

In Greece, it is believed that there is a requirement for any educational system to produce civil engineering personnel with different individual qualifications. Many of the functions of the civil engineer can be provided for by a two-tier educational system. The first cycle, leading to a Bachelor's degree, should produce a lower level type of civil engineer. The second cycle, leading to a Master's degree on top of the Bachelor's degree, should produce the more specialist type of civil engineer. However, in addition to the two-tier educational system, there is a need to keep the integrated system, traditional to many European countries, to produce the high-level civil engineer or "Master Engineer" with solely a Master's degree.

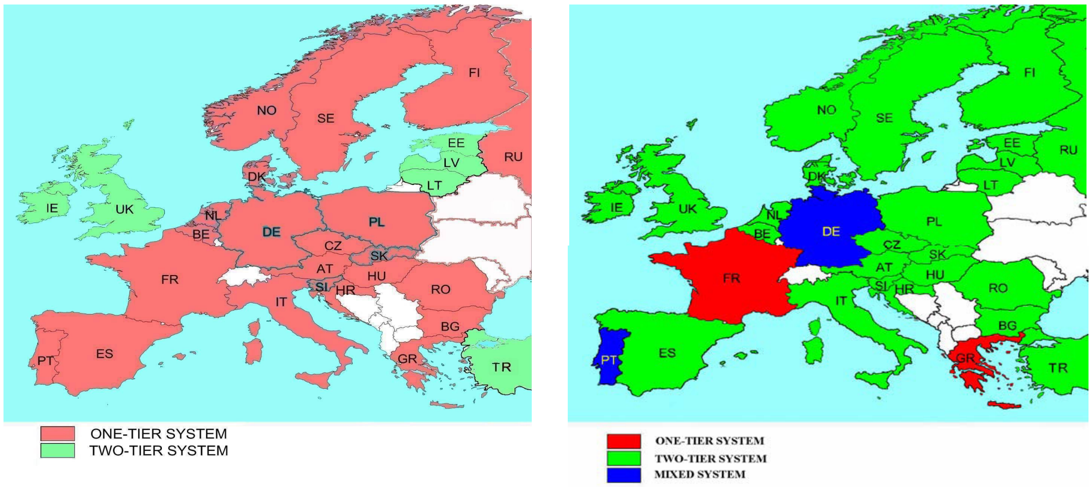
A Bachelor plus Master's degree obtained from a two-tier system cannot be considered as equivalent to a Master's degree obtained from an integrated system. Civil engineers with the latter type of qualification need to have not only a strong and very firm background in many sciences such as mathematics, physics, materials, etc. but also require a global education and a broad knowledge of other disciplines such as the environment, sustainability, etc..

3. EXPERIENCE FROM OTHER EUROPEAN COUNTRIES

The following two basic systems were present at the instigation of the Bologna Declaration: ""*the "continental" (or binary*)" (or one-tier or integrated) "*system characterized by the coexistence, in most European countries, of two parallel types of engineering education: of long duration, with nominal duration in almost all cases of 5 years and of short duration, with nominal duration of 3…4 years"* and *"the "anglo-saxon" (or two-tier) system, with undergraduate courses leading to Bachelor of Engineering degree after 3 years (in England and Ireland) and 4 years (in Scotland), followed by postgraduate studies leading to a Master of Sciences degree (1-2 years)*" (Manoliu, 2001).

Figure 1 presents the distribution of European civil engineering education systems at the time of the Bologna Declaration (Manoliu, 2004) and 10 years after the Bologna Declaration (Manoliu, 2010).

From a comparison of Figures 1(a) and 1(b), the case for Greece looks black, as Greece appears to almost stand alone in its opposition to the Bologna Declaration. Besides Greece, only France retains the "continental" system. This is due to the style of civil engineering education in France which involves two preparatory years prior to studies in the "Grandes Ecoles" and: "*adoption of a two-tier system is, practically, impossible*" (Manoliu, 2010).



(a) (b)

Figure 1: Distribution of European civil engineering education systems (a) at the time of the Bologna Declaration (Manoliu, 2004) and (b) 10 years after the Bologna Declaration (Manoliu, 2010).

Surprisingly, support from outside Europe for Greece's stance comes from America as: "*The American Society of Civil Engineers (ASCE) supports the concept of the Master's degree as the First Professional Degree for the practice of civil engineering at a professional level*" (Manoliu, 2001). Stating as the reason, the ASCE comment continues with: "*Four years of formal schooling were considered the standard for three professions (medicine, law, engineering) 100 years ago, and while medicine and law education lengthened with the growing demands of their respective professions engineering education did not. Perhaps this retention of a four-year undergraduate engineering education has contributed to the lowered esteem of engineering in the eyes of society, and the commensurate decline in compensation of engineers relative to medical doctors and lawyers*" (Manoliu, 2001). Presumably, America is one of the Bologna Declaration target countries from where Europe can expect prospective students. Here, it should also be noted that: *"engineering organizations, such as Washington Accord and the Engineers Mobility Forum, have established that the required academic component of the qualification of a professional engineer should be 4 or 5 years full time study in University"* (Manoliu, 2010).

Inside Europe, Italy was the first country to introduce reforms concerning a move from an integrated system to a two-tier system but some problems were encountered. That is, the Consiglio Nazionale degli Ingegneri, which represents the engineering profession in Italy, did not recognize the new three-year course as a professional degree (Manoliu, 2001). In fact, there were moves in Italy to partially return to an integrated system (Manoliu, 2004). In addition and more recently, the National Council of Engineers representing all engineering associations in Italy has asked the Minister for Universities to re-introduce the "old" five-year integrated system (Manoliu, 2010).

The ASCE and Consiglio Nazionale degli Ingegneri positions were echoed in Germany as follows: "*There are also serious doubts, at international scale, on the capacity of the Bachelor degree to provide a real qualification for the engineering practice. The American Society of Civil Engineers (ASCE) sees the Bachelor degree inadequate as a professional degree for today engineering practice. The same opinion is shared by the German construction industry and by the Conference of Faculties of Civil Engineering*" (Manoliu, 2001).

Further German disagreement can be found as Raimund Herz (a distinguished representative of a German Technical University) is quoted as saying: "*The Standing Committee of German speaking Civil Engineering Faculties at Universities has serious problems with accepting the political request of producing a professionally qualified Bachelor after only 3 years of study. On the other hand, 4 years of study for a B.Sc. are not feasible because in some German States a Dipl.-Ing. degree takes only 4 years plus Diploma thesis. In others, it takes 4 and a half plus thesis. So, with 4 years for a B.Sc. the period of specialization would be zero or be far too short. At Fachhochschulen, it takes 3 years of courses plus half a year of practical work plus half a year for the diploma thesis to get a Dipl.Ing (FH) degree, which is well accepted by the German construction industry. However, if this degree is to be equivalent to a B.Sc. at university level, according to the political concept, you would be entitled to enter a Master program at a University without sufficient theoretical background knowledge. These are the major objections against the two-tier model in Germany*" (Manoliu, 2004).

Further disagreement came from FEANI (FEANI is the European Federation of National Engineering Associations) as the FEANI Statement on Bologna and Prague Declarations says amongst other things: "*FEANI recommends that the existing European system of longer integrated engineering curricula leading straight to a Master's Degree should be maintained in parallel with a two-cycle Bachelor/Master system*" (FEANI, 2001).

FEANI is not alone as CESAER and SEFI (2003), in their second recommendation, state: "*In the context of the new first and second cycle degree structure, the engineering community of Europe agrees that in order to attain a high level of scientifically oriented competencies, engineering graduates need to be educated to a level corresponding to second cycle Masters level degrees. It is thus important that any new procedures and regulations do not compromise the number and quality of such graduates. In particular, there must continue to be provision for an integrated route through to the Masters level as this preserves the coherence and efficiency of the formation*". CESAER is the Conference of European Schools for Advanced Engineering Education and Research and SEFI is the European Society for Engineering Education. The statement by CESAER and SEFI is reiterated in their second joint communication on the Bologna process when they state: "*The 3+2 model has become a standard reference in engineering. This should not exclude other possible paths towards the second-level degree, such as an integrated 5 years curriculum or a 4+2 scheme or a 4+1 model*" (CESAER and SEFI, 2005). Further evidence for this opinion can be found. For example, it has been stated that: "*the integrated degree courses are compatible with the Bologna spirit and should not be replaced unless there are serious reasons in favour of such a replacement*" (Manoliu, 2004).

Finally, Prof. Torbjorn Hedberg, a former SEFI President, made the following relevant comments on the Bologna Declaration (Augusti et al., 2003): *"The Declaration talks about higher education and universities without making clear whether the intention is that it should be applied to all kinds of post-secondary education or if there are some sectors that could be excluded. The authors of the Declaration seem, however, primarily to have had the general non-professional university education in mind - the classical faculties of arts, letters and science - and not professional education, such as law, medicine, pharmaceutics, teacher training and engineering. As it turns out, nobody seems to think that medical studies should be reorganized according to the model proposed by the Declaration. The same arguments as for medicine also apply to engineering education ...".*

4. EXPERIENCE FROM TWO-TIER SYSTEMS EXISTING AT THE TIME OF THE BOLOGNA DECLARATION

In Estonia: "*By a law applied starting with the academic year 2002-2003, the two-tier system changed to 3+2 for all engineering fields, **except** civil engineering where only the integrated route of 5 years was reintroduced"* (Manoliu, 2004). The reason for this is given as follows: *"the former educational system was not capable of educating engineers with appropriate knowledge and expertise in the field of civil engineering"* (Koppel and Laur, 2004).

From Latvia: "*a two-tier system of 3 years for "Academical Bachelor", followed by 2 years for "Academical Master" coexists since 1995 with a "Bachelor professional study programme" of 4.5 years duration conferring the qualification of civil engineer. During this coexistence period, the "Bachelor professional" of 4.5 years proved to be much more attractive than the two-tier programme of 3+2, and the explanation cannot be separated from the recognition given by the labour market to the graduates of the integrated 4.5 years programme"* (Manoliu, 2004).

As in the case for Latvia, it is stated for Russia (although not an original two-tier country): "*a two-tier Ba-Ma route of 4+2 years, newly introduced in 1992, coexists with the integrated 5-year programme leading to "Diploma-Engineer" degree ..... The most popular proved to be the "Diploma-Engineer" route which, unlike the Bachelor route, was known and accepted by the employers*" (Manoliu, 2004).

The reason for the Latvian and Russian experiences is given as follows: "*the factor which seems to control the option of the enrolees is the preference given by the employers to the programmes followed by the graduates, which, not surprisingly, goes towards the integrated programmes"* (Manoliu, 2004).

In Ireland (one of the countries quoted as being the model for the two-tier system), surprisingly, the Institution of Engineers of Ireland (IEI) is quoted as saying: *"A five-year integrated Master degree is proposed, with a Bachelor degree (of "pivot" type) at the end of year three. Another proposal is for a three year engineering technology degree to run parallel, with possibility of transfer from engineering technology bachelor degree to year four of engineering master degree only on completion of bridging studies including mathematics. As one can recognize, in the vision of IEI the implementation of the Bologna Declaration means a move from the anglo-saxon system to the continental system, with programmes put in parallel"* (Manoliu, 2004).

Finally, in the United Kingdom (the other country quoted as being the model for the two-tier system), Smith (2004) provides a list of Joint Board of Moderators accredited courses with Engineering Council endorsement that are considered as an appropriate educational base for those proceeding to Chartered Engineer status. In the United Kingdom, Chartered Engineer status is the requisite for practicing civil or structural engineers. It can be noted that most courses appear to be integrated 4- or 5-year courses. Perhaps this is the reason for the following comment concerning the United Kingdom's attitude towards the Bologna Declaration: "*the UK, as ever, remains ambivalent*" (Kerr, 2010).

5. YOU CAN ALWAYS RELY ON THE STUDENTS TO PROTEST

This time, the students appear to arrive late on the scene. The Greek student protests concerning the Greek Government's attempts to implement the Bologna Declaration during the years 2006 to 2007 have already been documented in the introduction above. Elsewhere, according to an article by Euobserver.com, (2008), student demonstrations and occupations occurred in Spain in 2008. Students objected to the imposition of an "Anglo-Saxon" style tertiary education system on other countries. The article also states that: "*The Bologna Process has also provoked significant student opposition in Italy, Finland and Croatia*". It is to be noted that Croatia does not appear in Figure 1 above. Furthermore, Times Higher Education (2009) reports that in Germany and Austria in 2009, student protestors objected to tuition fees and "English-American"-style degrees introduced under the Bologna Process. The article also states that the protestors had the sympathy of some academics. Finally, Revolution (2010) claims that after a march and rally, a 10,000 strong demonstration including students from every European country occurred in artic conditions against an European Education Minister conference dinner in Vienna held to mark the opening of a Bologna Policy Forum. The European Education Ministers had previously met in Budapest in order to review progress on the Bologna Process. Writing in The Australian (2010), Steven Schwartz, the vice-chancellor of Macquarie University in Sydney, states that: "*Despite the arctic climate, protesters stayed out all night*".

6. ELSEWHERE IN THE WORLD

From a very brief Internet search, Table 1 lists the length of bachelor level civil engineering university education in some countries elsewhere in the World. It must be stressed that Table 1 is very much incomplete, unverified and may not be accurate as a proper in depth search was not possible due to time restraints.

Table 1: Bachelor level civil engineering university education in some countries elsewhere in the World.

Country (countries)	Study length
China	4-6 years
India	4 years
Japan	5 years
Latin America	4 or 6 years
Pakistan	4 years

As can be seen from Table 1, in every case found elsewhere in the World, it appears that bachelor level civil engineering courses are longer or much longer than those advocated by the Bologna Declaration. Although the actual numbers are disputed (Rogers, 2008), it appears that China and India alone graduate more civil engineers than the rest of the World put together. Therefore, it can be said that the norm for the length of bachelor level civil engineering university education in the World is 4 to 6 years of study. Consequently, there is a possibility that under the Bologna Declaration, European civil engineers will be educated to a lower level than those elsewhere in the World. It must be stressed that the above statements remain unverified until a full and proper investigation into this matter is performed.

7. DISCUSSION

According to the EUCEET Management Committee position statement concerning the implementation of the Bologna Declaration for civil engineering education: "*EUCEET is supporting and encouraging the application of the idea of two-tier education system in Civil Engineering as suggested in Bologna Declaration*" (Manoliu, 2010). In addition, the position statement recommends a 4 year duration for the first cycle (Manoliu, 2010). It is clear that if only Figure 1 from above is considered, then nearly all countries in Europe and its environs have moved from the integrated system to the two–tier system for civil engineering education. From Figure 1(b), it would be too easy to believe that the matter was clear cut and finished. Unfortunately, or fortunately in the case of Greece, Figure

1(b) does not tell the whole truth. From the arguments outlined in the preceding paragraphs, relevant authorities in the two-tier education system countries of America, Ireland and the United Kingdom recommend or appear to recommend through ambivalence the integrated system for civil engineering education. In addition, also from the arguments outlined in the preceding paragraphs, relevant civil engineering education societies and associations as well as academics and students in many other European countries are calling for a return to the continental system for civil engineering education, if this has not already been instigated. To be fair to the EUCEET Management Committee and its position statement concerning the implementation of the Bologna Declaration for civil engineering education, the door has been partially left open as it is also stated: "*The existing integrated 5-year curricula in civil engineering, leading straight to a Master's degree, is also compatible with the letter and spirit of the Bologna Declaration and with the vision of a European Higher Education Area"* (Manoliu, 2010). As stated above by the American Society of Civil Engineers, 100 years ago, the three professions of medicine, law and engineering were considered equivalent. If nobody is considering Bologna Declaration style reform for medicine and law, why should not the same be true for engineering? Again, from above, the former SEFI President Prof. Torbjorn Hedberg has reiterated this same concept. Today, the World is facing the immense problems of over population, environmental destruction, global warming, sustainability, etc. and many of these problems have been unwittingly caused by civil engineers in their desire to change the shape of the World for the better. Only the civil engineers will come up with solutions to these problems if they can be solved and these civil engineers must be educated accordingly. In this light, should not the EUCEET actually be encouraging the integrated system rather than the two-tier system for civil engineering education? Again, from the words of the American Society of Civil Engineers quoted above, how civil engineers are educated "*has contributed to the lowered esteem of engineering in the eyes of society, and the commensurate decline in compensation of engineers relative to medical doctors and lawyers*" (Manoliu, 2001). Who better positioned than the EUCEET to champion the cause of reversing the decline of civil engineers and assist in returning the profession to the equivalent public esteem position to that presently held by doctors and lawyers?

8. CONCLUSIONS

Civil engineers need to have a global education and a broad knowledge of other disciplines such as the environment, sustainability, etc. This is required in order to address the negative impact that engineers may have in their social environment that in the past have unwittingly lead to many of the current World problems. This is also required in order to provide solutions to other problems that face the world today. Society requires engineers with strong personalities that are able to take responsibility and are capable of giving solutions to any civil engineering problem during both the design and construction stages are required. Any university education must be geared towards the projected needs of the workplace. However, a two-tier system alone is not capable of educating civil engineers to the appropriate levels of knowledge and expertise required. An integrated education system is necessary to run in parallel to satisfy the requirements of European society.

Greece objects to the main purpose of the Bologna Declaration, which is the adoption of a system essentially based on two main cycles. Elsewhere in Europe, there appears to be a small but growing voice calling for a return to the continental system for civil engineering education. This is contradictory to the present EUCEET policy. The EUCEET is ideally placed to fight the cause for an integrated civil education system for Europe and help return the profession to the position of public esteem it held 100 years ago.

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CIVIL ENGINEERING EDUCATION, 12 YEARS AFTER BOLOGNA – A CASE STUDY: ROMANIA

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EXTENDED ABSTRACT

The paper updates the one written in 2004 by the author and published in the 4th EUCEET Volume dedicated to national reports on civil engineering education in Europe.

In the academic year 2011 - 2012 there are 112 universities in Romania, of which 56 public universities, 35 private accredited universities and 21 private authorized universities. From the 56 public universities, 12 are offering programmes in civil engineering and related fields. As related fields are considered: Installation engineering, Engineering Geodesy, Environmental Engineering, Mechanical Engineering, Engineering and Management.

Each year, the Ministry of Education submits for approval by the government a "*Nomenclator*" of fields and specializations. For the academic year 2011-2012, the "*Nomenclator*" lists 27 engineering fields. For the 27 fields, there are a total of 148 specializations, from which 13 belong to civil engineering field and 8 to related fields.

Before the implementation of the Bologna Process, the system of engineering education in Romania was a pure "**continental**" or "**binary**" system, with two types of programmes: a short (three-year) programme leading to the degree of "*inginer colegiu*"; and a long (five-year) programme leading to the degree of "*inginer diplomat*". The single-tier programmes of long duration (five-year) were predominant.

The implementation of the Bologna Process in Romania was set in motion by the "*Law on the organisation of university studies*" (Law 288/2004) and produced the following major changes in engineering education: the short 3-year programmes were dismantled and the long 5-year programmes were replaced by a two-tier type of education, with a first cycle of 4 years (240 ECTS) and a second cycle of 1,5 – 2 years (90 – 120 ECTS). Graduates of the first cycle degree programmes ("*licenţa*") receive a diploma of engineer, while the graduates of the second cycle degree programmes receive a diploma of Master.

The paper presents the structure of the study plan for a new 4-year programme, in which ¾ of the contact hours relate to core material and ¼ to specialisation.

A section of the paper is devoted to the Master programmes which were first offered in 2009 – 2010.

The last part of the paper is devoted to the implementation in Romania of the European system of accreditation in engineering EUR-ACE.

KEYWORDS

Bologna Process, Civil engineering education, European Higher Education Area, Integrated programmes, Two-tier system, Accreditation

1. INTRODUCTION

The syntagme "*European Higher Education Area*" appeared in the title of the Bologna Declaration, June 19, 1999. Two years later, at the meeting in Prague, on May 19th 2001, Ministers in charge of higher education affirmed their commitment to the objective of establishing the "*European Higher Education Area*" by 2010.

On March 11 and 12, 2010, Ministers responsible for higher education in 47 countries participating in the Bologna Process, met in Budapest and Vienne and launched the *European Higher Education Area* (EHEA).

Romania, which was admitted in the European Union on 1st January 2007, is part of the EHEA. The Law 288/2004 on the organization of university studies paved the way for the implementation of the Bologna process in Romania. The "Law on national education", of January 2011, creates the framework for the participation of Romanian system of higher education to the accomplishment of the objectives for the next decade of EHEA, as defined on 28 – 29 April 2009 in Leuven and Louvain-la-Neuve by the Ministers responsible for higher education.

12 years after Bologna Declaration, at the beginning of the new decade and a few months before the next Ministerial meeting to be hosted by Romania and to take place in Bucharest, on 26 – 27 April 2012, the moment seems appropriate to have a look at the civil engineering education in Romania in the context of the Bologna process.

2. CIVIL ENGINEERING EDUCATION IN ROMANIA – AN OVERVIEW

2.1 Brief historical outline

As in most countries, in Romania, too, engineering education started with civil engineering. Thus, in 1818 Gheorghe Lazăr founded in Bucharest a School for Land Surveyors which was followed by the creation in 1867 of a School of Bridges and Roads, transformed in 1888 into "The National School of Bridges and Roads". In 1921 it became the Polytechnic School of Bucharest. As a result of the Education Reform in 1948, the Faculty of Civil Engineering separated from the Polytechnic School and became an independent higher education establishment called the Civil Engineering Institute of Bucharest, while other faculties of the former Polytechnic School (in the field of mechanical engineering, electrical engineering, chemical engineering) formed the Polytechnic Institute of Bucharest. In 1994, the Civil Engineering institute adopted its present name: The Technical University of Civil Engineering of Bucharest, while the Polytechnic Institute was renamed University "Politehnica" of Bucharest.

Besides the two Technical Universities in Bucharest, other major institutions offering engineering education in Romania are the University "Politehnica" of Timisoara, founded in 1921, the Technical University "Gheorghe Asachi" Iasi, founded in 1946, the Technical University of Cluj-Napoca, founded in 1953.

2.2 Providers of programmes in civil engineering and related fields in the academic year 2011-2012

In the academic year 2011 - 2012 there are 112 universities in Romania, of which 56 public universities, 35 private accredited universities and 21 private authorized universities.

Of the 56 public universities, 12 offer programmes in civil engineering and related fields, which include: Installation engineering, Engineering Geodesy, Environmental Engineering, Mechanical Engineering, Engineering and Management.

Figure 1 shows the distribution of universities offering programmes in civil engineering and related fields in the academic year 2011-2012.

Each year, the Ministry of Education submits for approval by the government a "*Nomenclator*" of fields and specializations. For the academic year 2011-2012, the "*Nomenclator*" lists 27 engineering fields. For the 27 fields, there are a total of 148 specializations.

From the 148 specializations, 13 belong to civil engineering field and 8 to related fields previously mentioned. In table 1 are given names and codes of the first cycle degree courses for the specializations belonging to civil engineering and related fields.

The distribution of the first cycle degree courses (specializations) among the 12 universities is given in table 2. As one would expect, the largest number, 13 first cycle degree courses, are offered by the Technical University of Civil Engineering Bucharest which is the only Romanian university entirely devoted to higher education in civil engineering and related fields. T.U.C.E.B. is followed by the Technical University "Gheorghe Asachi" Iasi with 10 specializations, University "Politehnica" Timisoara with 9 specializations and Technical University Cluj-Napoca with 8 specializations.

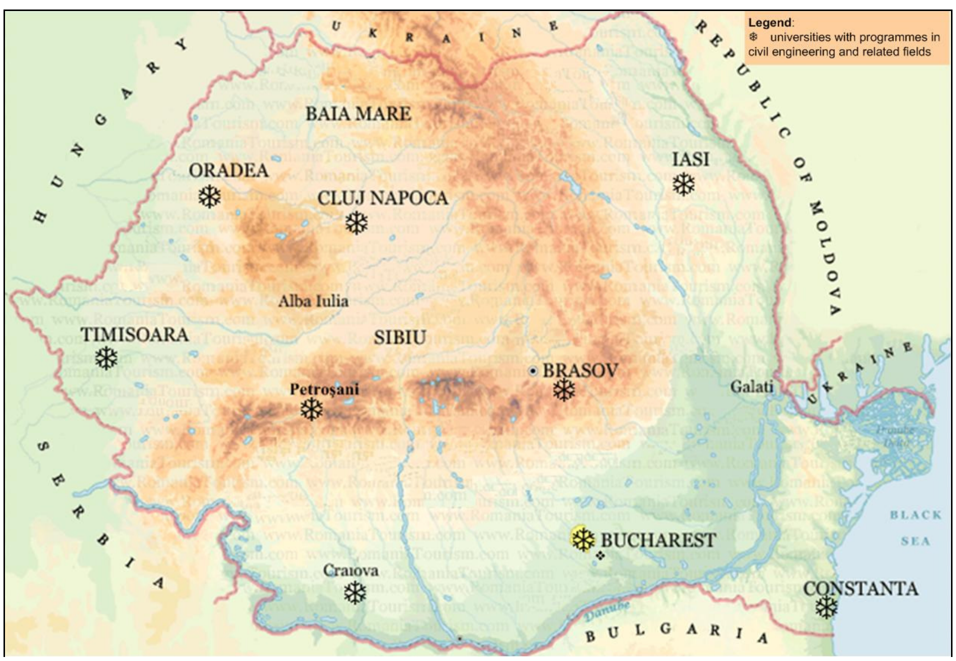

Figure 1: Map of Romania with the location of universities offering programmes in civil engineering and related fields in the academic year 2011-2012.

Table 1: Names and codes of the first cycle degree courses for various fields (profiles) 2011-2012.

Field	Code	Name of the degree course (specialization)	Code
Civil Engineering	CE	Civil, Industrial and Agricultural Buildings	CIAB
Civil Engineering	CE	Railways, Roads and Bridges	RRB
Civil Engineering	CE	Constructions and fortifications	CF
Civil Engineering	CE	Hydraulic Structures	HS
Civil Engineering	CE	Mining Construction	Min
Civil Engineering	CE	Sanitary Engineering and Environmental Protection	SANEP
Civil Engineering	CE	Land Reclamation and Rural Development	LRRD
Civil Engineering	CE	Civil Engineering	CE
Civil Engineering	CE	Urban Engineering and Regional Development	UERD
Civil Engineering	CE	Infrastructure of Metropolitan Transport	IMT
Civil Engineering	CE	Civil Engineering (in English)	CEEn
Civil Engineering	CE	Civil Engineering (in French)	CEFr
Civil Engineering	CE	Civil Engineering (in German)	CEGe
Installation Engineering	IE	Building Services	BS
Installation Engineering	IE	Installations and Equipment for Atmospheric Protection	IEAP
Installation Engineering	IE	Building Services for fire protection	BSFP
Installation Engineering	IE	Building Services (in French)	BSFr
Geodesy Engineering	GE	Geodesy and Land Cadastre	GLC
Environmental Engineering	EE	Environmental Engineering	EE
Mechanical Engineering	ME	Engineering and Management of Technological Resources in Construction	EMTRC
Engineering and Management	EM	Engineering Economics in Constructions	EEC

2.3 Study programmes before Bologna

In the academic year 2004-2005, the last year before the implementation of the two-tier system following Bologna, there were two types of undergraduate programmes in all fields of engineering education in Romania.

The long (five years) programme, leading to the degree of "*Inginer Diplomat*" was considered to be the equivalent of an MSc degree in the Anglo-Saxon or two-tier system. This was an integrated programme, with no intermediate step.
The short (three years) programme, leading to the degree of "*Inginer Colegiu*", was considered to be the equivalent of a BSc degree in the Anglo-Saxon or two-tier system.

The five-year programmes were intended to produce graduates with extensive knowledge and understanding of mathematics, science and engineering, able to solve complex civil engineering problems and to use the techniques, skills and modern engineering tools necessary for civil engineering practice.

The short three-year programmes were intended to produce graduates possessing relevant know-how in civil engineering and construction engineering technology, able to demonstrate independent judgment within the field of activity and to apply up-to-date knowledge in the construction and operation of civil engineering works. The curricula of the short engineering programmes were oriented toward practice.

As one can understand, before the implementation of the Bologna Process, the system of engineering education in Romania was a pure "**continental**" or "**binary**" system, with two types of programmes: a short (three-year) programme leading to the degree of "*inginer colegiu*"; and a long (five-year) programme leading to the degree of "*inginer diplomat*" The single-tier programmes of long duration (five-year) were predominant.

2.4 Study programmes after Bologna

The implementation of the Bologna Process in Romania was set in motion by the "*Law on the organisation of university studies*" (Law 288/2004).

Main provisions of Law 288/2004

• University studies in Romanian are organised in three cycles.
• The first cycle, with a duration of 3-4 years (180-240 ECTS Credits), is called "*Licenţa*" (synonymous with "*Licence*" in French). *The Law stipulates that for engineering education the first cycle is of* ***4 years duration*****. The qualification level acquired by graduates from the first cycle should be sufficient to assure employability.**
• The second cycle, with a duration of 1-2 years (60-120 ECTS Credits), is called *"Master*". The *cumulative duration* of the first, Licence, cycle, plus the second, Master, cycle, should correspond to **at least** 300 ECTS or 5 years.
• The third cycle corresponds to *doctorate studies* having, normally, a duration of 3 years which, in justified cases (for instance experimental studies), can be extended by 1 2 additional years, pending the approval of the Senate of the university.
• The existing short 3-year programmes are to be discontinued, unless they can be converted into programmes corresponding to the licence.
The provisions of the law came into force in academic year 2005 – 2006 and led to the two-tier system illustrated in figure 2.

Table 2: Degree courses in civil engineering and engineering related fields offered by the Romanian universities 2011-2012.

Field	Degree course	UNIVERSITY																	
		TUCEB	**TUI**	**UPT**	**TUCN**	**UOC**	**UTB**	**UO**	**UP**	**UC**	**UDJG**	**UAI**	**NUBM**	**UAVMB**	**UAVMI**	**UAVMT**	**UAVMCN**	**MTA**	**PA**
First cycle degree courses in civil engineering field																			
CE	CIAB	x	x	x	x	x		x		x				X					
CE	RRB	x	x	x	x		x												
CE	CF																	x	
CE	HS	x	x	x	x	x													
CE	Min								x										
CE	SANEP	x	x					x											
CE	LRRD		x	x		x													
CE	CE			x			x												
CE	UERD	x	x		x	x													
CE	IMT	x																	
CE	CEEn	x	x	x	x														
CE	CEFr	x	x																
CE	CEGe			x															
First cycle degree courses in other related engineering fields																			
IE	BS	x	x	x			x												
IE	IEAP	x																	
IE	BSFP																		x
IE	BSFr	x																	
GE	GLC	x	x	x	x		x	x		X[1*]	x	x	x	X		X[1*]	X[1*]		
EE	EE					x						x			x				
ME	EMTRC	x																	
EM	EEC				x	x													

Legend: TUCEB - Technical University of Civil Engineering Bucharest; TUI - Technical University "Gheorghe Asachi" Iaşi; UPT - University Politehnica Timişoara; TUCN - Technical University Cluj-Napoca; UOC - University "Ovidius" Constantza; UTB - University "Transilvania" Braşov; UO - University Oradea; UP - University Petroşani; UAVMB - University for Agricultural and Veterinary Medicine Bucharest; UC - University Craiova; MTA - Military Technical Academy Bucharest; PA - Police Academy "Alexandru Ioan Cuza" Bucharest; UAI - University „1 DECEMBRIE 1918" ALBA IULIA; NUBM – North University BAIA MARE; UAVMCN - University for Agricultural and Veterinary Medicine Cluj Napoca; UDJG – University „DUNĂREA DE JOS" GALAŢI; UAVMT - University for Agricultural and Veterinary Medicine TIMIŞOARA; UAVMI - University for Agricultural and Veterinary „ION IONESCU DE LA BRAD" IASI

[1]* - provisional authorization

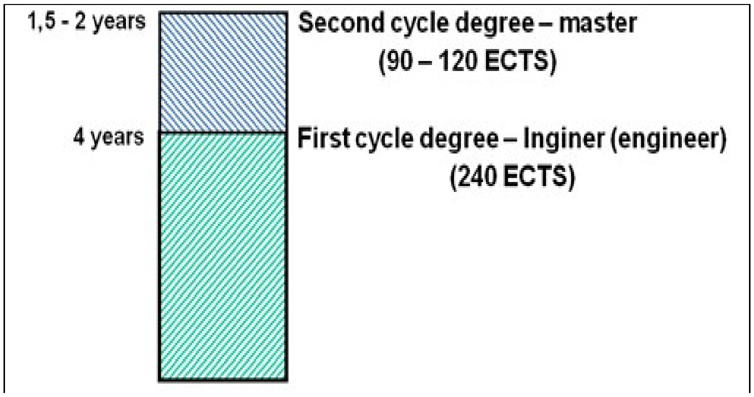

Figure 2: Engineering education in Romania after the implementation of Bologna process, starting with the academic year 2005 - 2006

Some considerations concerning the need for a reform in engineering education are necessary.

Although the system of engineering education existing in Romania in 2004 - 2005 was compatible with the spirit of Bologna, there was nevertheless room for improvement, in the light of the positive and negative features of the programmes on offer. In reality, the 3-year programmes delivered by the university colleges were very unpopular; many colleges failed to fill the places offered at the entrance examinations, and even when they did, the level of the students recruited was low. At the same time, industry showed little interest in the graduates from the colleges. On the other hand, the year of "*Advanced studies*", a kind of *post-Master programme* (the 5-year degree being assimilated to a Master), which was created mainly as a gateway or as access to Doctoral studies, proved not to do so in most cases, since very few of the graduates of the programme eventually enrolled for the doctorate.

With the 3-year programmes now out of the picture, it was legitimate to ask: is it reasonable and necessary to educate **all** students through 5-year integrated programmes, which have a strongly design/research character, when it is well known that only a minority will actually find employment after graduation in design/research/consultancy activities, and while the others will work as contractors or in areas such as public administration, banking, insurance, IT, and so on? The need of a *"generalist"* type of engineer, trained in a shorter period of time, was quite obvious.

3. SHIFT FROM THE CONTINETAL SYSTEM TO THE TWO-TIER SYSTEM

The shift from the continental system to the two-tier system in civil engineering education in Romania was done according to the provisions of the Law 288/2004 summarized at p.2.4. Although this shift was seen by many as a result of a top-bottom approach undertaken by Romanian authorities in order to implement the Bologna Declaration, it is fair to admit that, in fact, it responded to a real need for a reform.

3.1 First cycle degree

According to the Law 188/2004, the study duration for the first cycle degree programmes ("Licenta") in engineering is of 4 years (240 ECTS credits). As a consequence, the former programmes of short duration (3 years) offered by the university colleges ceased to be offered "beginning with 2005/2006".

As one can see from table 1, in the “nomenclator” of specializations approved for the academic year 2011 – 2012 there are 13 specializations pertaining to the civil engineering fields and 8 specializations related in some part to the civil engineering field but belonging to other fields. It is important to observe that all these specializations existed in the “nomenclator” before 2005 - 2006 when the two-tier system was introduced. However, changes occurred in the number of institutions offering various programmes. The most significant increase was noted for the specialization “Geodesy and Land Cadastre”: from 4 programmes offered in 2004 – 2005 to 13 programmes offered in 2011 – 2012. As shown in the table 2, 3 such programmes have for the time being only provisional authorization, while all others are accredited.

Curricular issues were of paramount importance when moving from integrated 5-year programmes to two-tier programmes. In what follows, steps undertaken in this respect at the Technical University of Civil Engineering Bucharest will be described. More details can be found elsewhere. [3]

In quantitative terms, the change from the integrated 5-year programme to the new 4-year programme, introduced in the academic year 2005/2006 is summarized in table 3.

Table 3

Programmes / **Item**	**5-year**	**4-year**
Duration	10 semesters	8 semesters
Contact hours	251 hours	236 hours
Diploma project	In the 10th semester	In summer, following the 8th semester
Final examination	End of June	End of September

The difference of only 15 contact hours between the two programmes was due to the fact that the eight semesters of the new programme were fully used for contact hours, while the elaboration of the diploma projects and the final examination were placed after the completion of the eight semesters. After only one year, a new change was operated, by reducing the number of contact hours from 236 to 218. A third and final change (so far!) was made in the academic year 2010/2011, following the decision to reserve 4 of the 14 weeks of the 8th semester for the diploma project and to have the final examination at the end of July. However, the number of contact hours was kept as before, 218.

In all variants, the structure of the study plan, expressed in % of the contact hours for various groups of subjects from the total number of contact hours remained practically unchanged and is shown in the table 4.

Table 4

No	**Group of subjects** *The "backbone"*	**Contact hours/ % from total**	
		2005 - 2006	**2006 - 2007**
1.	Basic subjects	42 h (17.8 %)	38 h (17.4 %)
2.	General technical education	53 h (22.5 %)	55 h (25.2 %)
3.	General engineering education	52 h (22 %)	46 h (21.1 %)
4.	General economic and technological education	16h (7.2 %)	10h (4.6 %)
5.	Foreign languages, social sciences, humanities	12 h (5.1 %)	14 h (6.4 %)
	Total	**175 h / 74%**	**163 h / 74.7%**
6.	The specialization	61 h (26 %)	55h (25.3 %)
	Grand total	**236 h (100 %)**	**218 h (100%)**

A conclusion to be drawn form examining the relative weight of different groups of subjects shown in the table 4 is that the degree awarded after the completion of the 4-year programme has all chances to be relevant for the labour market on appropriate level of qualifications. A programme in which ¾ of the contact hours is reserved to “core subjects”, i.e. subjects common to the entire filed, regardless of specialization, is aimed at educating a “generalist” type of civil engineer.

A relevant fact to be stressed before concluding this paragraph devoted to the first cycle degree programmes is that the qualification inginer (engineer) is the designation written on the diploma received by the graduates .

3.2 Second cycle degree programmes

Second cycle programmes, leading to the diploma of Master, could correspond, according to the Law 188/2004, to 90 ECTS (1.5 year) or 120 ECTS (2 years). They have been offered for the first time in 2009/2010, open for the first cohort of graduates of the “licenta” programmes.

Table 5 shows the number of Master programme offered by various universities in civil engineering and related fields for the academic year 2011 – 2012. All of these programmes are “consecutive master”, for which the access requires successful completion of First Cycle Degree studies [2].

As expected, the largest offer comes from the “four big” from Bucharest, Iasi, Timisoara and Cluj-Napoca.

Table 5

Field	Universities				
	TUCEB	**TUI**	**UPT**	**TUCN**	**UOC**
CE	9	9	6	7	2
IE	3	1	1	1	
GE	3		1		
EM	1			1	2
Total	16	10	8	9	4

There is a rather large diversity in the offer of these universities. Most of the Masters are of “vertical” type, representing a continuation at higher level of the “licenta” programme for a given specialization. Example of programmes of this kind are Urban Engineering and Regional Development (TUCEB), Transport Infrastructure (TUCEB, UTI, UPT), Hydraulic structures (TUCEB).

Broader specializations at “licenta” level, such as Civil, Industrial and Agricultural Buildings lead to several masters of “vertical” type: 4 at TUCEB and UTI, 3 at UPT and UTCN.

Similarly, the “licenta” specialization Building Services at TUCEB is followed by 3 Master programmes.

There are also Masters of “transversal” type, offered to graduates of all civil engineering specializations. The best example is Geotechnical engineering (at TUCEB, UTI, UPT and UTCN).

The appearance of this programme at all major universities is of particular relevance: for the first time Romanian universities confer degrees in “Geotechnical Engineering”, joining thus most of the universities world wide with civil engineering programmes.

Another type of master programmes could be included in the category of "professional masters". An example in this respect is a master on "Real estate evaluation and management" offered at UTI.

At TUCEB, UTCN and UOC master programmes are of 3 semesters, while UTI and UPT have chosen a 4-semester duration, which seems to be a better solution.

It is the opinion of the author that, at present, the number of the Master programmes is too large, corresponding merely to the desires of the teaching staff and/or to excessive preoccupation with compensating through these programmes for the contact-hours lost from the integrated 5-year programme, rather than being based on a study of the needs of the labour market. It is highly probable that in the near future a reduction in the number of programmes, together with a strengthening of the remaining ones (also by an extension of all programmes to 4 semesters, when the case) will occur.

4. BOLOGNA PROCESS MEANS MORE THAN THE ACTION LINE 2

Let's remind ourselves of the action line 2 of the Bologna Declaration:
"Adoption of a system essentially based on two main cycles, undergraduate and graduate. Access to the second cycle shall require successful completion of first cycle studies, lasting a minimum of three years. The degree awarded after the first cycle shall also be relevant to the European labour market as an appropriate level of qualification. The second cycle should lead to the master and/or doctorate degree as in many European countries."

This was, no doubt, the most famous (and controversial) action line of the Bologna process and the one which had the strongest impact, not always very favourable, on engineering education in Europe.

There are, however, other actions defined either in the document signed in Bologna on June 19th, 1999 by the ministers of education form 29 European countries or in the documents of the ministerial meetings which followed, with a 2-year pace, in Prague, Berlin, Bergen, London, Leuven, Louvain-la-Neuve.

The following section will tackle some of these actions and their impact so far on civil engineering education in Romania.

4.1 Student mobility and Bologna

"*Mobility of students and academic and administrative staff is the basis for establishing a European Higher Education Area*" showed the communiqué of the Conference of Ministers responsible for Higher Education in Berlin on 19 September 2003.

The mobility of students will be tackled in this paragraph, under a peculiar aspect: the impact of Bologna-based study programmes on the agreements/ conventions under which student mobility operates. Two examples from the recent practice of TUCEB will illustrate the case.

First example
A double-diploma convention was concluded between Ecole Nationale des Ponts et Chaussées Paris and the Technical University of Civil Engineering Bucharest in 2001. The 5-year integrated programme offered by that time by TUCEB was compatible with the 3-year programme of ENPC following two preparatory years (in fact also a 5-year

programme). The students of TUCEB were admitted to the 2nd year of study at ENPC (equivalent of the 4th year of study in Bucharest). After successfully completing the last two years of study at ENPC, including the final project, they presented and defended their project in Bucharest, in front of a commission in which both institutions were represented. Conditions to be awarded a diploma by each of the two schools were thus met.

The provisions of the convention concluded in 2011 had to be revised when TUCEB adopted the two-tier system, with the first-cycle degree ("licența") awarded after 4 years of study.

According to the new agreement, TUCEB, students are admitted also in the 2nd year of study of ENPC, but only after completing the "*licența*" programme (4 years) and being admitted at the Master programme at TUCEB. They then complete two years of study at ENPC, after which they return to TUCEB for the last semester of the 1.5 year master programme. The final project, prepared at ENPC, serves as a basis for the dissertation at the end of the master programme in Bucharest. As compared with their colleagues, who have to study 5.5 years to obtain two diplomas ("licența" – 4 years, master - 1.5 years) students beneficiaries of the double-diploma convention with ENPC study 6.5 years (4+2+0.5) but receive in addition the diploma of ENPC. The two years which passed since the new agreement was implemented showed no decrease in the interest of students for the chances offered by the double-diploma agreement TUCEB-ENPC.

Second example
Since the very beginning of the participation of TUCEB in the Erasmus programme, by the end of 90's, a bilateral agreement was concluded between TUCEB and the Technical University of Hannover, to facilitate mobility of the students of the faculties of Geodesy of both universities. Like in the previous example, the similarity in the programmes, both of them of integrated type (5-year programmes) made things rather easy. TUCEB students were admitted to TUH in the last (10th) semester, to work together with their German colleagues at the final project. The character of the activity and the fact that TUCEB students did not have to attend courses and to take exams, but only to work for the final project, made it possible to have English instead of German as a language prerequisite. Bologna brought changes in both universities when they adopted the two-tier system: 3+2 at Hannover, 4+1.5 at Bucharest. A final semester reserved for the diploma project at T.U. Hannover and TUCEB no longer coincided. To enable the fulfilment of the bilateral agreement, TUCEB students had to leave for the 5-months study period at TUH at the beginning of January, before end of the final examination session, then prepare the Master dissertation in Hannover and present and defend it after returning in Bucharest. The study duration was de facto extended by one semester, which was considered a worthwhile change.

4.2 The EUR-ACE system is implemented in Romania

"*Ministers recognized the vital role that quality assurance systems play in ensuring high quality standards and in facilitating the comparability of qualifications throughout Europe. … They encouraged universities and other higher education institutions to disseminate examples of best practice and to design scenarios for mutual acceptance of evaluation and accreditation/ certification mechanisms …*" said the Communiqué of the meeting of European Ministers in charge of the Higher Education in Prague, on May 19th , 2001.

This was for the first and only time when the word *accreditation* appeared in the Declarations/Communiqués issued at the meetings which followed Bologna. However, it was put under the heading "*Promotion of European cooperation in quality assurance*" which means an implicit recognition that accreditation is an intrinsic part of the quality assurance process. This reality is proved also by the fact that, in some countries, quality assurance and accreditation are made by the same agency. This is the case in Romania with ARACIS (Romanian Agency for Quality Assurance in Higher Education) which is an autonomous and independent public institution, founded on the basis of Law 87/2006.

ARACIS is a general agency, i.e. covering all fields of higher education, and has two strands:

- quality assurance
- accreditation

ARACIS is currently implementing the EUR-ACE system.

Steps which led to the development of EUR-ACE system are presented elsewhere, as well as the EUR-ACE project (2004 – 2006) supported by the European Commission. [4]

The EUR-ACE project, in which the author participated as representative of UAICR (Union of Associations of Civil Engineers of Romania) produced the EUR-ACE Framework Standards finalized in 2006 and revised in 2008.

The EUR-ACE Framework Standards define and require learning outcomes, that is to say, the specific knowledge, skills and/or competences to be acquired during the successful completion of a programme of study. The learning outcomes to be achieved by first and second cycle graduates in the three specific engineering components ("*Engineering Analysis", "Engineering Design"* and *"Research*") are qualified by the phrase "*consistent with their level of knowledge and understanding"*. For first cycle graduates this level is defined as a "*coherent knowledge of their branch of engineering, including some knowledge at the cutting edge*"; for second cycle graduates the level requires "*a critical awareness of the knowledge located at the cutting edge of their branch of engineering*".

Another very important outcome of the EUR-ACE project was the foundation of an international not-for-profit association, the "European Network for the Accreditation of Engineering Education" (ENAEE).

The association was founded in Brussels in February 2006 by 14 Associations and Agencies active in engineering education throughout Europe, including UAICR from Romania. In November 2009 ARACIS became member of ENAEE.

ENAEE has registered the EUR-ACE® Trademark and authorises National Agencies to add the EUR-ACE label to their accreditation. This authorisation may be defined as a "*meta-accreditation*".

Two EU-funded projects (EUR-ACE IMPLEMENTATION and PRO-EAST) ran between 2006 and 2008 and made a significant contribution to the launch of the EUR-ACE system, the first in the EU, the second in Russia.

In November 2006, ENAEE came to the view that six Accreditation Agencies (CTI in France, ASIIN in Germany, Engineers Ireland, the *Ordem dos Engenheiros* in Portugal, RAEE in Russia, and the Engineering Council in UK), all active partners in the EUR-ACE project, already fulfilled the requirements set by the Framework Standards and, as a consequence, were authorised to award the EUR-ACE label for a period of two years.

Between November 2008 and October 2010 ENAEE coordinated another EU-funded project, called EUR-ACE SPREAD, which principally targeted Turkey, Romania, Lithuania, Italy and Switzerland. The first concrete achievement of EUR-ACE SPREAD was the addition of the Turkish "*Association for Evaluation and Accreditation of Engineering Programs*" (MÜDEK) to the initial six EUR-ACE Agencies.

ARACIS was a partner in the Project worpackage 6 of EUR-ACE Spread – the *Spread of the EUR-ACE system in Romania*.

In October 2010, ARACIS applied to ENAEE for authorisation to award the EUR-ACE Label, thus fulfilling the objective set by the EUR-ACE SPREAD project for Romania.

5. CONCLUSIONS

The Bologna process led to profound changes in the Romanian system of higher education, including civil engineering education. The former 5-year integrated programmes were split in two-tier programmes, with a First cycle degree of 4 year (240 ECTS) and a Second cycle degree of 1.5 – 2 years (90 – 120 ECTS). The former 3-year programmes more practically oriented were dismantled.

The concept of "learning outcomes" is gradually gaining territory, as reflected in activities related to the development of the National Framework for Qualifications in Higher Education or to the accreditation of engineering programmes.

Only 2 years have passed since the first cohort graduated from the new 4-year (Licenta) programmes and 6 months since the fist cohort graduated at TUCEB from the new 1.5 year master programmes. This is too short a period to judge the results of the reform but sufficient to appreciate that the potentiality of the Bologna process has not yet been fully exploited. New actions and more efforts are needed, with the participation of all stakeholders. EUCEET Association, well represented in Romania, has an important role to play in this process.

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CIVIL ENGINEERING STUDIES AT THE SILESIAN UNIVERSITY OF TECHNOLOGY ACCORDING TO THE BOLOGNA DECLARATION

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EXTENDED ABSTRACT

In 1945, after World War II, the Polish government established new technical universities. The Silesian University of Technology was one of the first among those and it consisted of four faculties: Mechanical Engineering, Electrical Engineering, Metallurgical Engineering and Civil Engineering. The name of the Civil Engineering Faculty has been changed a few times; since 1977 it has been called “Faculty of Civil Engineering”. The academic staff of the new university was recruited from Lvov University of Technology (Politechnika Lwowska), which was moved from a former eastern part of Poland to the western part, in Wroclaw and Gliwice. The present structure of the university consists of 13 faculties with more than 30 000 students. The Faculty of Civil Engineering consists of eight departments and one laboratory and employs about 190 academic staff (including 9 full professors) and currently teaches 2500 students.

The methods of education have been continually improved during the history of Faculty. According to the Bologna Declaration, and in order to provide the unified educational level to the students in Civil Engineering Faculty, the Ministry of Science and Higher Education introduced the so-called educational standards. It is noted that the educational standards are created for all the faculties of studies, independently from the faculties themselves. The new type of studies according to the Bologna Declaration has been introduced to the educational system of the Faculty of Civil Engineering since the 1999/2000 academic year. As a result, the studies currently consist of three-tiers (three levels):

- tier I – lasts 8 semesters, includes 2880 hours of teaching (full-time studies), concludes with a Final project and leads to a BSc degree (Engineer degree in Poland);
- tier II – lasts 3 semesters, includes 1080 hours of teaching, concludes with an MSc thesis and leads to an MSc degree;
- tier III – lasts 8 semesters, concludes with a PhD thesis and a defence of the doctoral thesis and leads to the degree of PhD in Science (PhD Engineer in Poland).

The Faculty of Civil Engineering at the Silesian University of Technology takes pride in the many years of tradition of higher education and the high quality of the graduates entering the job market. In order to meet the demand of the constantly changing job market, the curricula of studies have been prepared in such a way that they give students the possibility to study in European universities within the Erasmus program, taking part in the international student exchange system. Enabling the students to study partially in universities abroad significantly broadens their possibilities of entering the open European job market. The curricula of studies are adjusted to the standards prepared by the Ministry and the positive opinion of the State Accreditation Committee guarantees the high level of education for future graduates. Thanks to the constant development of the staff of science experts and their devotion to the didactic process, education should remain on a high level. Close connections with the industry enable to create such plans of studies, so that the knowledge and the abilities of the graduates meet the needs of the industry of today.

KEYWORDS
Two-tier studies, Civil Engineering education, requirements of civil engineering degrees in Poland, Erasmus program

1. SHORT HISTORY OF CIVIL ENGINEERING FACULTY ESTABLISHMENT

The Faculty of Civil Engineering at the Silesian University of Technology was created in 1945 as one of the first four university faculties (Mechanical Engineering, Electrical Engineering, Metallurgical Engineering, Civil Engineering). The name of faculty has been changed over the years. The first name, Faculty of Sanitary and Civil Engineering, was used up to 1955 and then it was changed to Faculty of Civil Engineering for Industrial and Building Structures (1955-1969), Faculty of Civil Engineering and Architecture (1969-1977). Since 1977 and up to the present, it has been called the Faculty of Civil Engineering. The academic staff of the new university was recruited from Lvov University of Technology (Politechnika Lwowska), which was moved from a former eastern part of Poland to the western part, to Wroclaw and Gliwice. During the first academic year, 198 academic staff (including 32 Professors) lectured at the university, educating 2750 students. Presently, the university consists of 13 faculties with more than 30 000 students. The Faculty of Civil Engineering consists of eight departments and one laboratory, as listed below:

- Laboratory of Civil Engineering Faculty
- Department of Building Structures
- Department of Road and Bridges
- Department of Material Engineering and Building Processes
- Department of the Theory of Building Structures
- Department of Structural Engineering
- Department of Geotechnical Engineering
- Department of Theoretical Mechanics
- Department of Buildings and Building Physics

The Faculty of Civil Engineering employs about 190 academic staff (including 9 full professors) and currently teaches 2500 students.

2. BOLOGNA DECLARATION - GENERAL PROVISIONS

The rapid development of science, particularly in the area of information technologies, caused uneven scientific potential growth in various parts of the world. Europe was significantly left behind by scientific centres in the USA and the Far East. Because of that fact, Bologna Declaration [1] was created in 1999 and signed by Poland and other European countries. The basis of the declaration is the creation of a process towards a harmonized higher education system in Europe, raising the prestige of European universities in comparison to the American universities, and approving a comparable system for academic titles. The declaration introduces of three-tier system of higher education: a minimum of 3-year studies in the first tier (leading to a diploma of BSc or BA), 2-year studies of the second tier (leading to an MA or MSc degree) and 4-year-long studies of the third tier, which leads to the PhD degree [2]. According to the assumptions of the Bologna Process, the unification of the higher education systems is bound to occur due to the following reasons:

- introduction of the European credit transfer system (ECTS) for points earned;
- division in two tiers of studies;
- monitoring of education quality (accreditation and certification systems etc.);
- promoting the mobility programs of students and lecturers;
- promoting lifelong education.

Thanks to the early introduction of changes in the educational process by the former board of the Faculty, the requirements of the Bologna Process are now being realised in the present educational process. Changes in the methods of teaching were initiated in the year 2000 and the transformation process has been smooth.

3. HIGHER EDUCATION IN CIVIL ENGINEERING FACULTIES ACCORDING TO POLISH REQUIREMENTS

In order to provide the unified educational level to students of Civil Engineering Faculties, the Ministry of Science and Higher Education introduced the so-called educational standards (the educational standards are created for all the faculties of studies, independently from the faculties). The standards define first and foremost the educational outcomes that should be reached at each level of education and the subjects together with the necessary number of hours required to achieve a certain goal. For the first tier of studies, the Studies Plan should include at least 7 semesters of education with a minimum of 2500 hours, including 315 hours of basic science knowledge and 660 hours of faculty-specific knowledge [3]. Additionally, it is assumed that a student should be taught a foreign language, arts subjects, physical education and information technology (IT) education. The remaining hours may then be used for education in the field of specialised training.

Upon graduation from the first tier, a graduate should possess knowledge from the following areas:

- construction of structures, such as apartment buildings, municipal type constructions, industrial estate type and transportation structures;
- design of the basic objects and structural elements, technology and organisation of building /construction procedures;
- managing a team and a construction company;
- manufacturing, choosing and applying construction materials and computer technologies and other modern technologies in engineering practice.

A graduate is also prepared for:

- management of construction process of all types of building structures;
- co-operation in designing of public buildings, industrial and transportation buildings;
- organisation of structure element production (precast);
- supervision of construction process and continuing self-education and skill upgrading.

A graduate is prepared to work in:

- executive enterprises;
- building inspection;
- concrete and construction element factories;
- building materials industry;
- public administration units and councils connected with construction and architecture.

A graduate should have the knowledge of foreign language on B2 advancement level of the Common European Framework of Reference for Languages of Council of Europe and should be able to use the technical language within the chosen faculty of studies. A graduate is prepared to start studies at the second tier. The list of basic education subjects and faculty-specific education subjects for the studies of the first tier are presented in Table 1.

Second tier of studies should include Plan of Studies, which consists of minimum 3 semesters of learning with 900 hours of education divided into 30 hours of basic education subjects and 150 hours of faculty education subjects. The number of subjects suggested by the Ministry of Science and Higher Education is much shorter in this case – see Table 2.

The number of required hours to teach the suggested subjects (both basic and faculty-specific) does not comprise the total number of teaching hours in this tier of studies, and therefore gives a possibility to each of the faculty to implement its own programme of specialised education. The completion of each semester should be based on the rules of ECTS points, whereas the level of education should be based on the appropriate procedures of supervision and assessment. It is also recommended to co-operate with related units (faculties) in Europe in order to allow for unlimited student exchange.

Table 1. Ministry of Science and Education list of required subjects for the first tier of studies in Civil Engineering Faculties

No.	Basic education subjects	No.	Faculty education subjects
1.	Mathematics	1.	Drawing & Geometry
2.	Applied Physics	2.	Surveying
3.	Applied Chemistry	3.	Building Materials
4.	Engineering Geology	4.	Mechanics of Materials
5.	Mechanics	5.	Structural Mechanics
6.	Computer Science & Computational Methods	6.	Buildings
		7.	Soil Mechanics
		8.	Foundation Engineering
		9.	Structural Concrete
		10.	Metal Structures
		11.	Building Installation (system)
		12.	Transportation Infrastructure
		13.	Building Physics
		14.	Fluid Mechanics and Hydraulics
		15.	Organisation of Building Process
		16.	Technology of Building Process
		17.	Managing an Investment Process
		18.	Economics of Building Process

Table 2. Ministry of Science and Education list of required subjects for the second tier of studies in Civil Engineering Faculties

No.	Basic education subjects	No.	Faculty education subjects
1.	Advanced Aspects of Mathematics	1.	Elasticity and Plasticity Theory
		2.	Computer Methods
		3.	Complex Concrete Constructions
		4.	Complex Metal Constructions
		5.	Construction Enterprise Management

4. EDUCATION SYSTEM IN THE FACULTY OF CIVIL ENGINEERING OF THE SILESIAN UNIVERSITY OF TECHNOLOGY

The Faculty of Civil Engineering at the Silesian University of Technology actively participates in efforts towards defining the unified education system in faculties of civil engineering all over Europe. A network of faculties within the EUCEET organisation (European Civil Engineering Education and Training) worked out the basis of the so-called core subjects that should be taught in civil engineering faculties of European universities. Professor S. Majewski, the former Dean of the Civil Engineering Faculty, was an active participant of this organisation and developed the new programmes of studies based on the two-tier system. The first group of students who studied according to the new system started their education in academic year 1999/2000. The education of students following the older model of integrated studies ended in academic year 2004/2005. Currently the studies consist of the three-tier system:

- tier I – lasts 8 semesters, includes 2880 hours of teaching (full-time studies), concludes with a Final project and leads to a BSc degree (Engineer degree in Poland);
- tier II – lasts 3 semesters, includes 1080 hours of teaching, concludes with an MSc thesis and leads to an MSc degree;
- tier III – lasts 8 semesters, concludes with a PhD thesis and a defence of the doctoral thesis and leads to the degree of PhD in Science (PhD Engineer in Poland).

Besides the introduction of full-time education, which is free of charge, the Faculty also offers part-time studies with tuition fee. At present, part-time studies are conducted only in an "extramural" system: part-time studies are conducted during 12 weekend meetings (from Friday to Sunday) in each semester. The number of didactic hours is limited to 60% in comparison to full-time studies, but the curriculum of the subjects includes the same teaching materials. Equivalency was achieved by placing emphasis on individual work of students outside classes. In 2010, the Faculty started part-time studies of the third tier – PhD studies.

The faculty offers only one branch of studies – Civil Engineering. Qualifications of research and teaching staff enable the conduction, in the main building in Gliwice, of four main specialisations on the first tier of studies:

- Structural Engineering;
- Construction Processes Engineering;
- Transportation Building and Infrastructure;
- Railroads.

Studies in tier II offer further directions within specialisations and students may choose more detailed profiles of diploma studies, including the following:

- Structural Engineering (specialisation)
  - Urban and Industrial Structures;
  - Bridges;
  - Geotechnical and Underground Structures;
- Construction Processes Engineering (specialisation)
  - Ecological Buildings;
  - Building Technology and Management;
- Transportation Building and Infrastructure (specialisation)
  - Roads;
- Railroads.

Studies on the third tier (PhD studies) are not divided into specialisations, but each student cooperates with a particular department of the faculty, which determines the field of the student's specialisation. Coursework includes only general subjects, such as foreign languages, advanced topics from material mechanics, doctoral seminars etc. The emphasis is placed on the individual research and co-operation with the PhD thesis supervisor. PhD students are not considered to be university staff but they receive a governmental (Ministry of Science and Higher Education) scholarship in the form of money in the course of their studies. It is not predetermined, however, if after being awarded the degree of the PhD in Science the graduates will have the possibility to be employed at the university.

The university has also a daughter faculty in Rybnik (called in Polish: CKI), which is a Centre for Teaching Engineers (Bachelors in Science). Because of the fact that most lecturers are employed in the parent university in Gliwice, the studies in CKI Rybnik are conducted only at the first tier. The specialisations in Rybnik are different than those in Gliwice and include:

- Construction-architectural (only full-time studies);
- Urban Infrastructure Engineering (full- time and extramural studies).

Students from the Construction-architectural specialisation have the possibility to receive a "double diploma" due to the bilateral agreement with the VIA University College in Horsens (Denmark). They have the possibility to attend half of the classes in Poland and half in Denmark and the course of such studies concludes with a BSc Final project written and defended in two languages – Polish and English.

The new way of practical placement realization was introduced simultaneously to the new system of study. Thanks to this, a 13 week time period was obtained, during which the students are required to work in contractor companies or businesses related to construction. The 7^{th} semester of the 1^{st} tier of study (BSc level) was dedicated to this task. During the last two weeks of the semester (semester lasts 15 weeks), "Practical Placement Commissioning" is carried out. Within commissioning, the students are obliged to present their works: projects, building site or processes, in which they were employed. Presentation of the practical placement is limited the poster introduction and a short daily routine description. The presentations are held before the department staff and representatives of contractor companies that employed the students. It gives a very good opportunity to compare the work conditions, and also creates an opportunity to exchange experiences between the students education unit and contractors or designers who will employ further graduates.

It should be pointed out that a system of studies in English has been introduced – both in the first and second tier. Currently there is only one specialisation conducted in English – Structural Engineering. Due to their excellent knowledge of technical language, the graduates are particularly well-prepared to enter both the national and international job market. In addition, students of all the faculties and all types of studies have the possibility to take part in the international exchange Socrates-Erasmus program. The program includes one- or two-semester-long visits and education periods to the European universities. Because we offer classes conducted in English, students from other European countries are able to study in our Faculty.

The Teaching Standards for the Faculty of Civil Engineering appeared in 2007 after the introduction of the new type of education at the whole university. As a result, the process of evolution into full assimilation with the new Plan of Studies continues, so as to meet the requirements of the Standards. In order to achieve the required education results for the university as a whole and for each faculty separately, a System of Education Quality Assurance has been introduced. Following this system, the methods used in the didactic process, the grades and the methods of control of the classes offered have been unified.
The State Accreditation Committee is the statutory body which controls if the didactic process is conducted in the right way. The Faculty of Civil Engineering has received a positive opinion from the Committee in 2003 and 2010. The last visit of the Committee allows our Faculty to teach for the next six years.

5. SUMMARY

The Faculty of Civil Engineering at the Silesian University of Technology takes pride in many years of tradition of higher education and high quality of the graduates entering the job market. This was made possible due to both the close cooperation with the civil engineering industry and meeting their demand for employees, as well as due to the adjustment of the teaching methods to the requirements of the Ministry of Science and Higher Education. In order to meet the demand of the constantly changing job market, the curricula of studies have been prepared in such a way that they give students the possibility to study in European universities within the Erasmus program – international student exchange system. Enabling the students to study partially in the foreign universities significantly broadens their possibilities of entering the open European job market.

At present, the Faculty offers the possibilities to study on 3 tier of studies (according to Bologna Declaration) both of full-time and part-time (extramural) type. In addition, the Faculty offers studies conducted in English, which raises the prestige of the faculty and makes the mutual international exchange of students easier. The curricula of studies are adjusted to the standards prepared by the Ministry and the positive opinion of the State Accreditation Committee guarantees the high level of education for the future graduates.
Thanks to the constant development of the staff of science experts and their devotion to the didactic process, the education should remain at a high level. Close connections with the industry enable to create such plans of studies, so that the knowledge and the abilities of the graduates meet the needs of the industry of today.

The implementation of Civil Engineering teaching course completely in English language allows for the competitiveness of graduates in the labour market. This competition is not limited only to the internal Polish market, but graduates can look for an employment abroad. According to our observation the graduates are benefiting from the possibility of gaining work experience abroad and returning to the homeland after a few years. This phenomenon results in raising the quality of management and the building industry. Another aspect of the teaching course in English language takes the opportunity to use the ERASMUS student exchange program. The confirmation of the high quality education is verification of the young civil engineers by the labour market. The graduates of the Faculty of Civil Engineering do not have many problems with finding an employment in their profession in our country and abroad. The appreciation of the graduates qualifications, as attested by employers, as well as the easiness of finding occupation are confirmation of the proper selection of the CE course for future employees, which is a basic task of the university.

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CIVIL ENGINEERING EDUCATIONAL STANDARDS IN RUSSIA

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EXTENDED ABSTRACT

Higher education in Russia faces today problems connected not only with current requirements of national economy and the need for qualified professionals, but also with the integration into the European and international educational systems. In 2003 Russia joined the Bologna process, which aims at the creation of a uniform European educational space. Many Russians had the opinion that the process is going to reform higher education system in Russia according to European standards and to implement training under "the European" programs. Russia's joining the Bologna Declaration offers the possibility for Russian Universities to participate in European educational projects, and opportunities for students and academic staff to participate in academic and scientific mobility activities. It should be mentioned that two-level education exists in Russia since 1992, but it was mostly implemented in the fields of economics, management and the humanities. Engineering programs traditionally followed five year curricula.

Higher education in Civil Engineering in Russia is offered by 14 Civil Engineering Universities and more than 140 Civil Engineering Faculties in Technical Universities. All these institutions belong to the Association of Civil Engineering Higher Schools (ACEHS). The main goal of the academic community of Civil Engineering was to create adequate bachelor and master educational standards and programs acceptable both by universities and employers from industry. At the moment there are 15 specialties in civil engineering education in Russia. They are covering main professional areas – construction, technology of construction materials, engineering systems (water supply and waste water treatment, heat- gas supply and ventilation) etc.

The new Standards in education stipulate a single unified Bachelor's Standard for civil engineering. The former civil engineering specialties now form different profiles within this single standard. To achieve the goals of the new paradigm in higher education, special "didactical groups" from different civil engineering universities were formed, which created the so-called "basic part" of bachelor standards, which are obligatory for all universities, and the "variable parts", which correspond to specialities in civil engineering already existing in Russian universities. This arrangement was necessary from three points of view: first, we tried to save traditions in civil engineering education, second, it is very difficult (practically impossible) to "turn over" the minds of academic staff, who recognize only the five-year Engineering education Diploma, and third, the employers should understand "who is who", i.e. the correspondence of each Bachelors profile with existing specialities. These difficulties were addressed by an optimized structure of the educational programs, according to which the basic part of bachelor programs does not exceed 50 % of the total curriculum, while in master programs it does not exceed 30 %. This arrangement allows all the existing civil engineering specialties to be unified under a single program, i.e., the Bachelor in Civil Engineering. At the same time, such a structure gives Universities flexibility in creating their own variations of civil engineering programs, which take into account local features and employer requirements.

KEYWORDS
Civil Engineering Education, Bologna Process, Educational Standards, Bachelor Program, Master Program, basic part, variable part.

1. INTRODUCTION
1.1 International experience

Bologna Process and the changing of traditional five-year Engineering Diploma to two-level Bachelor (3 years) and Master (2 years) programs are issues widely discussed in many countries. These changes are closer to traditional higher education models in the UK and Ireland than those in most of Continental Europe. In many countries the Process was not implemented without criticism. In much of Continental Europe, the previous higher education system was modeled after the traditional German system, which is based on a clear difference between vocational and academic higher education. However, having two types of degrees can be counterproductive in the following cases:

- The vocational three-year degrees are not intended for further study, so those students who also want to advance to a master's degree will be at a disadvantage.
- The master's degree effectively becomes the minimum qualification for a professional engineer, rather than the bachelor's degree.
- The academic three-year degrees mostly prepare students to continue for a master's degree, so students who enter the workforce at that point will not be properly prepared. Yet they would have the same academic title as the fully trained vocationally educated engineers.

The final result of the change is that the agreements between professional bodies will require reevaluation in some cases as qualifications change.
The requirement of 60 European Credit Transfer System (ECTS) per year assumes that 1,500–1,800 hours are offered per year. However, the Bologna Process does not standardize semesters, which means that if the summer break at the university is long, the same material has to fit in a shorter study year. Also, there have been accusations that the same courses have been simply redefined, e.g. one course would be 1,5 times shorter upon conversion of the local credits to ECTS, without making any change to course content or requirements. This effectively increases demands without any countermeasure. The extent of this problem alone is such that in some countries, for example in Norway, one ECTS point is defined as equivalent to 20 hours of study, while in the Netherlands, it is defined as equivalent to 28 hours. These definitions essentially prove that the "ECTS point" is not standard at all.
It can hence be argued that a process that standardizes titles but not the content of the qualification creates a disadvantage for all candidates that take part in studies other than those requiring minimum effort.
So, students mobility, one of the main aims of the Bologna Process, can also be criticised because ECTS recognition in different universities needs bilateral or multilateral agreements.

1.2 The case of Russia

Russia is formally in a two-level education system since 1993, when the first Bachelor and Master educational standards were implemented. Since that time two routes of higher education existed till the end of 2010: 5-year Diploma of Engineering or 4-year Bachelor plus 2-year Master Degree. The difference between Engineering Diploma and Bachelor standards was essentially removing one year of study. This means that the first 4 years of Dipl. Eng. and Bach. curriculum are the same and students could change routes at any moment within the first 4 years of study. It is should be clarified that these 4-year bachelors were not professionally oriented and were not accepted by employers. Hence, students had to continue education on Dipl. Eng. or Master Programs.
In Civil Engineering previously we had 12 State Educational Standards (SES) for Engineering Diploma Programs:

- Industrial and Civil Engineering

- Hydraulic Power Engineering
- Municipal Construction and Economy
- Construction Materials Technology
- Heat- Gas Supply and Ventilation
- Water Supply and Waste Water Treatment
- Mechanic Equipment and Technological Complexes
- Mechanization and Automation in Construction
- Building Design (Architect Engineer)
- Real Estate Expertise and Management
- Highway and Airport Runway Construction
- Bridge and Transport Tunnel Construction,

and 2 SES for Bachelor and Master Degrees in the direction "Construction".

It should be clarified that the educational system in Russia, including higher education, is based on a system of State Educational Standards (SES). To issue Diplomas recognized by the State, as well as other education-related formal documents, university programs have to be accredited by the Federal Agency on Supervision in Education according to SES. This system ensures the unity of educational space and the recognition of education received at different universities. However, such unity limits the freedom of Universities to develop their own educational programs (to only 15 % of the total amount of theoretical training).

Upon signing the Bologna Agreement in 2003, the Russian Ministry of Education and Science declared that the reform of higher education would be directed mainly towards implementing a two-level educational system. As in many other countries in Europe, most Universities, students and employers in Russia were unhappy with this reform for the following reasons:

- most Universities and students could hardly believe that academic mobility would be possible for students with total, or even partial, financial support
- employers would not accept graduates with bachelor degrees and would instead prefer engineers with five-year diplomas, hence, students could not find job after graduating from bachelor program.

In addition, many public figures in Russia believed that this reform is connected with a desire to cut down expenses on higher education.

Nevertheless, under the pressure of the Ministry of Education and Science, to which universities are subordinate, they have been forced to follow the reform. It should be mentioned that in some training directions some engineering educational programs still remain, but their number was essentially decreased. For instance, there is only one new specialty "Construction of Unique buildings and structures" left in Civil Engineering instead of 12 mentioned above. These standards of new generation are called Federal State Educational Standards (FSES). It is easy to guess that the majority of developers of bachelor degree standards aspired to keep traditions and continuity of engineering education.

1.3 The goal of the paper

This paper aims at presenting the common requirements to Bachelor, Master and Engineering Programs according to the Federal State Educational Standards, which have been implemented since January 2011, and explain how the educational standards in Civil Engineering education were created.

2. COMMON REQUIREMENTS TO FEDERAL STATE EDUCATIONAL STANDARDS

By Russian Federal Law "EDUCATION" is stated, that workload of education should be measured in Credit Points (C.P.), one C.P. being defined as 36 hours study. Per year 60 C.P. (2160 hours) are required, weekly 1.5 C.P. (54 hours) maximum. The duration of

Bachelor Degree programs should be not less than 4 years (240 C.P.), Master Degree programs – 2 years (120 C.P.) and Engineering programs – not less than 5 years (300 C.P.). All programs are structured in Basic Part (BP) which is obligatory for all Universities and Variable Part (VP) which is a University prerogative.

Bachelor Program consists of Cycles:
B1 – Humanities, Sociology and Economics Cycle
B2 – Mathematic, Natural and Basic Technical Sciences Cycle
B3 – Professional Cycle
B4 – Physical Training
B5 – Field and Professional Practice
B6 – Preparation of Final Bachelor Degree Design
The workload of BP for Cycles B1 – B3 shouldn't exceed 50% of total workload of these Cycles.

Master Program consists of the following Cycles:
M1 – General scientific cycle
M2 – Professional Cycle
M3 – Professional Practice and Research Work
M4 – Presentation of Final Master Degree Dissertation
The workload of BP totally for Cycles M1 – M2 shouldn't exceed 30% of total workload of these Cycles.

Engineering Program consists of Cycles:
S1 – Humanities, Sociology and Economics Cycle
S2 – Mathematic, Natural and Basic Technical Sciences Cycle
S3 – Professional Cycle
S4 – Physical Training
S5 – Field, Professional Practice and Research Work
S6 – Preparation of Final Bachelor Degree Design
The workload of BP totally for Cycles M1 – M3 should be no less than 70% of total workload of these Cycles.

VP of Bachelor, Master and Engineering Programs should consist of two parts: the Main Part and optional disciplines, which should be not less than a third of VP.

New Federal State Educational Standards should be created according to:

- Competency approach (standards are describing cultural and professional competencies instead of previous didactic units, which students should gain after studying disciplines,
- The final-result orientation (the graduates should achieve a constant amount of professional skills prescribed by FSES),
- Employers participation.

Summarizing, we can clearly see that the most flexible are the Master Degree Standards, which allow the creation of various educational programs reflecting up-to-date developments in science and technology. Bachelor Degree Standards are rather more flexible than previous Engineering Diploma Standards, hence allowing the creation of a number of different programs reflecting various applications in professional activity and regional requirements. Engineering Standards are strictly determined to the specific field of professional activities and allow only close specializations.

3. CIVIL ENGINEERING EDUCATIONAL PROGRAMS

3.1 Bachelor Degree Programs

The greatest difficulty encountered was with the creation of the Bachelor Degree Standard. The problem was that, according to the educational reform, previously existing specialties should be transformed, under the new bachelor's system, to profiles. Taking into account the wide spectrum of specialties presented in Section 1.2, it was decided to give as much as possible C.P. for BP in cycles B1 and B2 and minimize cycle B3.
The credit distribution between Cycles, Basic and Variable parts are shown in the table 1.

Table 1: Credit distribution of Bachelor program

Cycle	Credit Points , (C.P.)	Basic Part		Variable Part					
				Total		Main		Optional	
	240	C.P.	%,	C.P.	%,	C.P.	%	C.P.	%
B1	30	21	70	9	30	6	66,7	3	33,3
B2	70	55	78,6	15	21,4	10	66,7	5	33,3
B3	105	25	23,8	80	76,2	56	70	24	30
B4	2 (400 hrs)	Summary for B1 – B3 Cycles: 205 C.P. Basic Part: 101 C.P. (49,3 %) Variable part: 104 C.P. (50,7 %)							
B5	18								
B6	15								

The use of VP has allowed to develop the profiles. Moreover, a big (24 C.P.) optional module in B3 Cycle allows to deepen the current profile program.
As an example, the content of the profile "Industrial and Civil Engineering" is shown in Table 2.

Table 2: The content of Bachelor program, profile Industrial and Civil Engineering

Cycle	Basic Part		Variable Part	
	Discipline (Module)	C.P.	Discipline (Module)	C.P.
B1	History	3	Main part	
	Philosophy	3	Psychology of social interaction	3
	Foreign Language	9	Sociology in Civil Engineering	3
	Jurisprudence. Legislation fundamentals in construction	3	optional	3
	Economics	3		
B2	Mathematics	12	Main part	10
	Informatics	5	optional	5
	Engineering graphics	5		
	Chemistry	4		
	Physics	6		
	Ecology (Environment)	3		
	Mechanics: Theoretical Mechanics Applied Mechanics Soil Mechanics	 5 5 2		

Continuing of the Table 2

Cycle	Basic Part		Variable Part	
	Discipline (Module)	C.P.	Discipline (Module)	C.P.
B2	Geotechnics: Geology Geodesy (Surveying)	 2 2		
	Architecture and Design	4		
B3	Health and safety	3	Main part	
	Building Materials	3	Strength of Materials	6
	Fundamentals of metrology, standardization, certification and quality assurance	3	Structural Mechanics	6
	Engineering systems of buildings and structures: Electricity supply and vertical transport Heat- Gas Supply and Ventilation Water Supply and Waste Water Treatment	 3 3 3	Architecture	6
	Technological Processes in Construction	4	Steel Strictures including Welding	7
	Bases of Organization and Management in Construction	3	Reinforced Concrete Structures	7
			Timber and Plastic Structures	5
			Basements and Foundations	5
			Building Machines and Equipment	4
			Technology of Construction	5
			Organization, Planning and Management of Construction	5
			One of the Modules by Choice	
			Research and Design of Buildings and Structures	24
			Technology and Management of Construction	
			Project Management	
			Inspection, Testing and Reconstruction of Buildings and Structures	
			Safety of Buildings and Structures	
B4	Physical Training	2		
B5	Field and Professional Practice Geology Geodesy (Surveying) Professional (Construction Site or Design Company)	 3 3 12		
B6	Preparation of Final Bachelor Degree Design	15		

3.2 Master Degree Programs

For Master Degree 5 types of programs are foreseen:

- scientifically oriented research programs,
- educational research programs which include not only engineering aspects, but also didactical issues in teaching civil engineering,
- experimental programs,
- design programs,
- technological programs.

In comparison with the Bachelor Program, the structure of Master Program looks simpler, as shown in table 3.

Table 3: Credit distribution of Master program

Cycle	Credit Points (C.P.)	Basic Part		Variable Part					
				Total		Main		Optional	
	120	C.P.	%,	C.P.	%,	C.P.	%	C.P.	%
M1	30	9	30	21	70	14	66,7	7	33,3
M2	30	9	30	21	70	14	66,7	7	33,3
M3	57	Summary M1 – M2 Cycles: 60 C.P. Basic Parts: 18 C.P. (30 %) Variable parts: 42 C.P. (70 %)							
M4	3								

The Basic Part of Master Programs consists of common disciplines:

M1 General scientific cycle:

- Philosophical Problems of Science and Technology
- Mathematical Modelling
- Special Chapters of Higher Mathematics
- Methodology of Scientific Research

M2 Professional Cycle:

- Information Technology (IT) in Construction
- Business Foreign Language
- Methods of Solving Scientific and Technical Problems in Construction
- Basics of Pedagogy (including aspects of adult learning)

Variable Parts of Engineering Programs are created by Universities themselves and correspond to Master Programes. In Moscow State University of Civil Engineering, these programs include the following:

- Energy Efficiency and Energy Saving in Construction,
- Development and Expertise in Investment Activity in Construction,
- Systems of Microclimate Maintenance in Buildings and Structures,
- Urban Planning, Architectural and Constructional Concepts of Design in Available Environment,
- Architectural and Constructional Aspects of Energy Efficient Buildings Design
- Urban Planning Aspects of Underground Space Development.

The main goal in Master Degree programs is focused on research work and preparation of Master Dissertation (Thesis).

3.3 Engineering Programs

As it was mentioned above, instead of 12 specialties in Civil Engineering we got only one – "Construction of the Unique Buildings and Structures" with a 6-year duration (360 C.P.). This allowed to create a technical program of high standards, reflecting up-to-date scientific and engineering trends in construction. The specialty has five specializations:

- Construction of High-Rise and Long-Spanned Buildings and Structures,
- Construction of Underground Structures,
- Construction of Highly Reliable Hydraulic Engineering Structures,
- Construction of Heat and Nuclear Power Stations,
- Construction of Highways, Airport Runways and Special Transport Structures.

The credit distribution between Cycles, Basic and Variable parts are shown in the table 4.

Table 4: Credit distribution of Engineering program

Cycle	Credit Points , (C.P.)	Basic Part		Variable Part					
				Total		Main		Optional	
	360	C.P.	%,	C.P.	%,	C.P.	%	C.P.	%
S1	33	31	94	2	6	2	6	0	0
S2	115	113	98	2	2	2	2	0	0
S3	145	120	83	25	17	15	67	10	33
S4	2 (400 hrs)	Summary S1 – S3 Cycles: 293 C.P. Basic Parts: 264 C.P. (90 %) Variable parts: 29 C.P. (10 %)							
S5	33								
S6	30								

As an example the content of specialization “Construction of High-Raised and Long-Spanned Buildings and Structures" is shown in table 5.

Table 5: The content of Engineering program, specialization “Construction of High-Raised and Long-Spanned Buildings and Structures"

Cycle	Discipline (Module)	C.P.
S1	**Basic Part**	
	History	3
	Philosophy	4
	Foreign Language	9
	Jurisprudence. Legislation fundamentals in construction	3
	Economics	3
	Sociology	3
	Psychology	3
	Cultural Science	3
	Urbanistic tendencies of development high-rise and long-spanned buildings and structures construction	2
	Variable Part	
	History of Architecture and Construction Techniques	2

Continuing of the Table 5

Cycle	Discipline (Module)	C.P.
S2	**Basic Part**	
	Mathematics	19
	Informatics	9
	Descriptive Geometry and Engineering graphics	8
	Chemistry	5
	Physics	13
	Ecology (Environment)	4
	Theoretical Mechanics	7
	Applied Mechanics: Strength of Materials Structural Mechanics Elasticity theory with plasticity and creep fundamentals Soil Mechanics	 6 6 3 3
	Fluid Mechanics	3
	Technical Heating Engineering	2
	Theoretical fundamentals of Electrical Engineering	2
	Fundamentals of metrology, standardization, certification and quality assurance	3
	Geotechnics: Geology Geodesy (Surveying)	 3 4
	Architecture	4
	Stochastic Methods in Structural Mechanics and Reliability Theory of Structures	6
	Chemistry in Construction	3
	Variable Part	
	Modern Building Materials	2
S3	**Basic Part**	6
	Health and safety	
	Building Materials	6
	Nonlinear Problems of Structural Mechanics	6
	Theory of Plates and Shells Design	6
	Dynamics and Stability of Structures	5
	Seismic Stability of Constructions	5
	Reinforced Concrete Structures	9
	Steel Structures including Welding	8
	Process Technology in Construction	6
	Organization and Management in Construction	8
	Manufacturing Process in Construction	7
	Mechanization and Automation in Construction	5
	Economics in Construction	7
	Project Management	4
	Physics in Construction (includes acoustic engineering, heat engineering, illumination)	4
	Inspection and Testing of Structures	6
	Operation and Reconstruction of Structures	8
	Architecture of Industrial and Civil Constructions	5
	National Codes for Design of High-Rise and Long-Spanned Buildings	3
	Engineering systems of buildings and structures: Electricity supply and vertical transportation (elevators and escalators) Heat- Gas Supply and Ventilation	 2 2

Continuing of the Table 5

Cycle	Discipline (Module)	C.P.
	Water Supply and Waste Water Treatment	2
	Variable Part	
	Basements and Foundations	5
	Timber and Plastic Structures	4
	Structures Monitoring by Natural and Technogenic (man triggered) Hazard Impacts	3
S3	Eurocodes	3
	Optional Advanced Module:	
	Theory of Structures	11
	Reinforced Concrete Structures	11
	Steel Structures	
	Architecture	11
	Erection of High-Rise and Long-Spanned Buildings	
S4	Physical Training	2
	Field and Professional Practice	
	Geology	3
	Geodesy (Surveying)	3
S5	Computer and Informatics	6
	Professional (Construction Site or Design Company)	12
	Research Work	9
S6	Preparation of Final Engineering Degree Design	30

4. CONCLUDING SECTION

The goal of this article was to present the changes made in Civil Engineering education in Russia, as a result of the Bologna reform. Moscow State University of Civil Engineering together with academicians from Russian Civil Engineering Universities and Employers from leading construction companies and professional associations managed to create bachelor educational standards practically equivalent to former Diploma Engineering programs. They managed to achieve this by reducing credits for the Humanities, Sociology and Economics Cycle and by increasing the Professional Cycle.
Flexibility of Bachelor and Master standards allows Universities to create their own educational programs according to requirements of employers in their region.
New Diploma Engineering Standards "Construction of Unique Buildings and Structures" are covering all up-to-date requirements for a Civil Engineer.

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GRADUATE AND MASTER CURRICULA IN THE FIELD OF CIVIL ENGINEERING AT ESCOLA DE CAMINS OF UPC (SPAIN)

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EXTENDED ABSTRACT

This paper describes the degree and master curricula that are being implemented at *Escola de Camins* (UPC) in Barcelona. This new organization of the studies is motivated by the European convergence in the education at the university level. One of the convergence points is the ECTS (equivalent credit transfer system) in which the subjects and blocks are described.

The new curricula are developed following the structure proposed in Spain which consists of four year degrees followed by one or two year master degrees. In order to satisfy the different interests and skills of students, three different degrees have been implemented at Escola de Camins, namely Civil, Construction and Geological Engineering. Master studies corresponding to different thematic areas of specialization are also in place, as well as the corresponding doctorate studies. Masters, with the professional qualification, are still under design and will be implemented as the newly graduated reach the point to enter the master studies.

The CaminsOpenCourseWare is a newly developed platform to prepare the programs of the different courses forming the degree and master programs. It is based on the concept of competences acquired by the students in each subject or course, and it also permits to describe in more detail the way the course is organized, what is the support material to be used, how the evaluation will be done, and any other aspects of the course organization.

1. A HISTORICAL PERSPECTIVE

The Escola de Camins is the UPC-BarcelonaTech engineering school is responsible for education and research in civil engineering in its broadest sense. Namely, it comprises engineering disciplines like: structural, construction, geotechnical, transportation, urban planning, hydraulic, coastal, environmental, as well as theoretical and applied mechanics. It was created in 1973 and the studies of "Enginyeria de Camins, Canals i Ports (ECCP)" were implemented following the Spanish system at that time which implied that this was a long curriculum (5 years according to national regulations). Graduates from this degree have in-depth abilities to plan, design, construct, and operate society's infrastructure. And consequently, they are empowered to gain the technical, design, and management skills needed to consistently become leaders in education, industry, and government.

Starting in 1987, the degree: "Enginyeria Tècnica d' Obres Públiques (ETOP)" was implemented to fulfill the marked needs for a professional with a shorter academic curriculum (3 years according to national regulations) yet, with a deeper focus on technological and practical aspects of construction engineering. The final project usually requires at least an additional semester. Graduates in ETOP are professionals with good technological skills and usually work in project and construction of infrastructures such as roads, railways, hydraulic, ports, etc depending on their major (specialization). Master programs on specific engineering branches are standard technical and managerial complements for these graduates.

In 1990, the studies of "Geological Engineering (EG)" (5 years) were implemented to cover a professional demand in this field. Graduates in EG are professionals with a deep understanding in engineering and natural sciences. This dual thrust empowers them with the technical and managerial aspects of engineering and the fundamentals of natural science. They are especially valuable in analysis (including risk assessment), design and construction of infrastructures with particular emphasis in underground works, engineering sedimentary geology such as river or coastal dynamics, as well as environmental issues related to soils, surface hydrology and groundwater hydrology.

2. THE GLOBAL PERSPECTIVE

The Escola de Camins is a public institution that must encompass a wide range of objectives and engineering branches, which is substantiated, among other aspects, by its magnitude (viz. over three thousands undergraduate and graduate students). This implies that a large number of undergraduate and graduate degrees are implemented to embrace society needs. They incorporate all inherent disciplines to the School (viz. structural, construction, geotechnical, transportation, urban planning, hydraulic, coastal, environmental, as well as theoretical and applied mechanics), and, at the same time, the complete range: from technological aspects to basic scientific engineering issues. The latter are critical in substantiating a critical aspect in this School: cutting-edge research that advances the frontiers of knowledge and engineering capabilities in emerging disciplines as well as traditional subjects.

Consequently, each three-cycle academic degree (bachelor, master and doctorate) presents a large variety of options. At bachelor's level four options are offered: Engineering Sciences (civil), Civil Eng., Construction Eng., and Geological Eng., which range from more scientific to more technological or specialized. Following Spanish legislation, they are four-year programs designed after leaving secondary education ($\geq$18 years old).

At master's level two main groups are present. Programs with a global approach and professional qualification such as the Master in *Enginyeria de Camins, Canals i Ports*, which follows Spanish professional qualification rules, the Master in *Civil Eng.*, and the Master in *Geological Eng*. Alternatively there are thematic programs more or less specialized covering all the areas of expertise in the School. Among those, several are jointly offered with other European institutions under the label of Erasmus Mundus programs: *Hydroinformatics and Water Management* (EuroAquae), *Computational Mechanics*, *Structural Analysis of Monuments and Historical Constructions* (SAMHC), *Coastal and Marine Engineering and Management* (CoMEM), *Flood Risk Management*. The list is completed with the following master programs: *Geotechnical and Seismic Eng., Structural and Construction Eng., Numerical Methods for Eng., Water Resources, Marine Sciences, Environmental Eng., Logistics, Transportation and Mobility,* and*, Sustainability*. The list of available Master programs is published at the *Escola de Camins* web page (www.camins.upc.edu) and information can be found following the corresponding link to other web areas of the *Escola de Camins*.

This structure of general programs (*Civil Eng.*) and specialized ones is also proposed at doctoral level. The following programs have received the maximum qualification (programs of excellence) by the Spanish evaluation agency: *Civil*, *Structural*, *Construction*, *Geotechnical*, *Earthquake Eng. & Structural Dynamics*, and *Marine Sciences*. The list of available doctorate programs is published at the *Escola de Camins* web page (www.camins.upc.edu).

3. UNDERGRADUATE DEGREES

In this section, a more detailed description of the Civil, Construction and Geological Engineering (CivE, ConsE, GeoE) undergraduate programs is presented. These new curricula are the natural transformation at the degree level of the studies described in the historical perspective.

The first one includes a general and comprehensive formation in the broad field of civil engineering (viz. structural, construction, geotechnical, transportation, urban planning, hydraulic, coastal, environmental, as well as theoretical and applied mechanics). The second is characterized by more specific technological contents. Both degrees (CivE and ConsE) have a Spanish professional qualification. Figure 1 shows the structure of the *Civil Eng*. degree. The blocks shown in the flowchart are decomposed into subjects ($\geq$4.5 ECTS), most of them having 6 ECTS or more (7.5 or 9). Spanish and University regulations have favored the 1.5 ECTS multiplicity. Actually, subjects for the basic contents cannot have less than 6 ECTS.

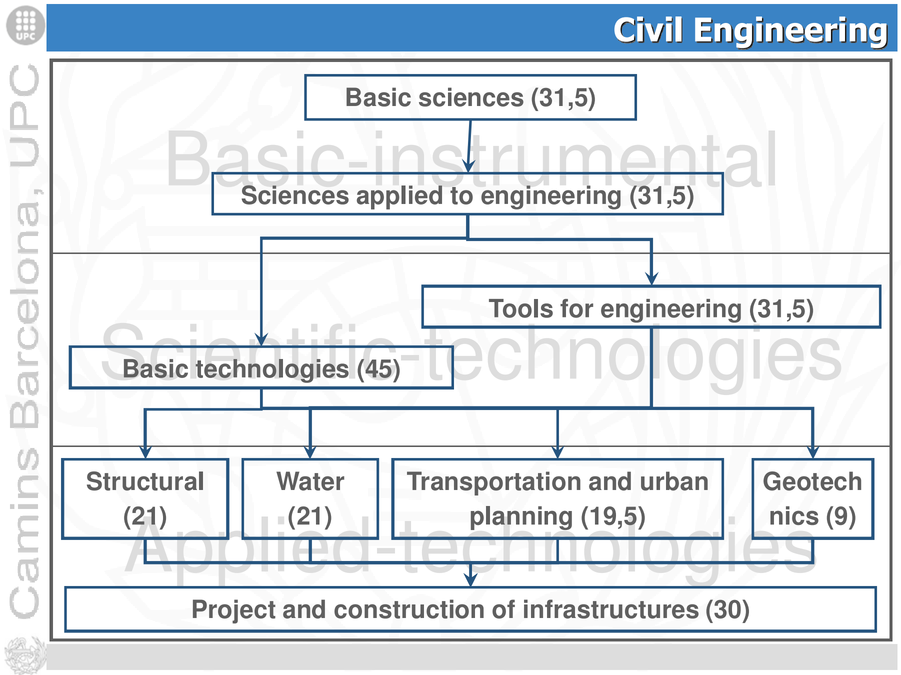

Figure 1. Structure of the degree in civil engineering

The CivE degree is characterized by a comprehensive education in civil engineering, which includes: structural, construction, geotechnical, transportation, and water (including hydraulic, maritime and water quality) engineering, as well as urban planning. Before these specialized technologies are studied, the necessary applied scientific technologies are consolidated. For instance, in the block of basic technologies modules with the basics in these technological branches are covered and, moreover, a global perspective is also presented with modules in continuum mechanics and engineering modeling. The block on tools for engineering is concerned with more instrumental topics, such as graphics, surveying, GIS and statistics.

In contrast to the Civil Engineering degree, the Construction Engineering degree (Figure 2) contains a deeper specialization in technological aspects. Consequently elective options are proposed to specialize the students according to their preferences or abilities. After some general contents in classical fields within civil engineering, an eligible block of 33 ECTS is proposed.

The ConsE degree splits into 3 alternative blocks: Civil Constructions (CC), Hydrology (H) and Transportation and Urban Services (TSU). A unique block is chosen and pursued during the fourth year. Each of these blocks contains compulsory and eligible modules and it is ended by the final graduation project. This degree is oriented to develop professional careers, for instance, in the field of construction and conservation of infrastructures in general, or in the field of hydraulic infrastructures or transportation infrastructures.

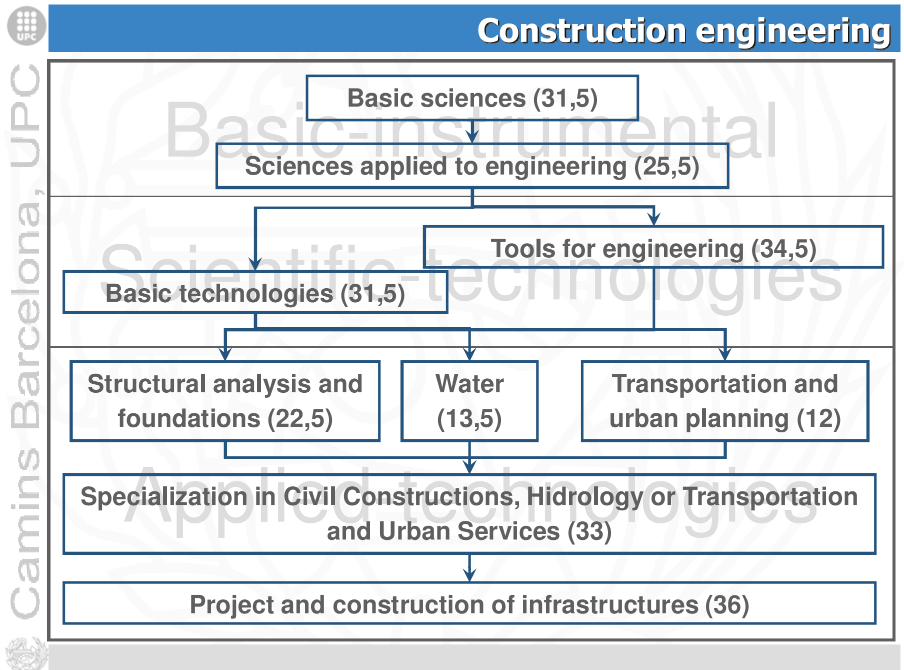

Figure 2. Structure of the degree in construction engineering

As noted previously a degree in Engineering Sciences (Civil) is also being developed in order to permit the students with a larger abstraction capacity to follow a curriculum more theoretical and fundamental. This degree is not conceived to give professional qualification.

Graduates from these previous detailed bachelors are prepared to access the Master in *Enginyeria de Camins, Canals i Ports*. This is a Master that forms professionals in the field of civil engineering which are prepared to undertake jobs and develop a career at the highest level of the administration and industry both in engineering or management orientation. The maximum duration of the Master is two years, but in practice a shortening is expected depending on the competences acquired during the degree. The students finishing the Master may develop a professional career in the field of engineering mainly devoted to design, planning and management of large infrastructures and other engineering projects. Contents of these degrees and master studies include Structural Engineering, Geotechnics, Construction Engineering, Hydraulics, Maritime and Environmental Engineering, Transportation Engineering and Urban Planning, as well as Theoretical and Applied Mechanics.

In addition, Geological Engineering is a shared curriculum, also with a Spanish professional qualification, taught jointly at the *Escola de Camins* of *Universitat Politècnica de Catalunya-BarcelonaTech* and the *Facultat de Geologia*, this latter belonging to *Universitat de Barcelona* as it is a faculty of geological sciences. It is important to highlight that this engineering degree is intended for students aiming an engineering degree and that also like geology. The combined education in an engineering school and a geological science faculty is unique and empowers the students with abilities and skills in sciences and engineering. Figure 3 shows a block of 30 ECTS devoted exclusively to geology, note also that some geology subjects are present in other blocks, viz. mineralogy and petrology included in the sciences blocks.

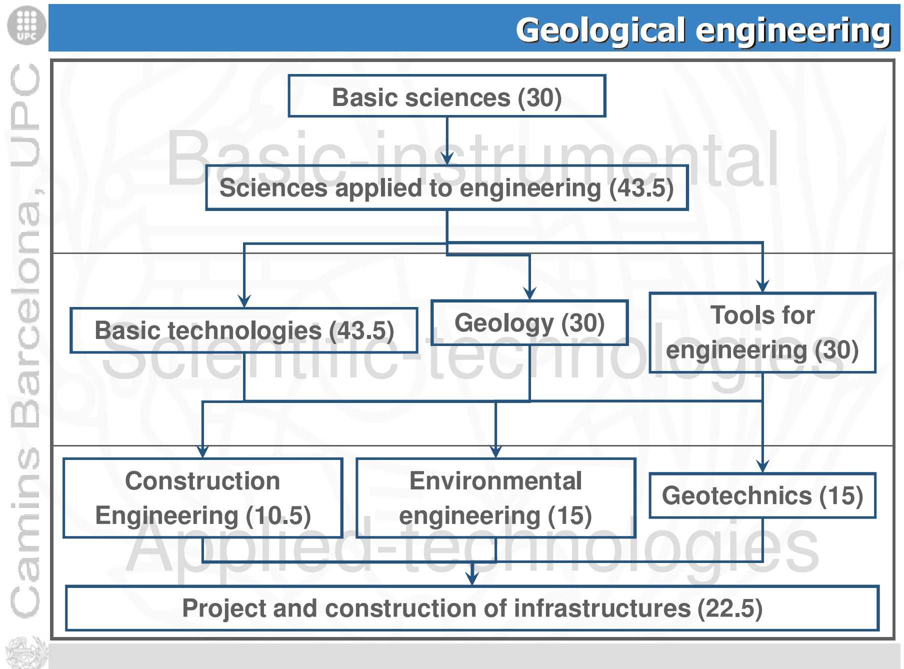

Figure 3. Structure of the degree in geological engineering

This degree focuses on three specific topics which are closely related to the types of jobs offered to these engineers; however the formation is very comprehensive without going into specialization. Master in Geological Engineering is the natural continuation of the degree, and when implemented will have an eligible block. Contents of the Geological Engineering degree and master include geotechnical constructions, environmental engineering related to the ground and natural resources.

4. CAMINS OPEN COURSE WARE (CAMINSOCW)

In order to develop the academic guide of each course a new platform has been developed. This platform is being used to prepare the planning of the courses including the contents, references, competences both technological and transversal (such as work in group, writing skills, or sustainability), abilities, skills, support material among other things. This is an open system in the sense that all the contents are free access via internet. The CaminsOpenCourseWare (CaminsOCW) follows the idea initially developed at Massachusetts Institute of Technology (MITOpenCourseWare).

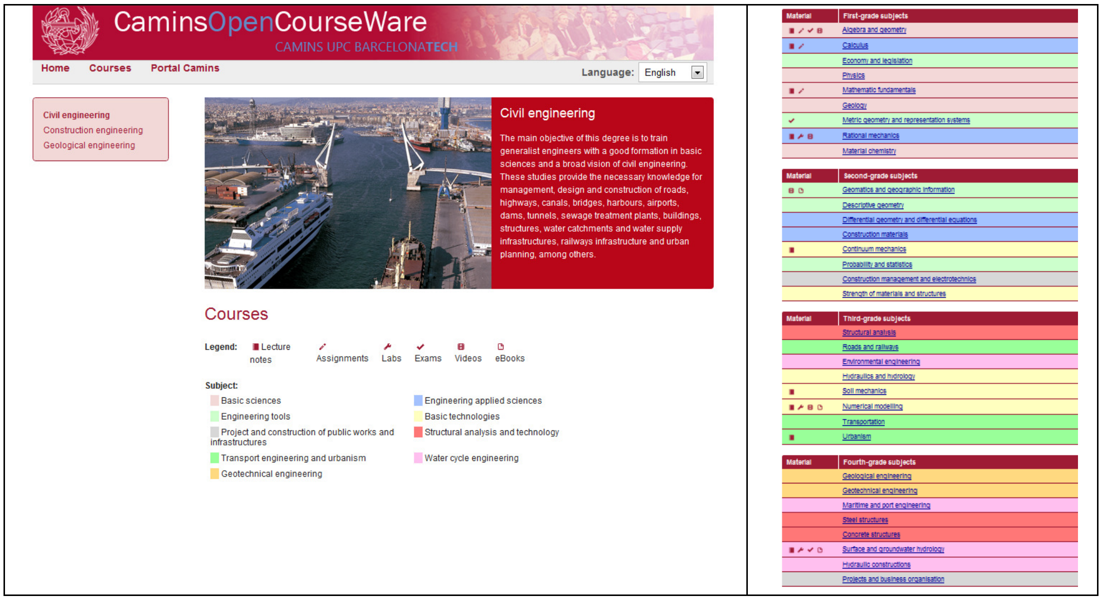

Figure 4. View of the CaminsOCW first page and list of courses forming the Civil Engineering program. The colors indicate the different blocks in which the subjects are grouped.

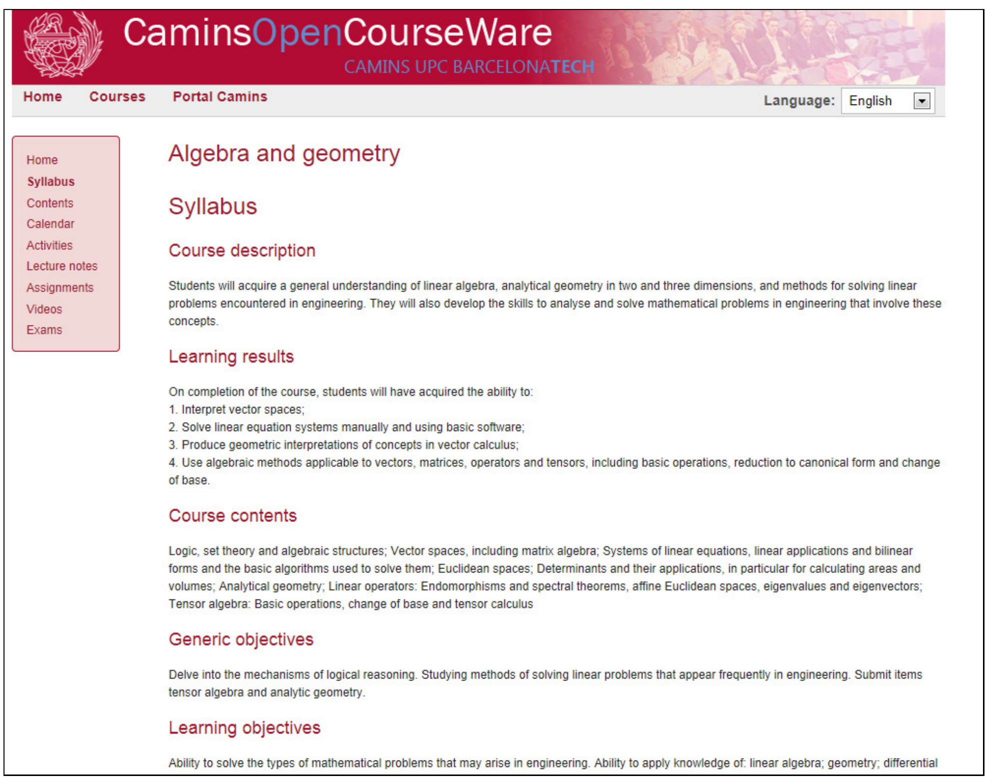

Figure 5. View of the syllabus utility for one of the courses that is included in the CaminsOCW.

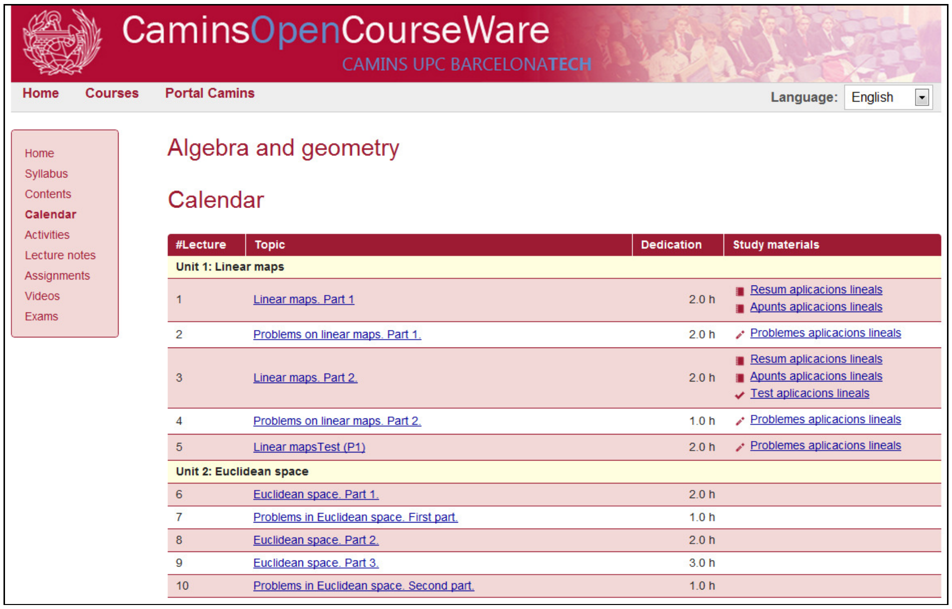

Figure 6. View of the planning using the calendar utility for one of the courses that is included in the CaminsOCW.

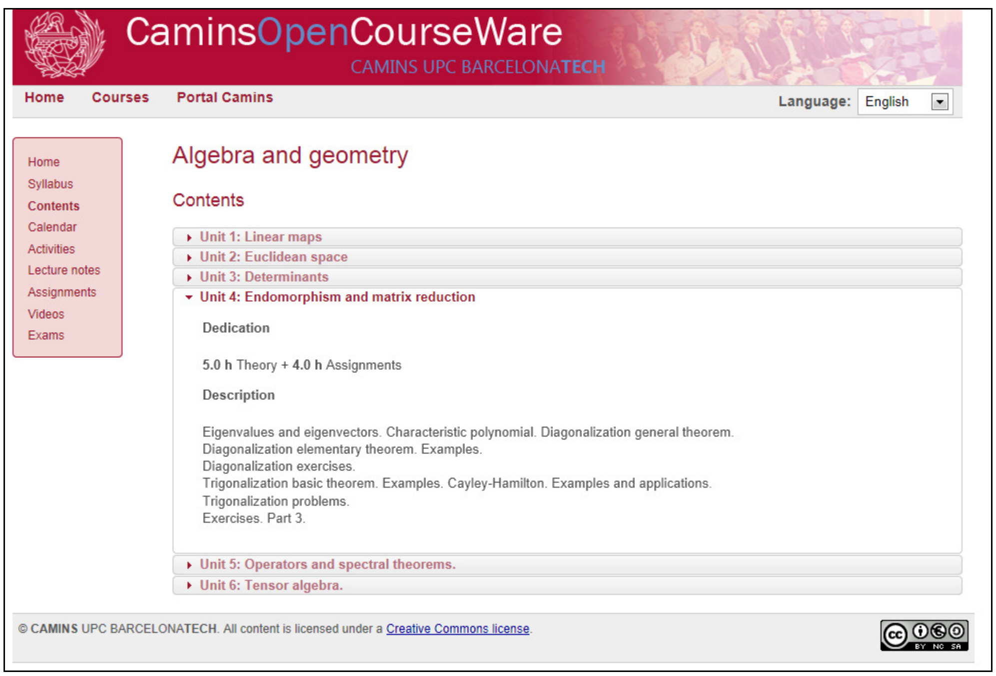

Figure 7. View of the Contents utility for one of the courses that is included in the CaminsOCW.

The main objective of the CaminsOpenCourseWare is to describe students for each subject: objectives, competences and abilities achieved in it, how this is done, any material that the students should use, the distribution of the contents in lectures, laboratory sessions, other practical sessions, computer sessions and how the acquired abilities and skills are evaluated. Figure 4 shows a snapshot of the web site and the list of courses as they are organized by years. The colors indicate the block that each course belongs and this is related to the flowcharts described above in this paper.

For each of the courses a number of sections should be filled (Figures 5, 6 and 7): Calendar, Contents, Activities, Lecture Notes, Assignments, Videos and Exams. In this system, the calendar is the most important section and most of the others develop automatically as they are dependent sections of the calendar. This means for instance that when the planning of the course is done using the calendar, the contents are also generated and the table of contents is automatically constructed.

In addition to the CaminsOCW, the students use a system based on Moodle called ATENEA for the daily activity. This is a more dynamic system which permits to manage assignments, to answer questions, to modify or include new material according to the course evolution.

5. SOME CONSEQUENCES OF THE BOLOGNA PROCESS

In this section some of the consequences of the implementation of the Bologna process are highlighted.

Credit transfer system (ECTS): This is probably the most important improvement which implies that effort is centered in hours of study of students, new standard in Europe, and favors mobility. In addition, a common system of qualification is desired and an ECTS grading scale has been proposed by the European commission.

Mobility: The target is that every student does mobility during the university studies. Actually, the engineering degrees above mentioned have a minimum of mobility compulsory or eligible. One semester at a foreign university following some courses is essential for the final formation of engineers. This is supported by the Erasmus programs but more resources are required. On the other hand, a number of double diploma and interchange agreements are being developed, some of the coming from the existing ones in the old system, but others which are easier to develop thanks to the ECTS system. Mobility is already quite significant at present.

Cyclicity: The studies are cyclic in the new curricula and this was not the case for the traditional system which was based on two categories of engineers (3 and 6 year duration) with little permeability when it was designed. This has some implications and modifies the traditional system in Spain. The classical 5-6 year curricula permitted students to follow the studies at a slow velocity and with minimum marks. Even though they were good the system permitted some slow rate of passing the courses. Now, both the marks and the velocity obtained by graduated will be very important for the admission to Master studies, and therefore the performance of the students is expected to improve as the organization is more competitive. In other words, at the entrance to the system there is no guarantee that a certain reputed master can be finished.

Controllability: The CaminsOCW described above is a new concept for contents, activities, bibliography, and other things publication in which much more transparency of what the students should learn is set up. The system is new and the feedback from professors and students is still not available. The learning methods and the evaluation methods are shown in detail. Concerning the teaching, it is clear that a transformation from the classical lectures to more participative classes is essential. One point is that at present practically all the support material is available through internet. The Escola de Camins is a center with significant scientific production and this should have a consequence on the material and the contents that are included, especially at the Master level.

Profession: Graduated in Engineering can access the professional marked. However, it is expected that a large number of the continue studies at the Master level. This is a consequence of several factors for instance economical as the access to jobs is delayed especially in developed countries or because the students believe that the basic formation at the degree level should be complemented by more technological and specialized courses. The orientation of master courses can be: professional, academic or scientific, thematic, or combination of them.

6. CONCLUSIONS

Following the European convergence of university studies, four year degrees (240 ECTS) are being implemented at *Escola de Camins*. After a historical and global perspective of the *Escola de Camins*, the structure of the recently developed and implemented degrees has been described in the paper.

Three degrees which permit three different professional curricula correspond to the transformation of the formerly existing curricula. The new programs are: Civil Engineering, Construction Engineering and Geological Engineering. At present, the students willing to follow a career in this field are applying for one of them. As the degree is finished a number of possibilities are offered in terms of Master studies, some of them clearly oriented to professional career with comprehensive background and other with a specialized program that permits to get a more profound knowledge in most of civil engineering areas. Some of them follow international Erasmus Mundus structure. Finally, the contents are sometimes oriented to scientific career and belong to eligible subjects which are necessary for carrying out later a doctorate.

A new platform has been developed at *Escola de Camins* in order to open new possibilities for planning the courses and give more transparency to what should be included in each course. The CaminsOpenCourseWare is operative and the courses for the three degrees have been planned using the new platform, as briefly introduced in this paper. This is an accumulative process and it is expected that it will improve during the complete implementation of the new degrees and masters.

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DEVELOPMENT AND IMPLEMENTATION OF A POSTGRADUATE COURSE ON RESEARCH METHODOLOGY FOR ENGINEERS AND SCIENTISTS

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EXTENDED ABSTRACT

With an overall aim to contribute to the ongoing discussion of improvements and reforms in doctoral programmes worldwide, the present paper focuses on the development and implementation issues of a postgraduate course administered by the Department of Civil Engineering of the Aristotle University of Thessaloniki in Greece. The course is compulsory for all doctoral students and also for the students of the MSc postgraduate programme "Environmental Protection and Sustainable Development" of the Department.

The main purpose of the course, which is provided during the last six academic years, is the familiarisation of the postgraduate students with the basic principles of research (objectives, means, methods, conduct and results) together with the development of appropriate relevant skills The principal objectives of the course are those that make the postgraduate students, after its successful completion, capable of: recognising the main features of science, engineering and technology, being familiar with the scientific methods of research, identifying the processes and the final approach to the design and implementation of a research project, accepting all ethical rules in conducting scientific research, carrying-out efficiently a literature survey, using terminology standards and glossaries and applying good practices in definition giving and term rendering, presenting the results of their research in oral and written form, and selecting and composing their material for presentation through slides and posters.

In the paper all issues mentioned above are discussed from the perspective of the two main categories of the course's learning objectives/outcomes aiming at: (a) acquiring knowledge on critical research-related issues (knowledge outcomes), and (b) developing transferable and personal skills necessary in practicing research, but also for career development (skills outcomes). Particular points that are emphasised in the paper include the multilevel educational structure of the course, the contents of the lectures, and the requirements for assignments undertaken by the postgraduate students, which aim at building research competencies and developing communication skills. Finally, the fact that the course is provided to a class, which is composed of graduates originating from a wide spectrum of disciplines, is also examined. It is apparent that, due to this discipline-mix of the class, the synergies developed between civil engineers and graduates from other engineering and science fields, either by taking part in the classroom activities or in preparing the assignments, form an additional positive characteristic of the course.

KEYWORDS

Civil engineering, Postgraduate course, Research methodology, Skills development, Course assignments

1. INTRODUCTION

In the last decade doctoral studies in European universities have increasingly achieved recognition as a key part of a wider process aiming at the development of a knowledge society. Implementing a European mandate for a reform of doctoral programmes, the European University Association (EUA) initiated in 2003 a series of actions (i.e. various workshops, seminars and surveys) that at first led to a report (EUA, 2007) summarising recent achievements and challenges and proposing recommendations on the further development of basic principles for doctoral programmes. That report focused on three clusters of issues: (a) the quality of the programmes, (b) the role of higher education institutions, and (c) the public responsibility and the role of state. In a more recent brief review (EUA, 2010) a series of updated recommendations is proposed to serve as a set of guidelines for the diverse landscape of European doctoral schools and programmes.

Among the issues underlined in the above mentioned publications, of particular interest to the present paper are those of a proper supervision of doctoral candidates and of a better provision to them of specific knowledge and skills training. Both issues are the subject of many individual studies (e.g. Lee, 2008 and Hoffmann and Nagl, 2010), as well as of group reports, like those produced by members of two European Thematic Networks: (a) TREE, which covers all engineering disciplines (Avdelas, 2007), and (b) EUCEET, which focuses on civil engineering only (Boswell, 2006, Pantazidou, 2010).

The purpose of the present paper is to present an educational module that aims specifically at the preliminary provision of knowledge and skills training to doctoral candidates of the Department of Civil Engineering of the Aristotle University of Thessaloniki (AUTh) in Greece. Yet, in some parts of the paper, the importance of a good supervision, particularly in complementing the educational programme of the institution, is also highlighted. Doctoral studies in Greece follow a typical path of combining the provision of postgraduate education -at the early stage of a doctorate- and the production of research. Details regarding the structure of the Greek higher education system in civil engineering schools/departments, as well as its connection with career development and employment issues can be found in selective publications (e.g. Latinopoulos, 2004, Dritsos and Moseley, 2010 and Latinopoulos, 2010).

The educational module presented herein is a postgraduate course entitled “Introduction to Research Methodology” that is administered by the Department of Civil Engineering since the academic year 2005-2006. Within this sense, the type of the paper’s content is that of a case study, as it fully describes the educational approach adopted in designing, organising and implementing the course at hand. All that follows is a review and a discussion of relevant issues, as perceived and presented by the paper’s author who has been the instructor of the course along the above mentioned six-year period.

2. DESIGN AND ORGANIZATION OF THE COURSE

2.1 Aim and objectives

The postgraduate students, who enroll in the study programme of the Civil Engineering Department that leads to the doctorate degree (PhD candidates, referred hereafter as PhDs for brevity), have to attend four courses during the first year of their studies (two compulsory and two optional). The course “Introduction to Research Methodology” is one of the two compulsory courses, the second being “Applied Computer Science”. The two optional courses can be selected from a list of postgraduate courses that are taught in the MSc programmes of the Department. The overall aim of this part of the study programme is the acquisition of specific knowledge and the development of skills and competences necessary for conducting research in specialised scientific fields of civil engineering.

Within the above context the course "Introduction to Research Methodology" aims at the familiarisation of PhDs with the basic principles of research (objectives, means, methods, conduct and results), as well as at the development of various relevant skills and competences. As explained in more detail below, this aim is fulfilled through a multilevel educational process. Yet, the learning outcomes of this course, although necessary in this first cycle of studies, are not sufficient for the doctoral candidate, and, therefore, additional knowledge and skills should be acquired and developed along the whole time span of his studies, mainly through the guidance of his supervisor and by his own effort and self-education (Latinopoulos, 2010a).

2.2 Learning outcomes

The general educational target of the present course is directly related to specific learning outcomes, which refer exclusively to the conduct of research. These can be distinguished in two categories: (a) those concerned with the acquisition of specific knowledge and (b) those connected with the development of specific skills. The full list of learning outcomes is expanded immediately below.

Knowledge outcomes

The knowledge outcomes from the specific course include facts, concepts, principles, and theories that will be useful to the PhD student in practicing research in his academic environment and with particular emphasis in engineering issues. These outcomes are:

- knowledge of the basic concepts (science, research, knowledge) and their mutual relationships
- understanding the principles of ethical conduct of research (avoidance of plagiarism and generally of research misconduct, allocation of credit and authorship, etc.)
- apprehension of the research process and the relevant concepts (structure and design of a research project, types of novelty, the researcher's role etc.)
- familiarisation with research activities in sciences and engineering (methodology, methods, techniques, appropriate application of technology etc.)
- recognition of the basic concepts, principles and sources of terminology with an emphasis on their proper use in practicing basic and technological research
- acquaintance with the ways and forms of communicating research results and with the relevant activities of a young researcher

Skills outcomes

From a wider spectrum of skills, which a young researcher should develop, the specific course aims at providing a particular subset needed in the first stage of a doctorate. After completing the course the doctoral candidate should be able to demonstrate the following skills, grouped in five thematic lists.

<u>(a) Research design and organisation</u>

- recognise and validate scientific/research problems
- comprehend and effectively employ appropriate research methods and techniques
- critically analyse and evaluate the findings of other researchers
- summarise, document and report, in relation with the progress of a research project

<u>(b) The research environment</u>

- understand the context in which research is conducted
- demonstrate awareness of issues related to research proper conduct and ethics
- understand the rights and responsibilities of researchers in various forms of research (basic, applied, funded)
- understand the processes of research results exploitation (academic /commercial)

(c) Research Management

- identify and be able to access bibliographical and other information sources
- effectively use information technology tools for database management and for recording and presenting data and relevant information

(d) Communicating research

- effectively use appropriate forms and levels of communication (progress reports, scientific papers, theses etc.)
- prepare and deliver oral presentations to diverse audiences (composed of specialists or non-specialists)
- prepare and use presentation material of high quality (slides and posters)

(e) Teamworking

- develop and maintain working relations with supervisors and colleagues
- understand personal behaviours and their impact on others in relation with teamworking and contributing to collective success

2.3 Educational methods and material

The course is taught in the Spring Term of every academic year. The whole educational process is structured into four main components, as described below.

Educational method

The teaching and learning activities that are implemented in the educational process of the course are:

(a) Lectures (compulsory attendance in the classroom)
(b) Creative activity (team/co-operative activity in and outside the classroom)
(c) Active learning (undertaking and accomplishment of individual and group roles)
(d) Self-education (learning and skills development outside the classroom environment)

Assignments

All PhD attendants of the course should undertake and complete: (a) a general assignment (team-work), and (b) two specific assignments (personal work). The content, requirements and ways of implementation of these course assignments are described in detail in section 3.3.

Educational material

The educational material of the course is uploaded in the Blackboard e-education platform that is operated by the Central Library of Aristotle University of Thessaloniki. All course attendants have direct access to the following.

(a) The extensive PowerPoint presentations used in the classroom lectures
(b) A collection of informative material that accompanies all lectures issues
(c) Various guidelines and examples for the proper completion of the course assignments
(d) All completed assignments of the students

Students' evaluation

The criteria for the evaluation and assessment of the students are the following.

(a) The overall presence and activity in the classroom
(b) The contribution in the general (team-work) assignment
(c) The individual performance in the two specific assignments (personal work)

3. IMPLEMENTATION OF THE COURSE
3.1 Class participation and attendance

The class attending the course "Introduction to Research Methodology" is composed of two groups of postgraduate students. The first is the one already mentioned, i.e. the PhD candidates of the Department of Civil Engineering of AUTh, while the second consists of the students (hereafter referred as PostGrads for brevity) who attend the MsC course "Environmental Protection and Sustainable Development", administered by the same Department (Latinopoulos, 2002). This joint teaching can be considered as an interesting educational form from various points of view. Maybe the most important aspect relates to students' participation and can be assessed by two relevant characteristics. The fist concerns the class composition in terms of the proportions of the two subclasses populations, whereas the second reflects the wide spectrum of scientific disciplines from which class attendants have obtained their first degree. The latter is a distinctive mark of the interdisciplinary nature of the postgraduate programmes of the Department of Civil Engineering, while the former signals the likelihood of dominance of one subclass over the other, which could probably result in different patterns of reactions and behaviors in the classroom and/or in performing other activities.

Figure 1 shows the variation of class size and composition along the six years of the course's implementation. In this period a total of 313 students attended the course (145 - 46% PhDs and 168 - 54% PostGrads). The annual attendance varied from 38 to 66 with an average of 52 students. These figures show that the whole class was manageable (in terms of size) and that the two subclasses were more or less equivalent (in terms of student composition). These two facts allowed a quite convenient handling of the human potential in all four components of the educational process.

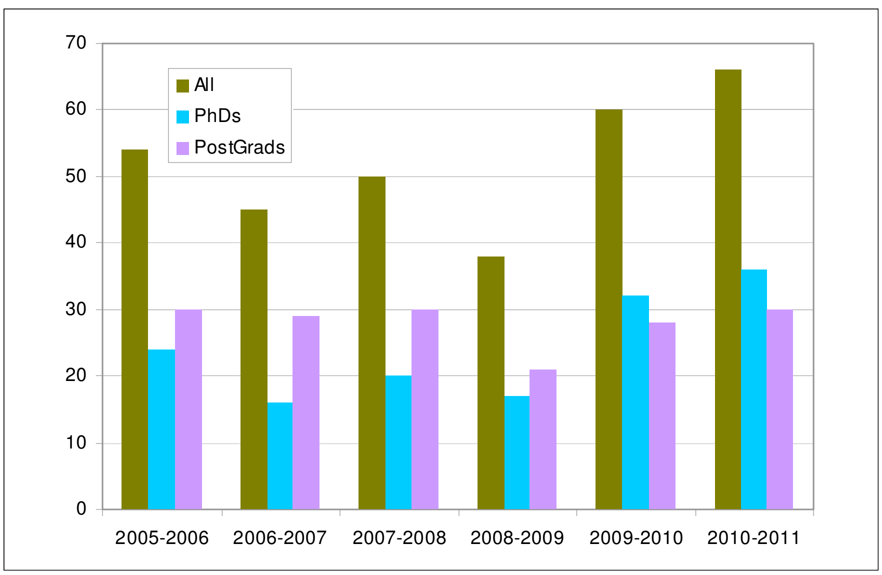

Figure 1: Variation in time of the class composition (number of PhDs, postgraduate students and total of attendants)

Admission to the two postgraduate programmes (i.e. for MSc and PhD students) is open to every candidate who holds any engineering specialisation but also to graduates from other disciplines, more or less relevant to the content of the two study programmes. Obviously, the demand from civil engineering graduates is higher and therefore there is a clear predominance of them over the rest engineers and scientists. This can be seen in figure 2, where the composition of the course's class is presented in terms of these two groups of graduates. In average, two out of three course attendants are civil engineers. In the two subclasses the particular ratios are different, but still in favor of civil engineers: 4:1 in the PhDs group and 3:2 in the PostGrads one.

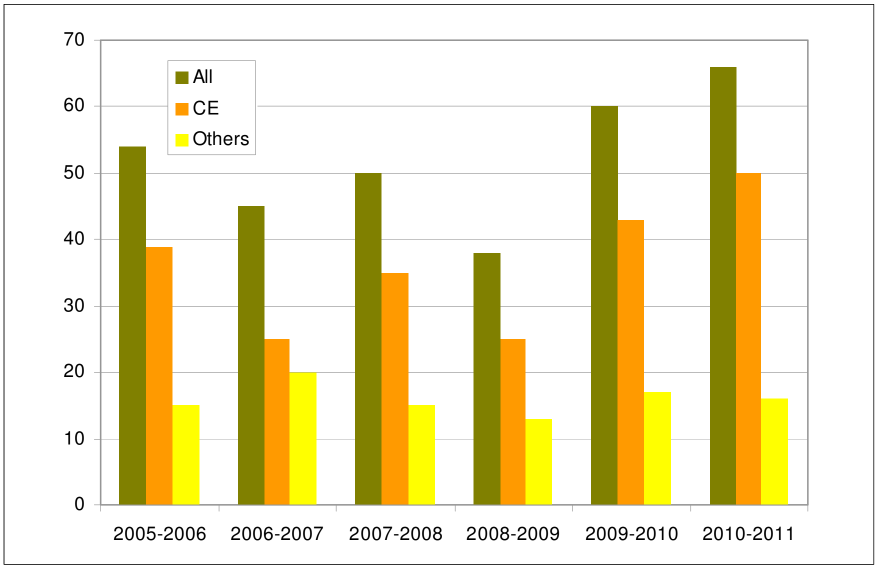

Figure 2: Variation in time of the class composition (number of civil engineers, graduates from other disciplines and total of attendants)

Of specific interest and therefore worth mentioning is the wide spectrum of graduates' disciplines other than civil engineering. From 96 non-civil engineers, who attended the course in all six years, 60% are engineers of seven other specialisations and 40% are scientists of 8 different disciplines. All these graduates hold the degrees listed in the following two groups.

a) Engineering specialisations: Planning and Regional Development Engineering (PE), Mechanical Engineering (ME), Rural and Surveying Engineering (RE), Chemical Engineering (CE), Environmental Engineering (EE), Architecture (AR) and Electrical Engineering (EL).

b) Other disciplines: Forestry (FO), Geology (GL), Environmental Studies (ES), Agriculture (AG), Marine Sciences (MS), Physics (PH), Biology (BI) and Law (LW).

In figure 3 the above mentioned data are shown in more detail, first for each subclass and then for the total of the class.

3.2 Course schedule

The course's main activities take place along a period of 10 weeks in the Spring Term. On a specific day of each of these weeks there is either a lecture (given by the course instructor) or a students' activity taking place in the classroom. As shown in table 1 there are eight lectures and two students' activities. Each lecture deals with a single topic related to at least one specific knowledge or skill issue. In most lectures active participation of the attendants is highly encouraged. On the other hand, the two students' activities are fully undertaken by themselves and have the form of public events. These activities are directly related to the general assignment, as described in the following section.

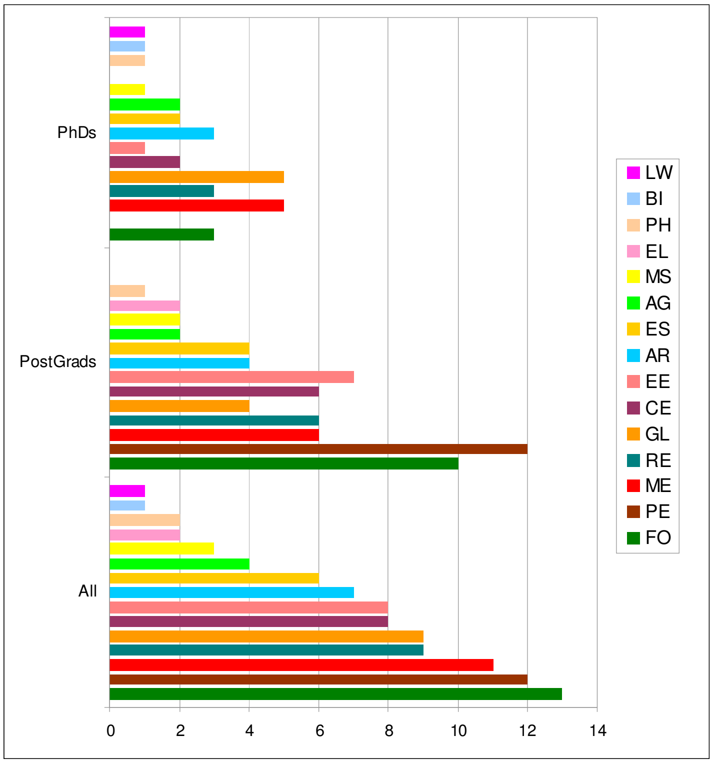

Figure 3: Disciplines of non-civil engineers attendants in all six years (of PhDs, PostGrads and total attendants)

Table 1: Outline of course lectures, activities and assignments

Week	Event / Topic	Student Assignment / Activity
1	**Lecture 1** Introduction – Basic concepts	
2	**Lecture 2** Research methodology and ethics	**General assignment**
3	**Lecture 3** Literature review and management	
4	**Lecture 4** Technical terminology	**Specific assignment A**
5	**Lecture 5** Quantitative research methods	
6	**Lecture 6** Oral presentations	
7	**Students activity 1** Oral presentations of paper critiques	Presentations and discussion of the critiques of journal papers
8	**Lecture 7** Posters and diagrams	
9	**Lecture 8** Scientific writing	**Specific assignment B**
10	**Students activity 2** Conference	Formal presentations (oral with PPTs) and poster presentations

3.3 Course assignments

The course assignments fall into two categories: team-work and individual work. They are all compulsory for the PhDs, while PostGrads have to take part only to the team-work, i.e. the general assignment. Details of the assignments are given immediately below.

General assignment
This assignment is undertaken by small teams composed of four or five students of the same or similar discipline. The successful completion of the assignment requires from each team to accomplish the following three separate tasks.

<u>(a) Paper critique</u>

- Search in various literature sources and select a paper recently published in a peer-review journal with a content that falls within the scientific interests of the team members
- Critical analysis/evaluation of the paper in terms of: scientific content, structure and style of writing, completeness of literature review, methodology used, presentation and discussion of results and conclusions made
- Oral presentation in the classroom of the paper critique by a team representative (all teams presenting together in students activity 1 - see table 1) followed by discussion

<u>(b) Paper presentation</u>

- Reversed use of the paper: from an object of critique (as a third person's work) it is now considered to be the brainchild of the team members (hypothetically, as their own authored work)
- Preparation of a complete typical conference-type oral presentation supported by PowerPoint slides (following specific guidelines for authors)

<u>(c) Poster preparation and presentation</u>

- Preparation of a typical conference-type poster presentation of the same paper by following specific guidelines for authors

Oral and poster presentations are given during the second students' activity in the classroom which concludes the series of the 10-week activities. This event is a simulation of a real scientific conference, in which all students participate by sharing various roles: session chairpersons, speakers, poster presenters, discussants or audience members. Besides the development of various skills along the whole span of actions of the general assignment, every individual student has the additional benefit of extending and widening his personal knowledge, not only through the involvement in the study and presentation of a high quality research issue undertaken by his team, but through his participation as an audience member in the two students' activities, in which a large set of scientific issues, selected from a wide spectrum of disciplines, is presented and discussed.

Specific assignment A
This assignment is undertaken by every doctoral candidate individually and aims at his familiarisation with principles and sources of terminology and on their proper use in basic and technological research. Each student examines four different English terms selected from his team's paper, evaluates them as well as their definitions, and repeats the same process for the terms translated in Greek. A written report from this assignment should be delivered within a 10-day period.

Specific assignment B
The second personal assignment requires the preparation of a typical conference paper that should be written by every doctoral candidate on a topic relevant to his current

research activity. All students are provided with a set of instructions for authors (guidelines for paper preparation). The deadline for the paper's submission is two months after the end of the course classroom activities. The purpose of this assignment is twofold: (a) every doctoral candidate becomes familiar with the style, structure and presentation of research in a typical written form, and at the same time gets used to conform to relevant guidelines, and (b) he can correctly write a research paper in terms of content, literature review, presentation of methods and results, and conclusions. The fulfillment of the first issue is evaluated collectively by the course instructor, while that of the second one is evaluated individually by the supervisor of every PhD student.

4. CONCLUSIONS

Any appropriate analysis based on recent reports and scientific papers dealing with the doctoral studies in higher education institutions shows that this educational form is indeed a dynamically changing issue, as many universities have been or still are in the process of a kind of reform in the structure and/or content of their educational programmes related to doctoral studies. Doctoral education, aiming at specific (research-related) knowledge acquisition and skills development, is more or less a distinct training process for doctoral candidates considered as early stage researchers. From such analyses two main conclusions can be drawn regarding the current trends: (a) to many doctoral education is an individual journey and, therefore, at a significant degree, it is the outcome of the relationship of the candidate with his supervisor, or even better, of the apprenticeship of the former by the latter, and (b) due to the rapidly increasing rate of research outcomes and products, particularly in the technological sector, and also to multiple transformations of the society and its needs, there is an equally rising demand for extra educational provisions to doctoral candidates, in the forms of learning research-related issues and developing skills of a similar kind.

As result of the above, most universities in Europe and elsewhere have adopted doctoral programmes that are a combination of individual supervision and coursework of various types. The latter takes place usually in the first stage of the doctorates and may consist of compact (integrated) modules, a number of individual courses on different subjects, usually of a semester-long duration, or a series of short-duration seminars on specialised issues.

The doctoral programme of the Department of Civil Engineering of AUTh consists of four individual courses, among which the one presented in this paper is the most closely related to all aspects of practicing research. It is worth noting that this is one of the very few examples of coursework, not even in the country but also abroad, on research methodology specifically for engineering. Due to the more or less modular form of the course's teaching and learning process, it could be alternatively considered as equivalent to a set of inter-connected short seminars. In any case, the course is considered a successful enterprise, not only by the instructor or the members of the Department, but especially by the postgraduate students who attended it during the last six years.

Necessary at the first stage but not sufficient for the whole time span of doctoral studies, the educational programme of the Department of Civil Engineering of AUTh should be complemented by a research training that would be more specialised, student-oriented, and tailored to the needs of every individual doctoral student. Self-education and self-training are important ways of acquiring the additional expertise and skills, but the much more valuable training is on the very hands of each supervisor who should provide it to his apprentices adequately and in good time.

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EUGENE: AN LLP ACADEMIC NETWORK FOR ENGINEERING EDUCATION

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EXTENDED ABSTRACT

Engineering and Engineering Education (EE) play an important role in the development of Europe. The opening of European EE to the world is a challenge for engineering academic institutions all over Europe. Yet, there are a lot of issues to be addressed. Among them are competitiveness, innovation and attractiveness of engineering education and especially of PhD training. These issues are closely linked with the emerging field of engineering education research and with the mobility, both within Europe and in a global scale of engineering students, graduates and professionals but also with lifelong learning and continuing engineering education. All the above issues demand close cooperation between European engineering academic institutions involving also industrial stakeholders. The Lifelong Learning Programme (LLP) Academic Network in the field of Engineering Education "EUGENE-EUropean and Global ENgineering Education" (October 2009 to September 2012) is an attempt to study all the above subjects. This is done through the five Activity Lines and the three Transversal Activities of the project: **Line A**-Structure and Bologna follow-up in the competitiveness issues of PhD studies, **Line B**-Promoting EE in Europe as a true research field, **Line C**-Improving transnational mobility of engineering students, graduates and professionals, **Line D**-Life Long Learning & continuing education as a tool to improve competitiveness and innovation of European engineers**, Line E**-Increase attractiveness of studies in science and engineering and to the European Higher Education Area**, TA 1**-Direct involvement of industrial stakeholders, **TA 2**-Promote the establishment of the standing European Engineering Deans Council, **TA 3**-Identify and put in practice sustainability tools beyond the 3 years of life of the project.

The 78 partners of EUGENE come from 32 countries. In addition, there are 6 associate partners from 4 other countries. Partners are not only higher education institutions but also engineering societies and associations like IFEES, SEFI, CESAER, EUCEET and APE, quality assurance institutions like ASIIN, ENAEE and CTI and companies like Dassault Systèmes and Hewlett-Packard.

KEYWORDS
LLP ERASMUS Academic Network, Engineering Education, European Higher Education Area, EUGENE

1. INTRODUCTION

In the last decade Engineering Education (EE) in Europe has been changing. Economic globalization, the Bologna Process, and many other factors have created an environment of continuous evolution. The introduction of the three-cycle structure has made engineering study programmes more accessible and more understandable, also to non–European students. Furthermore, the introduction of English in many Second Cycle and PhD programmes have helped European universities to attract more international students, teachers and researchers and to prepare their own graduates for a truly global environment.

Socio-economic growth and competitiveness are "technology driven" and EE plays a central role in supporting key factors such as innovation and entrepreneurship. This is particularly true for Europe because of its historic heritage and its worldwide role. On the other hand, after many years of cooperation within Europe, it is time for European EE to discuss and analyze its position in a global context. The opening of the European educational borders to the world makes mandatory the analysis of the strengths and weaknesses of European Higher Education (HE), especially if one takes into account the impressive figures of emerging HE areas in the world. This is more true for EE. The Lifelong Learning Program (LLP) Academic Network EUGENE-EUropean and Global ENgineering Education, being a large network representing all European countries, constitutes a truly pan-European project that will contribute to many key European policies related to EE at the highest level.

After its lifetime as a European supported project, EUGENE is expected to take the form of a permanent observatory flanking SEFI, possibly at the occasion of regular meetings, and work on, at least some of, its main activities. Thus, EUGENE is expected to offer a permanent service to the EE community in Europe.

2. THE COMPOSITION OF EUGENE

EUGENE started running in October 2009, the third in a series of successful Academic Networks related to EE: Enhancing European Engineering Edication-E4, Teaching and Research in Engineering in Europe-TREE and TREEdiss [1]. Its overall aim was stated as: Setting up a top level discussion and action forum to follow the continuous evolution of Engineering Education (EE) in Europe and enhance its competitive profile worldwide.

Because of the many and complex tasks of EUGENE, 5 Activity Lines and 3 Transversal Activities have been created. Each Activity Line and Transversal Activity is coordinated by one or two active academic or non-academic members [2]:

Activity Line A-PhD STUDIES: Structure and Bologna follow-up in the competitiveness issues (main question: are PhD studies in Engineering and Technology in Europe effective/innovative/competitive enough?)
In recent years in many universities in Europe doctoral schools have been established and doctoral programs are offered. In the past PhD consisted exclusively of individual research, under the supervision of a promoter/ advisor. Now, (advanced) courses are offered to doctoral students, trainings are organized; doctoral students participate in projects with industry etc. The proportion of these activities with respect to the individual research effort varies. Most of us are convinced that individual research should remain the backbone and the main constituent of PhD work. In many places we have already some experience with the doctoral programs and activities of doctoral schools. It would be most interesting to find out how effective these new activities are: are the PhD theses better? Are the PhDs better engineers? Are they better innovators or entrepreneurs? The

purpose of this Activity Line will be to collect information on the experience with different doctoral programmes and formulate recommendations for the future. Activity Line A will build on previous work by Academic Networks TREE [3] and European University Civil Engineering Education and Training (EUCEET) [4]. Expected outcomes:

- Guidelines for the introduction of a common set of excellence standards and principles in Engineering PhD programs.

In this context, a number of interviews have been set up and questionnaires sent to staff responsible for doctoral schools, doctoral students in the end phase of the PhD-who went through a doctoral program, employed in industry doctorate holders-who went through a doctoral program and employers of doctors (with and without PhD training). Among the preliminary conclusions the following can be listed [5]: The doctoral program should support and facilitate the PhD work and not be an extra burden. Because of big differences in the background (2nd cycle) of PhD candidates, in their character and talent, in the subjects, in research groups, in advisers, in aspiration for the future career etc, PhD programmes should be individualised: the different components should be offered, but the candidate himself should be free to make his own choice (with the help of his adviser) according to his own preferences, needs and aspirations (career perspectives). Further, a list of indicators aiming at Quality Measurement has been prepared in the form of a questionnaire and distributed to the members of Line A in order to be tested anonymously. The similarity of the answers showed the validity and strength of the relevant indicators [5]. The questionnaire can be accessed through the EUGENE web site, in the Documents area reserved for Line A [2].

Activity Line B-Promote EE in Europe as a true research field, with comparison to worldwide developments in Engineering Education Research (EER): a true and innovative research area to improve entrepreneurship, innovation and competitiveness

The second Activity Line is targeted to promote the recognition in Europe, as it already happens in other regions of the world, of EE as a true research area. In fact in order to develop the potential of European Higher Education institutions it is of paramount importance to identify aspects of the learning process where innovation is needed, putting in place the required research activities. These will require the contribution of researchers from the EE community as well as from other fields, as for instance social sciences and psychology, when possible already active in the study of the learning processes in science and engineering. A substantial part of this research activity will be devoted to measure the effectiveness of some of the suggestions contained in a frequently updated "repository" of guidelines for the enhancement of European Engineering Education. For doing this, the obvious tool is the diffusion of questionnaires, but other measuring tools must be designed, such as for instance experiments of small groups of institutions, so that this part of the Academic Network activity can qualify as true research in (engineering) education. Expected outcomes:

- Reports on: the current position and future trends for EER in Europe, European Taxonomy of EER, European EER methodologies accessible for EE staff and other interested;
- Series of Journal articles;
- Workshops on: existing research groups and research methods, working on taxonomy and research methodologies for engineering education research in Europe, impact of educational research and up-scaling of projects;
- European Summit on EER that will take place in K.U. Leuven on 28-29 of October 2011.

Activity Line C-Improve trans-national mobility of engineering students, graduates and professionals

This Line will involve two main aspects: (a) within the European Higher Education Area (EHEA), that is checking and improving the applicability and consistency (in the

Engineering field) of the European Qualifications Framework, the EU Directive on Recognition of Professional Qualifications, Accreditation Standards and other relevant "European" documents and (b) on the global scale which will imply the comparison of the "European" documents with other documents and agreements (Washington and other Accords in the international education area, but also regional and national Standards in other parts of the world: e.g. North Africa, S.E. Asia, Latin America); tentative agreements for mutual recognition. Both aspects should involve not only the "academic" side, but also the "professional training" (and "Vocational education and training"). Expected outcomes:

- Round Table Discussion "Towards a globally shared Glossary of terms in engineering programme accreditation and quality assurance: a preliminary public presentation and discussion";
- High Level European Qualifications Frameworks and Engineering Standards: a critical comparative review and suggestions for improving applicability and consistency;
- Comparison of the EUR-ACE Standards and the requirements of the Washington and Sydney accords;
- Glossary-A tentative towards a globally shared Glossary of terms in engineering programme accreditation and quality assurance;
- Engineering Standards worldwide: a comparative collection;
- Proposals for Mutual recognition of engineering degrees and qualifications.

Activity Line D-Life Long Learning (LLL) and Continuing Education (CE) as a tool to improve competitiveness and innovation of European engineers
European universities are facing enormous challenges in developing their LLL practices and processes to help European working life to meet the requirements of fast change towards the new business logic of global industrial value networking. A practical consequence of this is that the necessary competence development of knowledge professionals and other academic level experts is becoming more complex. Requirements for systemic lifelong professional development are increasing. The latest research results need to be integrated to the CE programmes and these to be transformed to become facilitated work-based learning practices, where innovation and effective use of Information and Communication Technologies (ICT) are the most critical success factors. Productivity and innovative use of ICT are prerequisites for competence development and through that for empowerment and social well-being. Universities' knowledge based on research is, however, not well utilized in societal interaction. The purpose of this Activity Line is by the help of benchmarking good practices and analysing the latest university research results in this focus area to conceptualize the needed actions in the university-industry collaboration. Special focus is on the modern use of ICT and the orchestration of the activities to increase synergy between and through that societal impact of research, teaching and the third mission operations. The major outcomes within Line D will be conceptualized core processes with benchmarked good practices and implementation manual. By the help of these universities can develop their LLL and CE activities as a powerful tool for employability and competitiveness of European engineering graduates. Expected outcomes:

- Concepts and tools for: increasing university's societal impacts, university's own innovativeness, improving university's own productivity.

Activity Line E-Increase attractiveness of studies in science and engineering and to the EHEA: involve students in organisations (Erasmus Mundus Network, TEMPUS Mediterranean, as follow-up) and promote awareness outside the EU of EE evolution and opportunities
The main aim of the activities of this working group will be to identify examples of good practice enhancing the attractiveness of engineering as a career both to traditional and non-traditional groups. The focus will be on attracting students of the right quality to both Bachelor and Master's degrees. Expected outcomes:

- Examples of good practice
- Reports outlining: the attributes that increase prospects of employability, the issues and potential barriers

Three Transversal Activities (TA) are supporting the Network:

TA1-Direct involvement of industrial stakeholders (European corporations with global dimensions) in all above Activity Lines A to E, with an active contribution. Expected outcomes:
- Professional Development Workshop;
- Handbook of practices.

TA2-Promote the establishment of the standing European Engineering Deans Council (as an interlocutory body with the newly established Global Engineering Deans Council-GEDC by the International Federation of Engineering Education Societies-IFEES). Expected outcomes:
- Joint GEDC/EUGENE forum;
- Establishment of the European Engineering Deans Council. The Kick-off meeting took place in Lisbon on September 27, 2011.

TA3-Identify and put in practice sustainability tools beyond the 3 years of life of the Academic Network, by means of: 1) ensuring visibility through an interactive web-site (informatic portal), 2) set-up a frequently updated “repository” of guidelines for the enhancement of European EE visibility world-wide, 3) foster the creation of a “Florence EE Group/Network” (an Academic Network like the Utrecht, or Coimbra ones, grouping Universities to work exclusively on EE items and future projects/initiatives).

International Advisory Board (IAB): The activities of the project are monitored by a three-member IAB. In order to ensure the independency of the experts the members of the IAB work on a subcontract basis and are not affiliated to any of the project partners. The members of the IAB have been nominated by the Management Committee on the basis of their solid experience in the field of Engineering Education and quality assurance issues. The IAB is delivering evaluation reports on the progress of EUGENE.

3. CONCLUDING REMARKS

EUGENE has now arrived at a crucial milestone: the last year of the project. The structure is set, the partners are actively involved, the web site is running and the activities are fully operating. It is therefore time for real actions to take place in order to demonstrate that such large cooperation projects are not a waste of time and public money but a concrete tool for the enhancement of the attractiveness of the European Higher Education Area, contributing to the global dimension of Engineering Education.

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DOCTORAL STUDIES QUALITY ASSURANCE AT UNIVERSITY OF RIJEKA WITH EMPHASIS ON STUDIES IN CIVIL ENGINEERING

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EXTENDED ABSTRACT

During 2005 all study programmes at Croatian universities underwent reforms according to Bologna declaration. Within the changes, the existing university postgraduate doctoral studies were reformed and the new ones started. There are 11 active postgraduate doctoral studies at the University of Rijeka today, among which the postgraduate university doctoral study of Civil Engineering performed by the Faculty of Civil Engineering was also started in 2005.

In order to assure the quality of doctoral studies and increase the doctoral studies completion rate at the University of Rijeka, the Postgraduate Studies Evaluation Board together with the Centre for Science and Centre for Quality Improvement of University of Rijeka has made the assessment plan for all doctoral studies and conducted the doctoral studies implementation evaluation at the University of Rijeka. The evaluation was based on self-evaluation report, doctoral student surveying and doctoral studies development plan.

This paper specially refers to the evaluation of university postgraduate doctoral studies at the Faculty of Civil Engineering, University of Rijeka, as well as to the recommendations made in order to improve this study. In implementing the doctoral studies evaluation, the Faculty of Civil Engineering has recognized the possibility of a systematic quality analysis of this study, the results of which are the base for its improvement.

In our opinion, the doctoral studies evaluation model established at the University of Rijeka and the experience made during the implementation at the Faculty of Civil Engineering are worth presenting to the representatives of facilities engaged in education of civil engineers as an example of good practice.

KEYWORDS

Bologna declaration, Study programme reform, Postgraduate university doctoral study, Evaluation, Postgraduate doctoral study of civil engineering

1. INTRODUCTION

During 2005 all study programmes were reformed according to the Bologna declaration principles at all universities in Croatia. The main principles of the Bologna declaration which are the base of the high education reform are the following [1]:

- adoption of a system characterized by easily recognisable and comparable academic and professional grades and introduction of a Diploma Supplement which enables easier employment and international competitiveness,
- adoption of a system based on two main cycles, the pre-graduate and the graduate, followed by the third, doctoral postgraduate cycle,
- introduction of ECTS (European Credit Transfer System) credits as an indicator of student obligation amount,
- promotion of mobility and impediment overcome to student and teacher circulation,
- promotion of European standards in quality assurance and
- promotion of a European dimension in high education.

Introduction of the aforementioned principles is conducted within the study programme domain while the principle implementation is based on introducing changes into the very educational process which includes new teaching methods, more student activity in classes, larger amount of independent student work outside classes and other.

The expected outcome is that the studies enable students not only to acquire the basic and technical knowledge but also specific general competences which are encouraged through European education systems so that upon completion of the studies the students are more qualified for work and, at the same time, also prepared to improve their knowledge and professional skills. Besides technical knowledge, the developed learning skill, proficiency in mother tongue and one foreign language, mathematics, entrepreneurship, social skills within a multi-cultural surroundings and good manners are the required competences at the European parliament level. Since those are the basic elements of the European education policy, the introduction of those into the Croatian high education, where all the stated elements must be transparent, was an imperative. By reforming the existing and introducing the new study programmes, the University of Rijeka (Figure 1) has been developing in the mentioned direction.

Figure 1: University of Rijeka (Croatia) – Location

A new model of university studies has been introduced which has three education cycles at most faculties, this being 3 + 2 + 3 years. Within this model the pre-graduate study lasts for 3 years, the graduate study for 2 years and the doctoral study for 3 years (Figure 2). At some faculties the pre-graduate and the graduate studies are performed as integral studies in duration of 5 or 6 years (Faculty of Medicine and Faculty of Law) which are followed by a postgraduate doctoral study cycle.

Within the above mentioned reform, the existing studies have been reformed and the new university postgraduate doctoral studies introduced. The University of Rijeka has 11 active postgraduate doctoral studies today among which is the postgraduate doctoral study of Civil Engineering which was introduced in 2005 and is performed by the Faculty of Civil Engineering, University of Rijeka (Figure 3).

UNIVERSITY STUDIES

PRE-GRADUATE STUDY
3 years
180 ECTS
University baccalaureus/baccalaurea of the profession

GRADUATE STUDY
2 years
120 ECTS
University master of the profession

POSTGRADUATE DOCTORAL STUDY
3 years
180 ECTS
Doctor of science (Ph.D.)

Figure 2: The most common schemes of university studies at faculties of University of Rijeka

Figure 3: Faculty of Civil Engineering, University of Rijeka

According to the Strategy of University of Rijeka [2], the University goal is to become a research university with the established research profile, quality centres, collaborative research projects, institutional care for development of research careers and a doubled scientific production.

In order to ensure the doctoral study quality and increase the success rate of doctoral study completion, by the Resolution of the Senate dated on May 12th 2009 the University of Rijeka founded a Committee for Postgraduate Study Assessment whose task is to implement the assessment of postgraduate study programmes which have executed at least one year of study.

The paper presents the procedure and the results of the conducted assessment of all postgraduate doctoral programmes at the University of Rijeka in detail with special regard both to the assessment of the university postgraduate doctoral study of Civil Engineering which is being performed at the Faculty of Civil Engineering, University of Rijeka and to the recommendations made for improving this study.

2. POSTGRADUATE DOCTORAL STUDY PROGRAMME ASSESSMENT PROCEDURE AT UNIVERSITY OF RIJEKA

As aforementioned in the introduction, the postgraduate doctoral study programme assessment at the University of Rijeka was based on self-evaluation of study holders, surveying of doctoral candidates and doctoral study development plan. When assessing the doctoral programmes, the outcomes and tasks stated in the Strategy of University of Rijeka as well as the principles of the European Research Charter according to the European Researcher Conscription Codex had to be taken into account. Besides a thorough analysis of programme implementation and standard quality evaluation parameters, the following parameters were included into the assessment process:

- tutorial capacity of studies and advisors' systematic supervision of student progress;
- advisor selection criteria;
- duration of studies, that is, the length of time required for completion of doctoral thesis after study enrolment;
- investments into the doctoral studies and doctoral candidates;
- the opportunity of being educated at other institutions during doctoral studies;
- the involvement of participating in doctoral studies and advisorship when setting teaching quotas.

In order to introduce the resolutions of the Senate and the assessment, the outcomes and the tasks had to be made concrete. The self-evaluation form and the doctoral candidate surveying form (questionnaires) were prepared. The University Board for Quality and the vice-deans for science affairs of all University components stated their opinion on the forms. Each component of the University had to have the self-evaluation of their doctoral programme conducted. The Committee founded an "evaluator base" which includes eminent Croatian and foreign scientists. The schedule for new doctoral study implementation assessment which undergoes the evaluation was created for each University component. Those are study programmes which have executed at least one year of study.

The Self-evaluation form and the student questionnaire were forwarded to the Faculties and University Departments which were also expected to make the self-evaluation report within a month. The reports were then forwarded to external evaluators for judgement and in the meantime the dates for expert team visitations were arranged with heads of institutions.

Expert team members visited the components and, based on the self-evaluations and student questionnaires as well as visits to the institutions, entered their opinions and remarks about the doctoral studies into the forwarded forms which were then delivered to the University of Rijeka. The Committee has included all evaluations into the Study – Doctoral Study Implementation Assessment at University of Rijeka. Based on evaluator opinions, that is, the final reports of the Doctoral Study Implementation Assessment at University of Rijeka, every component was requested a statement. Then the Committee for Postgraduate Study Evaluation wrote the final report containing recommendations about improvement/changes in implementing doctoral studies at each component of the University. The Faculties and University Departments which have so far not sent the postgraduate doctoral study programmes to accreditation or have not been performing such programmes are asked to discuss the matter and make a plan of their contribution to the development of the University as a research university.

The conducted assessment has pointed out that the doctoral studies of University of Rijeka have been assessed as relatively good, but that there are some deficiencies. It seems that different evaluation groups were unequally critical towards the present state and that some of the proposals do not concur with the University development strategy or are not in accordance with the positive legislative regulations of Republic of Croatia.

The main objections of the committees and the problems which were pointed out regarding one or several doctoral studies of the University of Rijeka can be shortly presented in relation to the Faculties:

- A better selection of the doctoral candidates must be performed (School of Medicine, Faculty of Maritime Studies).
- There is an unequal treatment of doctoral candidates who are employees of the faculty and those who are not, which occasionally creates problems (Faculty of Engineering, Faculty of Humanities and Social Sciences).
- The research priorities should be better defined (School of Medicine).
- The criteria for teachers and advisorship should be better defined (School of Medicine, Faculty of Civil Engineering, Faculty of Maritime Studies).
- The advisor should have a greater influence in selecting the doctoral thesis topic (Faculty of Engineering).
- The submission of the doctoral thesis topic upon registration for the second year of studies is untimely (Faculty of Economics).
- The number of courses should be reduced (School of Medicine, Faculty of Engineering, Faculty of Civil Engineering, Faculty of Humanities and Social Studies).
- Number of elective courses: too large a number of elective courses at the School of Medicine makes the teaching more difficult; on the other hand, the students of Faculty of Economics are of opinion that the number of elective courses is far too small.
- Teaching in English should be introduced so that experts from abroad could be involved in the teaching process (School of Medicine).
- Financing the studies only from tuition fees is insufficient for conducting studies of high quality (Faculty of Civil Engineering, Faculty of Humanities and Social Sciences).
- The premises, the equipment and the professional literature are insufficient (Faculty of Civil Engineering, Faculty of Humanities and Social Sciences).

The Committee for Postgraduate Studies recommends the Senate to give consideration to the stated objections of the evaluators and accordingly oblige the faculties to particular changes in implementing their doctoral studies, which has been done.

3. ASSESSMENT OF POSTGRADUATE DOCTORAL STUDY OF CIVIL ENGINEERING AT THE FACULTY OF CIVIL ENGINEERING, UNIVERSITY OF RIJEKA

3.1 Description of the doctoral study programme

The Faculty of Civil Engineering of the University of Rijeka runs a doctoral study programme organized within the subject areas of Geotechnics, Hydraulics, Materials, Fluid Mechanics and Mechanics of Solids and Structures.

The main objective of the study programme is to endow the students with efficient education on the basis of the proposed educational and research activities, including the expansion of their existing knowledge, skills and expertise through conducting original scientific research activities. Such activities must meet the internationally accepted quality standards and contribute significantly to the development of the scientific thought within one of the fields of research available at the Faculty. After the completion of the study programme, the students are qualified to independently conduct advanced scientific research. An additional objective of the doctoral study programme is to develop or enhance the ability of students to present their work, lead a debate providing logical argumentation in regard to positive scientific facts (related to information, problems and possible solutions) to the professional and non-professional audience.

Monitoring the quality of the programme is of key importance and is being conducted through various forms of evaluation and self-evaluation of teachers, students and the related services, through supervision of the implementation and delivery of the study programme, and by accepting objective quality measuring methods [3].

The study programme lasts six semesters, during which time the students acquire 180 ECTS if they complete all their study obligations successfully. The semesters are not necessarily linked to the academic years (apart from the first semester in which the obligatory courses are being lectured) and the students are free to adapt the rhythm of studying according to their other obligations and abilities. The study obligations are divided in three categories:

1. Taught (educational) study obligations – attendance to core and optional courses and taking exams on the basis of which the students earn at least 48 ECTS, including
   1.1 Core courses within a chosen subject area by means of which the students earn 30 ECTS;
   1.2 Optional courses by means of which the students earn at least 18 ECTS.
2. Research activities, by means of which the students earn at least 120 ECTS.
3. Additional study obligations in teaching and knowledge transfer by means of which the students earn at least 12 ECTS.

During the first semester the students are introduced to the theoretical basics essential to the chosen subject area. During the second semester the students take optional courses and commence with the research leading up to the selection of the doctoral dissertation topic. During the third semester the student starts with the doctoral dissertation research activities, the topic of which must be registered and publicly defended during the semester in order to be accepted by the Faculty Council at the end of the semester. During the fourth, fifth and sixth semesters the student dedicate their time fully to doctoral dissertation research activities, including the process of writing it up. The procedure is explained in more detail in [3].

At the enrolment in the study programme the student is appointed a counselor and within the period of two semesters, the Faculty Council must confirm the student's choice of counsellor as a thesis supervisor or appoint another supervisor. Twice a year (January and July) the consellor/supervisor submits to the Dean the Student Progress Report. The report gives a concise evaluation of the student's work during the last six months, his/her progress in the framework of the overall study programme, and the estimated dynamics of the further course of study.

The student must submit an application for acceptance of the chosen dissertation topic at the beginning of the third semester and publicly defend the proposed topic of his/her doctoral dissertation before the relevant committee appointed by the Faculty Council.

After the completion of the doctoral dissertation and fulfilling all other doctoral study obligations, the student submits a written application for evaluation of his/her doctoral dissertation. The article in which the student, as the first author, presents the results and findings of his/her entire research conducted during the preparation of the doctoral dissertation or a part of it must be published in one of the reputable SCI non-domestic journals. The doctoral dissertation is evaluated by the Doctoral Dissertation Evaluation Committee. If the Faculty Council receives a positive report on the doctorate dissertation, it appoints a Doctoral Dissertation Defence Committee. The defence of the doctoral dissertation is also public. After the doctoral dissertation has been defended, the Doctoral Dissertation Defence Committee reaches a decision on the results of the doctoral dissertation defence which is publicly announced.

3.2 Self-evaluation and student questionnaires

All surveys and interviews have been conducted on the University forms prepared beforehand and made available to the external evaluators along with the actual study programme. Various methods and procedures have been used to monitor and evaluate the quality of teaching and the effectiveness of course delivery:

1. Surveys and interviews with students in regards to all aspects of the teaching process:
    - Regularity and organization of course units,
    - Literature,
    - Methods of improving the quality of teaching,
    - Exams,
    - Communication and cooperation with lecturers,
    - Course programme and methodology of delivery.
2. Public presentation of results obtained on the basis of surveys and interviews,
3. Analysis of the examination system (performance, transparency, objectivity, and the like).

3.3 External evaluation

External evaluators have visited the Faculty and met with Dean and the member of the management, members of the Postgraduate Study Board, teachers, students and the administrative staff. Principally, they concluded that the proposed postgraduate doctoral study programme is well organized, well written, the subject is contemporary, the teachers are highly qualified and the proposed doctoral study is comparable to the study on other high qualified universities.

However, they have drawn the attention to the following points which require action for improvement [4]:

1. An appropriate University body should verify and confirm thesis selection;
2. As the work on the doctoral thesis is considered the core of the study, it is advised to increase the proportion of elective courses while at the same time decreasing the total study load related to formal subjects to at most 20% of the total study load, make elective courses less teaching and more learning orientated, and make elective courses more related to the selected thesis (e.g. by declaring possible theses directions prior to particular thesis selection, and selecting electives within this directions);
3. Nominal duration of two years for the work on a thesis is traditionally considered insufficient in engineering fields and should be increased to e.g. three years for a full time student. Increasing the percentage of time dedicated to research is suggested;
4. Somewhat insufficient is the distribution of scientific articles in good journals per lecturer. More consideration should be paid to this deficiency in the future in order to ensure the quality of study. At the same time, according to the world trends, for the rating of teacher quality more thought should be paid also to ensure adequate number of citations in high quality journals;
5. Perhaps there is not enough cooperation on international projects, which can however be increased with the active Faculty politics;
6. According to regulations, a supervisor should at the same time be an active researcher. In principle, this is demonstrated with the number of published scientific articles in high quality journals (journals in Science Citation Index Expanded base). Since this criteria, as noted, is not defined quantitatively yet, we suggest to make it formal in the way that the supervisor should have a certain number of papers published in good journals with adequate citation record.
7. The number of students per mentor seems in some cases rather high (two mentors have six PhD students each.)
8. It would be advisable to implement a formal complaining procedure that students could safely undertake whenever necessary.
9. The accessibility of scientific literature is accordingly regulated, but nevertheless, more attention should be placed on it.

As examples of good practice the evaluators pinpoint the following:

1. The PhD student needs to actively participate at another scientific institution for one semester during his study. This can take place in the Republic of Croatia or abroad. This aspect of study is extraordinarily positive since it may give a flavor of international research to the students and help establish international cooperation for the teaching staff.
2. An important requirement is also that the candidate needs to write at least one scientific paper related to his thesis, which must be issued in an elite scientific magazine. This extraordinarily useful requirement ensures additional quality of the PhD thesis but may be tough for part time students working elsewhere.

3.4 Faculty closure

The Faculty has closely examined the evaluators' report and decided to take the following steps to improve its study programme:

1. Support the idea that thesis selection should be approved by a newly formed University body and pass the initiative to University;
2. Support the finding that doctoral study programmes in engineering require at least three years of full-time research work on the thesis. As some teaching is necessary in the

third-cycle Bologna stage (old MSc courses do not exist anymore) [4] doctoral study programmes should of necessity last at least four years and carry 240 ECTS. Pass the initiative to University and prepare for a modification of the study programme in future.
3. Support the suggestion that the selection of teachers and in particular the supervisors should be made depending on their scientific output in reputable international journals and prepare for a modification of the study programme in future.
4. Make the international collaboration on the grounds of joint research projects a strategic goal for the Faculty.

4. CONCLUSION

The conducted assessment has pointed out that the doctoral studies of University of Rijeka have been assessed as relatively good, but that there are some deficiencies. It seems that different evaluation groups were unequally critical towards the present state and that some of the proposals do not concur with the University development strategy or are not in accordance with the positive legislative regulations of Republic of Croatia. This can partly be explained by the fact that the consulting editors are mostly foreigners who are not familiar with the Croatian legislative regulations.

The evaluation which was conducted at the postgraduate doctoral study of Civil Engineering has also resulted in a fairly well assessed programme with lesser constructive objections. The Faculty management has taken the conducted assessment very seriously. Based on observed deficiencies an improvement programme has been created and is prepared to be implemented.

Based on the objections of evaluators, the Committee for Postgraduate Study Assessment and the Senate of University of Rijeka has obliged the all faculties to introduce programme and implementation changes of postgraduate doctoral studies which they perform.

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DOCTORAL STUDIES: IMPLEMENTATION AND PERFORMANCE OF EDUCATION AND RESEARCH PROGRAM AT THE FACULTY OF CONSTRUCTION MANAGEMENT IN BELGRADE

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EXTENDED ABSTRACT

The preparations and later implementations of the Bologna process at universities in Serbia started at the beginning of the last decade. Apparently, this process was the most slowly developed in the field of doctoral education. Possible reasons for this could be concerned with the low interest of civil engineering students for pursuing the PhD studies from the practical standpoint as well as changes in the evaluation systems and requirements addressed to academic staff supposed to carry out the curriculum and mentorship. In addition, better relations and cooperation between faculties and scientific and R&D institutes must be established dealing with PhD courses. However, doctoral studies in Serbia are on their way to define integrative framework comprising research and education. The Faculty of Construction Management is one of the two civil engineering faculties in Belgrade which has been accredited for PhD program by Serbian Ministry of Education and Science. In order to provide students with the state-of-the-art knowledge and various research topics, several prominent professors who are leading experts in their fields are engaged from universities in USA and UK. Distance problem considering that students and professors live in the different states has been overcome by the use of the latest ICT approaches. The aim of this paper is to present the conceptual and organizational aspects of the doctoral studies at The Faculty of Construction Management with implementation of new teaching and learning technologies based on IP and up-to-date software tools. Special efforts have been made to include the best PhD students in scientific and R&D projects supported by Serbian Ministry of Science and Technological Development. There is considerable interest to participate in European FP6 and FP7 programs as well as in bilateral cooperation with universities in neighbor countries. Young researchers have been stimulated to publish investigation results under the leadership of their mentors. For the sake of illustration, PhD course topics in structural engineering are presented with the emphasis on curriculum, implementation of new technologies in teaching and learning, and inclusion of PhD students in scientific and R&D projects.

KEY WORDS

Civil engineering, Doctoral studies, Education and research, New teaching and learning technologies.

1. INTRODUCTION

The functioning and development of national and regional socio-economic systems depend on the increasing level of general education, professional expertise and usability of skills and knowledge. Therefore, it is not surprising that the European Union has chosen the development of knowledge society as its way to progress. The education process has become more complex and longer, and the need for continuous acquisition of new knowledge and skills has been more expressed. In this context, doctoral studies, especially regarding the strong research component, are recognized as a crucial factor in generating and improving the creative society and the innovative economy [2].

In order to complement the existing information on various experiences in implementation of Bologna process in PhD programs, this paper gives an illustration and analysis of education and research program at the Faculty of Construction Management in Belgrade. At the beginning we highlight the substantial changes that implementation of the Bologna process has brought to the European PhD education and then continue with the brief overview of reforms in Serbian higher education. In the main part of our study, we present PhD course topics in structural engineering as the example of doctoral studies program at the Faculty of Construction Management (FCM) in Belgrade and analyze to which extent this program overcomes certain problems and succeeds in providing the high-quality education and research conditions.

2. PhD STUDIES IN EUROPEAN CONTEXT

The doctoral studies were not directly involved in the Bologna Process until the Conference of European Ministers of Education in Berlin in 2003. This form of higher education was for the first time incorporated as a third level of study at the conference. The exclusively research-based character of PhD courses has been changed by including the teaching component and consequently making these studies more strongly linked to the previous two higher education levels (Bachelor and Master). The old definition of doctoral studies as a generator of new, original knowledge has been relativized in the sense that PhD level should be an open system where knowledge is generated and transmitted at the same time [4]. Also, contemporary doctoral studies have become more oriented to multidisciplinary fields so the possibilities to implement gained experiences and knowledge are now wider and more varied. Having this in mind and the fact that soft-skill workshops and trainings are more often included in PhD programs, it becomes more common that doctors of sciences have not been employed only at universities and laboratories but also as advisors, experts, project leaders and managers in large firms and corporations, as well as in political and economical institutions.

The inclusion of doctoral studies as a third cycle in the Bologna process has created new opportunities but has also opened a number of questions for which there are no simple answers. They are as follows: 1) considerable diversity in the organization and structure of individual programs caused by rapid changes in the global labor market, 2) implementation of new, innovative mentoring methods and multiple mentorships due to the increasing multidisciplinary nature of PhD studies, 3) internationalization through the development of joint doctoral programs, 4) mobility of the researchers etc. With regard to civil engineering education, some of these issues were studied in the third project of the EUCEET (European Civil Engineering Education and Training) Thematic Network started in 2006 on the basis of a 3-year grant.

3. DOCTORAL STUDIES IN SERBIA

Reforms and harmonization process in the field of higher education in Serbia started with two significant events: 1) signing of the Bologna Declaration in September 2003 and 2) adoption of the new Law on Higher Education in September 2005. Comparison of the structure of higher education under the old and the new law is given in Figure 1. We can see the reduction of the nominal time required for completion of doctoral studies from 11-12 to 8 years.

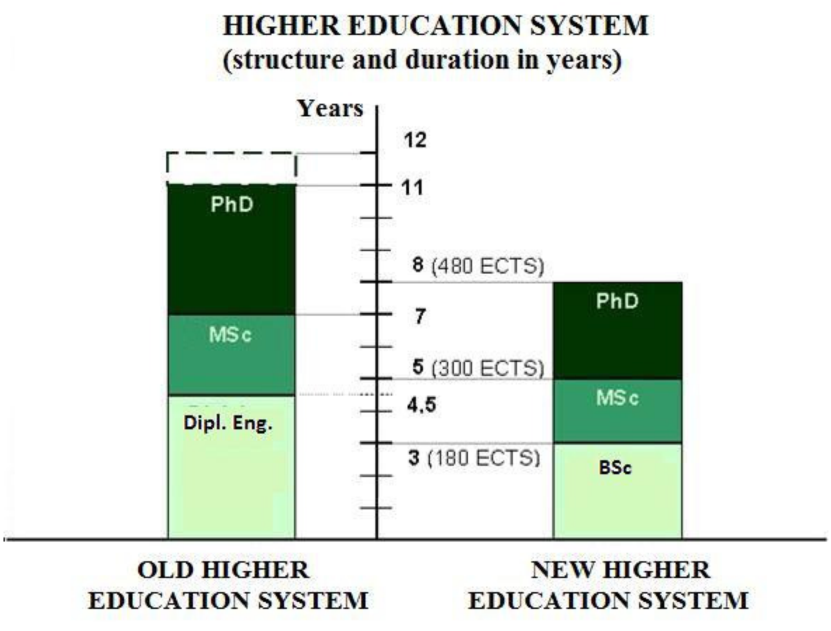

Figure 1: Comparison of nominal time required for completion of doctoral studies under the old and the new Law on Higher Education [4]

The period of transition for Masters of Science and postgraduate students under the old law to defend their doctoral dissertation was extended to 2016 according to the Amendments of new Law on Higher Education in June 2010.

The first implementation of new program of doctoral studies in Serbia started in 2006. This process was difficult and with a lot of starting uncertainties due to the fact that doctoral studies were sparsely covered by Serbian Law on Higher Education [6] and one can only find few clauses related to this issue:

- Credit hour requirements for PhD level corresponds to 180 ECTS (European Credit Transfer System) and the requirement for the admission of applicants is that they have previously realized at least 300 ECTS at lower education levels (Bachelor and Master);
- The doctoral dissertation is the final part of the study program at the doctoral studies implying that research and teaching process, mentorship, as well as PhD thesis submission and defense procedures should be regulated by General Act of higher education institution;
- Ranking conditions for acceptance of candidates on PhD programs are prescribed by General Act of higher education institution.

It is evident that Law on Higher Education left the higher education institutions to individually define plenty of issues such as application requirements, curricula, additional trainings and workshops, dissertation structure and defense procedure etc. Accreditation of doctoral studies has brought more clarity and order to this area.

Serbia has 8 state and 11 private universities. PhD programs in civil engineering have been accredited at 4 of them: 1) Faculty of Civil Engineering - University of Belgrade, 2) Faculty of Civil Engineering and Architecture - University of Nis, 3) Faculty of Technical Sciences in Novi Sad and Faculty of Civil Engineering in Subotica - University of Novi Sad, and 4) Faculty of Construction Management - University “Union Nikola Tesla”.

Strategy of Scientific and Technological Development in Serbia for period 2010-2015 was adopted in July 2010 [7]. Seven research priorities, including civil engineering, have been established with the emphasis on:

- Improvement of research infrastructure,
- Creation of Serbian Scientific Center,
- Stimulation of young researchers and PhD students to participate in R&D projects financed by the budget,
- Optimal usage of experimental facilities through mandatory cooperation of relevant institutes and faculties.

4. DOCTORAL STUDIES AT THE FACULTY OF CONSTRUCTION MANAGEMENT IN BELGRADE

The Faculty of Construction Management (FCM) was accredited as a scientific and research institution by the Serbian Ministry of Science and Technological Development in January 2007, while accreditation of study programs for three levels of higher education (undergraduate, Master and Doctoral) was realized in May 2009. Civil and construction engineering requirements for the PhD degree relate to academic regulations (program standards, thesis requirements, credit hour requirements) and procedural elaborations (selection of mentor, forming a committee, review of study program, qualifying examination concerned with PhD theoretical basis, PhD thesis submission and defense).

Doctoral studies comprise two programs: 1) structural engineering and 2) management of sustainable development in construction. Considering the limited scope of this paper, the authors will focus on the structural engineering program, particularly to the education and research program in the area of vibration serviceability.

The key points of structural engineering PhD program defined by FCM are:

- Development of the exceptional expertise in the major area,
- Providing the background and adjunct knowledge required to practice or teach this specialty at the highest professional level and to conduct significant research in this field,
- Providing significant and original contribution to engineering knowledge.

The authors have made the list of most relevant aspects of the program in order to give the systematic presentation and analysis.

4.1 Model of studies

Serbian Law on Higher Education [6] prescribes the model of PhD studies based on the Bologna principles (structured program which comprises individual research and coursework). This model is established at all universities and higher education institutions in Serbia.

Doctoral studies at FCM last three years, although they can be extended to at most six years in the case of experimental research. The total number of ECTS attached to doctoral studies in structural engineering is 180, where 105 ETCS are realized through 4 obligatory and 4 elective courses examinations, 15 ETCS for qualifying examination of theoretical basis of doctoral dissertation, 40 ETCS assigned to two study research works towards PhD thesis and 20 ECTS by completing and successful defense of PhD thesis [1].

4.2 Admission

The main requirements for application to structural engineering PhD program are at least 300 ECTS gained at both BSc and MSc levels in the related field as well as high grades and proven research ability. These criteria are used in order to rank and select applicants [1].

4.3 Curriculum

Doctoral study program in structural engineering consists of 3 phases: 1) coursework intended to improve the student's knowledge in the field of interest and to provide tools for individual research (first 3 semesters), 2) theoretical foundations of PhD thesis - initial research which comprises review of the relevant literature, classification and comparison of existing approaches and solutions for the chosen problem (1 semester), and 3) research work, submission and defense of PhD dissertation (2 semesters). Curriculum example for structural engineering PhD program at FCM is presented in Table 1.

Table 1: Curriculum example for structural engineering PhD program at FCM.

N^o	Course description	Course status	Semester	ECTS
1	Methodology of scientific and research work	obligatory	1	5
2	Selected topics in mathematics	obligatory	1	10
3	Selected topics in computational mechanics	elective	1	15
4	Selected topics in management and ICT in civil engineering	elective	1	15
5	Selected topics in concrete structures	elective	2	15
6	Total quality system control in civil engineering	elective	2	15
7	Selected topics in geotechnical engineering	elective	2	15
8	Selected topics in international projects management	elective	2	15
9	Selected topics in theory of structures	obligatory	3	15
10	Selected topics in earthquake engineering	obligatory	3	15
11	Selected topics in fracture mechanics	elective	3	15
12	Selected topics in civil eng. companies management	elective	3	15
13	Theoretical foundations of doctoral dissertation	obligatory	4	15
14	Study research work I - PhD	obligatory	5	30
15	Study research work II - PhD	obligatory	6	10
16	Doctoral dissertation (submission and defense)	obligatory	6	20

Coursework in the first phase consists of 4 obligatory and 4 additional elective courses, out of the offered list. The list of elective courses covers most important and fundamental fields of civil engineering and PhD candidate selects them in consultation with mentor and relevant professors. Usually, the student is required to complete satisfactorily examination of the theoretical basis of the selected course topics and to give a seminar on the topic suggested by student and approved by professor. Total numbers of active teaching classes per year during doctoral studies are given in Table 2. These classes comprise lectures, exercises, individual research work and other teaching activities.

Table 2: Total number of active teaching classes for structural engineering program at FCM.

N^o	Study year	Total number of active teaching classes
1	First	630
2	Second	600
3	Third	600
4	Total	1830

Better correlation between courses and research work was requested by PhD students, according to the survey on the quality of doctoral studies in Serbia, carried out by The Association of PhD Students and Young Researchers of Serbia [3]. Transferable skills trainings are not included in structural engineering PhD program at FCM. This problem is partially solved at the PhD program in vibration serviceability by the mentor who recommends the literature on these topics (e.g. “Your PhD companion” by S. Marshall and N. Green etc.).

4.4 Mentorship

Mentors are selected among professors working at FCM or scientists and researchers employed at R&D institutes who have published minimum 5 papers in international journals from SCI list in the relevant field in the last 10 years [1]. Except the mentioned formal requirement, FCM policy implies that mentors should be experts in the concerned scientific field with great experience in both teaching and research areas. Thus, several professors who are leading experts in the areas of interest are engaged from universities in USA and UK. If a PhD project is multidisciplinary, it is a practice that two mentors are assigned for mentorship (competent in different scientific disciplines).

Students choose research areas and corresponding mentor shortly after they enter the PhD program in structural engineering at FCM. Structural engineering PhD program covers several research topics such as vibration serviceability, earthquake engineering, geotechnical engineering, and computational mechanics. We shall pay particular attention to vibration serviceability PhD studies in the following sections.

Mentor assigned to the field of vibration serviceability is a prominent professor at the Department of Civil & Structural Engineering of Sheffield University. The key operating concept proposed by the professor is multitasking work. Students are advised to review the relevant literature and master necessary software and information management tools simultaneously with course attendance in the first year of studies. This model of student engagement in initial research related to PhD thesis at the very beginning of the studies leads to the publication of approximately two scientific papers and involvement of students in scientific projects in the second year of studies. Monitoring and evaluation of students work is accomplished through reports that students are required to regularly submit every month.

4.5 Implementation of new technologies in teaching and learning

E-learning, primarily referring to computer and network based transfer of skills and knowledge, becomes increasingly popular and utilized at all levels of higher education in Serbia. The Government National Counsel for Higher Education determined 12 standards for a study program that must be fulfilled for accreditation. The last one deals with distance learning. Considering the differences between distance learning and e-learning there is an opinion that 12th standard should be rewritten and put in the broader context. More information about this topic can be found in [5].

Negotiations on the procurement and implementation of Blackboard platform, consisted of Learn, Content and Community modules, started at FCM in March 2011 and finalization of the process is planned in October 2011, before the beginning of the upcoming school year. The platform will speed up and facilitate administrative work and remarkably improve the quality of teaching, consequently opening the way to distance learning opportunities and better cooperation with other faculties and R&D institutions.

Considering the fact that mentor in the field of vibration serviceability is the professor from Department of Civil & Structural Engineering of Sheffield University, and research students live in Serbia, there is a considerable experience in utilization of ICT for the collaboration and teaching purposes. For the sake of illustration, there are few examples:

a) Consultations are organized via Skype. One of the features offered by Skype is that one calling party can see the PC screen of the other and this is especially favorable if screen is pen-sensitive. Thus, professor can highlight the part of the text, make the sketch or directly view and put comments on the student's work. Also, Skype offers other possibilities like conference calls (if there are more than two interlocutors) or sending files by transferring them into the chat window.
b) Sharing of documents is done by Dropbox software. Sending files by e-mail may cause several problems. Firstly, sending large files (>10 MB) is difficult and time consuming. Secondly, mail can get lost or be placed in the spam folder. Even if everything went well and you have received the mail, you have to save the file and sometimes there is a problem later to find the folder where the file is placed. With installation of Dropbox software, Dropbox folder is created on your computer. Files that are stored in this folder can be accessed from your account at Dropbox website. It is more important that you can send an invitation to collaborators to share a folder created in your Dropbox. Every document that you save in this shared folder is automatically saved in Dropbox folder of the person you are sharing folder with. There is no possibility that file can be lost and everything is stored at one place. Free Dropbox account has 2GB space.
c) Management of courses is realized by using the wiki and Blackboard course sites. Students can access the course site only if the professor previously shared the link of the site with them. This is a very simple way to present the program and aims of the course, provide students with course material, and post notifications. Also, one page of the site can be designed for discussion so students can review the history of asked questions, ask the new ones or answer the questions posted by other students. Wiki sites are additionally used for monitoring student's work at PhD program in vibration serviceability. Every PhD student has a page where he/she writes about project and posts research results thus creating a research record.

d) Lectures and tutorials are recorded by CamStudio. This software doesn't provide top quality sound and image, but it is free of charge and suitable for the recording of specific topics explanations.

4.6 Inclusion of PhD students in scientific and R&D projects

Participation of doctoral students in scientific and R&D projects is important and beneficial in several ways as follows: 1) research towards PhD dissertation is usually part of the project, 2) work on the project is paid as well as conference fees and presentation of the results, 3) measuring equipment and components can be bought using project budget for this purpose, 4) mobility of researchers, 5) students have an opportunity to upgrade communication and organization skills, 6) results of the R&D project contribute to the development of national and regional economy. PhD students at doctoral studies in vibration serviceability were included in the scientific project TR36023 supported by Serbian Ministry of Education and Science from the beginning of 2011. The project entitled "New Trends of Construction Design and Management of Buildings" investigates the ways in which the physics and management of problems can be integrated into a unified approach. The first benefits for PhD students will comprise scientific visits to experimental facilities at the University of Sheffield. Total number of the researchers at the project is 11 and cooperation is mainly realized by wiki sites and Asembla web application. Mentor and project leader are responsible to give reports on activities and results of PhD students included in the project at the end of every year.

In addition, it is also necessary for PhD students to become familiar with appropriate software tools for modeling and dynamic analyses (e.g. Ansys).

4.7 Publishing of investigation results in SCI journals

Research related to doctoral dissertation and also investigations within the scientific projects should result in journal articles and conference papers. Formal requirement is that two papers have to be published or at least accepted for publication in scientific journals from SCI list before the approval of thesis defense [1].

The publishing of scientific papers is the indispensable part of doctoral program in vibration serviceability and its realization usually starts at the beginning of the second year of studies. For example, the student who entered structural engineering PhD program in school year 2009/2010 published the paper in EURODYN conference proceedings (held in Leuven from the 4th to 6th July 2011) and the abstract for another one was accepted for IMAC conference in USA in February 2012. One of the PhD program concepts is that all research results have to be published in high ranking journals or conference proceedings (4 or 5 papers during the studies) so the future PhD holders are not only advanced by the possession of doctoral degree but also by high-quality references and visibility in the world scientific community.

4.8 Structure of PhD dissertation

Doctoral dissertation is original research project with truthful and significant contributions to the scientific field. Commonly, PhD thesis is in the form of monograph but it may also be a collection of papers related to the relevant topic previously published by doctoral student in the high-ranking international journals.

Doctoral dissertation in vibration serviceability topics is a collection of scientific papers published in conference proceedings and journals from SCI list. Every scientific paper corresponds to one phase of research and represents a chapter in the future doctoral dissertation. It is important that some contents like theoretical explanations, illustrations, examples etc. are not repeated in different papers. Usually, first scientific paper is the review of literature relevant to the subject of the PhD thesis. The following papers are related to experimental research and observations and solutions that PhD candidate has made. This form of PhD thesis is favorable because the quality and originality of research results and scientific contributions were previously evaluated and validated by competent and usually quite demanding journal reviewers.

4.9 Mobility

Most of the student and staff mobility activities are realized through research projects and bilateral agreements. The Faculty of Construction Management established the bilateral cooperation with 4 foreign education and research institutions: 1) Rutherford Appleton Laboratory in Oxfordshire, 2) School of Mechanical and Materials Engineering of Washington State University in Pullman, 3) Florida International University in Miami and 4) Architectural Faculty of University “Crnorizac Hrabri” in Varna. Part of the mobility activities is also carried out through various international students' associations, Erasmus Mundus, and Tempus programs.

5. SUMMARY AND CONCUSIONS

A detailed analysis of doctoral studies in civil engineering from the stand point of education and research program implementation and performance at the Faculty of Construction Management in Belgrade is presented in this paper. Despite the fact that it is a relatively new education institution, the faculty is one of the few in Serbia that provides enough quality conditions for realization of PhD studies in civil engineering based on the Bologna principles.

Having in mind that higher education, which includes doctoral studies in Serbia, had gone through dramatic changes in the last years, it was necessary for authors to find all aspects where changes were the most evident. In addition, these criteria could be used to estimate and evaluate the implementation and performance of PhD programs in civil engineering. That is why authors’ contribution in this paper consists of the suggested list of the most relevant aspects for systematic presentation and analysis of doctoral studies at FCM. These criteria suggested by the authors are as follows: 1) model of studies, 2) admission, 3) curriculum, 4) mentorship, 5) implementation of new technologies in teaching and learning, 6) inclusion of PhD students in scientific and R&D projects, 7) publishing of investigation results in SCI journals, 8) structure of PhD dissertation, and 9) mobility.

Authors choose PhD studies in structural engineering at FCM to give curriculum in more details as an example. In particular, the paper addressed aspects such as: 1) mentorship, 2) implementation of new technologies in teaching and learning, 3) inclusion of PhD students in scientific and R&D projects, 4) publishing of investigation results in SCI journals, and 5) structure of PhD dissertation. These aspects are covered using very successful experiences and results in vibration serviceability PhD course at FCM. Authors feel that these topics are of the considerable interest for dissemination purposes and exchange of practical solutions in the fields of PhD education and research programs in civil engineering within EUCEET as well as in the cases of bilateral cooperation between universities and institutes worldwide.

6. ACKNOWLEDGEMENTS

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ENDURING CONSTITUENTS OF CIVIL ENGINEERING CURRICULA: EDUCATIONAL FIELD TRIPS AND DIPLOMA THESIS

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EXTENDED ABSTRACT

While calls for educational reform are frequent, there is a lack of systematic discussion on the forces that do or should change engineering curricula. Likewise, whereas some time-honored teaching practices, such as lecturing to largely passive audiences, are being questioned, there is a lack of systematic argumentation on the types of traditional educational experiences that are uniquely valuable and, hence, worth preserving. Considering the two issues of what should or should not change to be the two sides of the same coin, this article first describes four categories of potential forces for change relevant to engineering curricula, namely (i) technological advances, (ii) societal demands, (iii) industry needs and (iv) educational good practices and advances, i.e. advances in instructional technology and engineering education research.

Within the fourth category, educational good practices, the article attempts to identify characteristics of curricula constituents of high learning value, which are *not* candidates of replacement by instructional technology. From the educational experiences that fall in the category of "Advance Personalized Learning", the article focuses on research or research-like experiences, the educational value of which has been documented with evidence. It then presents two such educational experiences from the civil engineering curriculum at the National Technical University of Athens (NTUA), the annual geoengineering field trip and the diploma thesis. The field trip is designed for civil engineering students who need to appreciate the importance of engineering geology in the design decisions concerning civil engineering infrastructure. From the perspective of educational theory, the trip belongs in the tradition of inductive teaching: students are not simply shown the geological features that they should be observing, but instead are presented with a design problem and guided to identify themselves the pertinent geology and rock mechanics data. The diploma thesis helps students develop research skills and exercise autonomy. Data collected at NTUA showed that diploma theses frequently produce original findings, as attested by the number of publications resulting from or including thesis material.

Needs for further work are related to the following observations. The indirect evidence pointing to the success of the two educational experiences notwithstanding, assessment of skills developed by students as a result of engaging in these activities is missing. Hence, it is necessary to gather targeted data, which will enable evidence-based justification of preserving curricular elements on the basis of the skills they promote. In addition, since both educational experiences are faculty-time intensive, their presentation is meant to underscore the need to steer the development of instructional technology towards instructional tools that will free faculty time to be devoted to time-consuming educational activities that technology cannot replace.

KEYWORDS

Engineering education, Engineering curricula, Engineering instruction, Engineering Geology, Undergraduate research

1. INTRODUCTION

1.1 Forces for change in engineering curricula

Engineering is an applied endeavor which interacts with society. As a consequence, engineering education has to change continually, in order both to keep up and to lead. Several forces for change exist, which can be grouped in four categories.

Technological advances, resulting from innovations and research findings, is the category easiest appreciated as a force for change by engineers themselves. One example of this trend is nanotechnology, one of the newest fields being incorporated in civil engineering curricula (Zheng et al., 2011). The same applies to analysis tools, such as finite elements, which gradually become widespread and eventually find their place in engineering curricula (Gilewski, 2010). The agents of change for this category include funding agencies, which selectively support promising or needed research areas, university faculties, when they seek opportunities to expand in new fields, and faculty members trained in these new fields. Typical contested issues regarding implementation of such technology-driven changes include questions as to how central a place these new topics should have in the curriculum and whether they are more appropriate for undergraduate or graduate study programs.

Shifting *societal needs* are perceived as a more indirect force bringing about curricular changes. To a large extent, these needs are related to changes in the perception of the engineering profession by the society. Hence, the resulting curricular modifications address the changing obligations of the profession to society. Typically, these changes are reflected in the continual revisions of codes of professional practice and of engineering curricula, to include “new”, at the time, concerns, such as environmental protection and sustainability. Examples relevant to sustainability include the latest revision to the ASCE code of ethics (ASCE, 2010) and a good number of curricular reforms (Haselbach, 2011).

Shaping engineering curricula to respond to *industry needs* may be considered as unwelcome commercialization of education (Bok, 2006). Granted, such an orientation cannot be made independently of the aims of education, an issue on which society has a saying, especially when it concerns higher institutions accepting public funds. However, for students who choose to study an applied field such as engineering, it makes sense that their educational program is informed by the practice and the future challenges of the profession (Sheppard et al., 2009). To this end, accreditation boards contribute significantly, by supporting the development of a breadth of skills, including both subject-matter and horizontal skills (e.g. communication skills) by the graduates of engineering programs (EUR-ACE, 2008; ABET, 2010). When gathering evidence of successful developments of such skills is not stipulated by national law, the main agent of change having the power to respond to the needs of the industry is university administration.

The fourth category, *advances in engineering education*, has yet to be recognized on a par with the rest. This state of affairs is somewhat puzzling, considering the first category of the forces for change: all engineers recognize that progress in *engineering research* should affect both engineering practice and *engineering education*. In contrast, most instructors apparently do not recognize that the same relationship exists between progress in *education research* and *instruction* (Bok, 2006). If we consider this lack of recognition to be not a failure but a lag, then it may partly be due to the slowness of disciplinary networks in providing dissemination avenues (Borrego et al., 2010). For research on engineering education in particular, there is an additional difficulty that must be accommodated: the fundamental methodological differences between engineering disciplines and education, which shares characteristics of academic fields such as social sciences and humanities (Borrego, 2007). In any case, even faculty who do appreciate the relationship between research on education and instruction, they may believe that educational advances influence the "how" but not the "what" questions of education. It appears then, that advances in engineering education are not forces for change of engineering curricula, at least not at present. Before we probe more into this tentative assertion, we first pose the antithetical question of what is better *not* to change.

1.2 What, if anything, should remain the same?

This question can be analyzed from two perspectives: in terms of (i) subject matter and (ii) instructional approach. In this paper, we adopt the latter perspective. It may sound counter-intuitive, but we will claim that it is the advances in engineering education research that point to the invariant elements of an engineering curriculum. More specifically, we believe that advances in engineering instruction make possible to secure places in the curriculum for "what instructional technology cannot replace" (in the logic of "what money can't buy"). We are not the only ones making this claim.

In a recent workshop of the Committee on Engineering Education of the National Academy of Engineering (NAE), which explored how engineering curricula could be enhanced to better prepare future engineers (NAE, 2010), the concept of "Advanced Personalized Learning" was proposed. Specifically, it was claimed that faculty members may now be able to focus on the big challenges of education (e.g. learning to design), if they can use computerized media for routine tasks (e.g. learning computer-aided design packages). This is not an entirely new concept but, rather, the natural evolution of earlier ideas on the sound use of educational technology. The characteristics of effective teaching media resemble the elements of human communication and according to Laurillard (1993) can be grouped in four categories: discursive, adaptive, interactive and reflective. The most challenging is the last one, whereby, in Laurillard's words, "the teacher must support the process by which students link experience to descriptions of experience".

Hence, as instructional technology and research on engineering education progress, engineering instructors have to decide which aspects of training are better suited for computer-aided instruction, which elements of their teaching can be enhanced by instructional technology and, finally, which constituents of the curriculum belong in the invariant category of elements that cannot be substituted with the aid of instructional technology. The remaining of this paper describes two such constituents of the undergraduate civil engineering curriculum at the National Technical University of Athens (NTUA), Greece.

1.3 The goal of the paper

The goal of this article is two-fold. First, to start a systematic discussion on the dynamic balance between invariant and changing elements of civil engineering curricula. Second, to highlight examples of the former category in the integrated 5-year civil engineering curriculum at NTUA, in a way that instructors from other institutions may benefit and NTUA instructors may appreciate opportunities for improvement. Two such examples are described herein: a 12-day long geoengineering field trip, which takes place during the 6^{th} semester, and the diploma thesis carried out during the last semester of studies. Each example has at least one unique characteristic that places the particular curricular constituent in the "irreplaceable" category. For the field trip, these characteristics include direct experience with the rock material itself, appreciation of spatial scale, guided descriptions of qualitative observations of the rock structure in a quantitative way. For the diploma thesis, these characteristics cover the entire spectrum of the apprentice-master interaction, typical of supervised research.

2. GEOENGINEERING FIELD TRIP

The geoengineering trip is an integral part of the Engineering Geology course taught in the 6th semester of the civil engineering curriculum at NTUA. Engineering Geology belongs in the group of core geotechnical courses in the civil engineering curriculum, which also includes in earlier semesters Geology for Engineers, in the 1st semester, as well as Soil Mechanics I and II, in the 5th and 6th semester, respectively.

The trip takes up a week of regular semester time and half a week from the Easter break. Most of the sites visited during the trip are in the French, Swiss and Italian Alps; hence such a trip can be organized by a good number of universities in nearby countries. The subsections that follow discuss the considerable logistics of the trip, give an overview of sites visited and the educational materials assembled, and attempt to sketch the educational philosophy of the trip through the presentation of its educational objectives.

2.1 Logistics

The trip has been attended by about 200 students on average each year. The second author of this article has designed the trip (Marinos, 2011) and led it for the last 20 years, assisted in organizational matters by a department secretary and a committee of volunteer student participants. A total of four engineering geology faculty members or teaching staff are needed for the trip, which is also attended by invited visitors from academia, consulting and construction, some of whom have recorded their impressions of the trip and their interactions with the student participants (e.g. Medley, 2010).

The cost of the trip in 2011 was 750 euros per student. This cost covers 4 coaches, 1 emergency coach, a doctor, special insurance and half board accommodation in good hotels. The School of Civil Engineering has been contributing, depending on the year, with 40,000 to 60,000 euros. The rest is covered partly by sponsorships, and the remaining by the students. Through the years, sponsors have included the Technical Chamber of Greece, major public corporations, construction companies and corporations and civil engineering consulting companies. The field trip leader has initiated exploratory contacts with potential sponsors and prepared a letter addressed to them. The letter explains the educational goal of the trip, includes an endorsing statement by the field trip leader and is signed by the student committee. Students are encouraged to take initiative and contact additional sponsors, provided they have a positive public profile. Every year, it is the responsibility of the student committee to contact old and new sponsors in order to cover as much as possible of the total cost. The sponsors are not offered any advertisement advantages; they only receive an appreciation letter.

2.2 Itinerary

Figure 1 shows the major sites of interest of the trip, which includes ferry rides between Patras and Ancona. The 2011 trip had overnight stays at Venice (2 nights), Florence area (1 night), Nice (2 nights), Gap (1 night), Geneva (2 nights) and Torino (1 night). From the ten days of the trip (excluding the ferry rides), only one whole day (9th day), in Geneva, is completely free, as well as one afternoon in Florence (4th day). The remaining time is fully covered by educational activities; nevertheless culture, behaviors and social issues are also discussed with the unfolding of the trip along the different places and countries crossed.

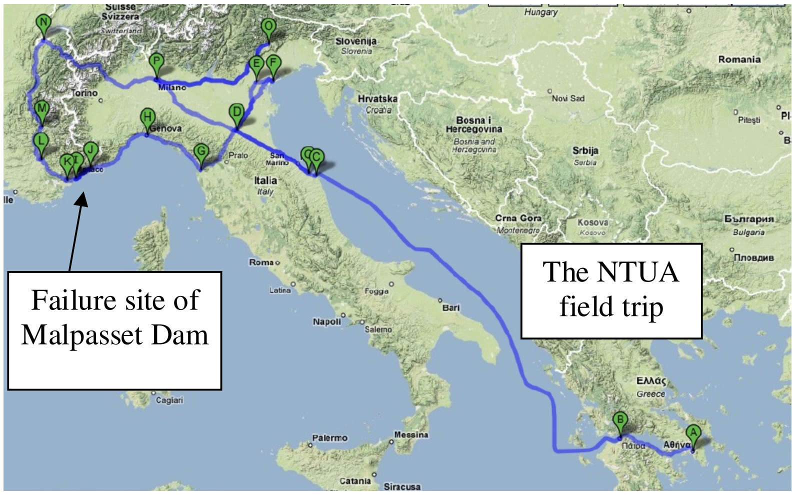

Figure 1. Itinerary of the 2009 field trip and location of Malpasset Dam discussed in Section 2.4.

2.3 Educational materials

The educational materials supporting the trip are summarized in Table 1. It is important to note that materials produced take into account the practical constraints at the field. Thus, students have both a brief handout for site visits and a thick volume (Marinos et al., 2011) with detailed information to consult while at the bus, later in the semester during report writing, and much later in their professional lives, as a reference source. The volume includes material written specifically for the trip and a selection of key publications for each site. Beyond the strictly technical content, the volume also includes personal stories related to the sites visited, as well as contributions of students participating in past trips. Some of these contributions consist of trip-specific lyrics written by students during the trip and fitted to the music of various popular Greek songs. The lyrics are mostly meant to be humorous, however, they also show very eloquently how much students enjoy the field trip.

Table 1. Summary of educational materials supporting the field trip.

Type	Content	Purpose
Program & advice: student handout	Day by day technical topics & topics of general interest. Advice is geared towards raising team morale, assuaging discomfort and addressing emergencies.	Students know very well what to expect each day. Advice is meant to prepare them for the physically demanding nature of the trip.
Site information: student handout	Key features of site visits.	Students have a handy reference on site.
Rock classification charts: instructor tool in a plasticized menu-like form	Major classification charts and systematic descriptions of rock structure and discontinuities.	Instructors can demonstrate in situ the use of charts under any weather conditions.
Field trip supporting volume: reference source (Marinos et al., 2011)	Extensive information and references for 25 topics pertaining to geotechnical engineering and civil engineering infrastructure.	Students consult during the field trip and while preparing trip reports.

Topics covered in the 600-page volume include problems with landslides and fault activity along the way from Athens to Patras, the subsidence of Venice, the tragic huge landslide in the Vajont reservoir (1963), the catastrophic flooding of Florence (1966), the stabilizing measures taken at the tower of Pisa (1993-2005), the sliding rock mass at Clapière under surveillance since 1982, issues specific to tunnels in urban settings (Monaco), the failure of the Malpasset Dam (1959), the tunnels crossing the Alps and the tunnels of the Torino Metro. Apart from Marinos et al. (2011), key references to some of these topics are also given in Marinos (2009).

2.4 Learning objectives and assessment

The overall educational goal of the trip is tailored to civil engineering students who need to appreciate the importance of engineering geology. The trip is designed so that students perceive the spatial scale of geological features and use the sites as the "laboratory of nature". Visits emphasize that site selection, safety, cost, construction pace and performance of major civil engineering structures depend to a large extent on geological features of the foundation material and on the surrounding subsurface conditions. Hence, sites are chosen to represent large-scale, well-known case studies of failures, some catastrophic, caused by geologic features either overlooked during the design phase (e.g. Malpasset Dam) or the role of which was underestimated (e.g. Vajont Dam). In terms of educational philosophy, students are not told what they are supposed to be observing but instead are guided to discover it themselves. This is achieved by following an inductive approach to learning, whereby students are given an open-ended question and asked to come up with a recommendation. The visit to the area of the failed Malpasset Dam (Figure 2) is a good example of this approach.

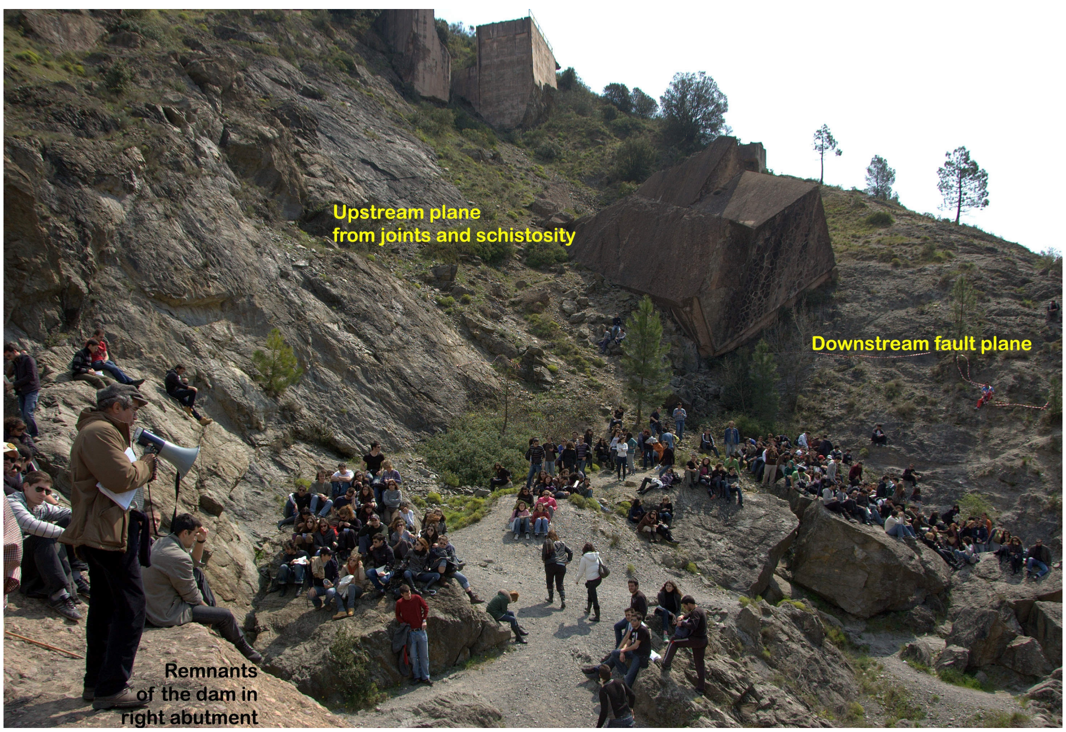

Figure 2. Malpasset Dam failure: The civil engineering students inside the dihedron, in left abutment, removed, together with the dam, by the uplift pressure.

Students are divided in four groups for the visit of the Malpasset Dam area. Each group is led by one of the four instructors on a 1.5 km hike in the gorge of the Reyran creek dammed by Malpasset. The students know of the leading explanation for the failure of the arch dam due to hydraulic uplift exacerbated by the unanticipated presence of a fault. But this is not the main focus of the visit. Instead, even for this well publicized case, students are invited to start thinking with a clean slate. Specifically, they are asked what type of dam they would build and at which location, considering the different rock types along the gorge. In order to make this recommendation, students must synthesize prior information on the importance of geologic conditions on the selection of dam type (also included in the volume) and their own evaluation of the rock types in the vicinity. As they walk along the gorge, they evaluate the strength of the intact rock using the geologic hammer. Then, they have to classify the discontinuities and estimate the overall strength of the rock mass. Students have some prior experience doing this in tutorials and homework assignments using photographs. The visit of the Malpasset Dam locale gives them the opportunity to refine this skill in a natural laboratory. Thus, borrowing once more Laurillard's (1993) words, "students link experience to descriptions of experience".

For the purposes of final assessment, students form small working groups. Each group is assigned one topic from the field trip and prepares a written report upon returning to Athens. Examination also includes group presentations of the reports. These reports are not assigned a grade, but they contribute to rounding up the final grade for the course.

3. DIPLOMA THESIS

Civil engineering students at NTUA have to pass about 65 courses taught in nine semesters. These courses are taught primarily by members of the civil engineering faculty, while there is a sizeable fraction of courses taught by members of other NTUA faculties, specializing in mathematics, mechanics, architecture, humanities, economics etc. The 10^{th} semester of the 5-year program is devoted to the preparation of diploma thesis, which culminates in a formal presentation and oral examination by a committee of three faculty members. Often students elect to take more time than a semester: it is common for students to work both during the spring semester and the summer and present their thesis in early fall. Admittedly, civil engineering students at NTUA have a "very full plate". Still, 30% graduate within the nominal study time of five years, while 74% have completed their studies within six years (Caroni, 2011).

For the diploma thesis, each student works under the close supervision of a faculty member on a topic relevant to any of the courses included in the civil engineering curriculum. A sizeable number of theses are practice-oriented and address some civil engineering design problem. Others involve extensive literature reviews and original research. Those are often independent elements of larger research projects, whereby students interact not only with their faculty supervisor but also work as members of larger research teams. The anecdotal evidence suggesting that the number of diploma theses published in the peer reviewed literature was sizeable motivated the systematic gathering of data presented in the following section.

3.1 Statistical data (2004-2010)

Data collected by the central administration office of the Civil Engineering School included a total of 1520 theses carried out in seven academic years, from 2003-2004 to 2009-2010. Data analysis showed the distribution of theses supervised by (i) faculty members of civil engineering, (ii) faculties of neighboring thematic fields, i.e. mechanics and architecture, and (iii) faculties of thematic fields other than engineering, such as humanities, economics and law. For the data included in Table 2, the calculated average percentages are 81.5%, 12% and 6.5%, respectively. Within the School of Civil Engineering, data are further broken down by its five departments: structural engineering, water resources & environmental engineering, transportation planning & engineering, geotechnical engineering and planning & construction management.

Table 2. Distribution of thesis topics from 2003-04 to 2009-10.

Academic year	Theses supervised within the School of Civil Engineering					Theses supervised outside the School of Civil Engineering			
	Structural Eng.	Hydraulics & Environ-mental	Trans-portation Eng.	Geo-technical Eng.	Construct. Manage-ment	Mechanics	Archi-tecture	Humanities, Economics, Law	Other
03-04	72	12	26	31	12	14	15	10	1
04-05	124	27	25	27	16	11	16	11	2
05-06	100	28	28	27	6	10	17	17	0
06-07	87	19	12	40	1	8	15	13	0
07-08	96	19	13	32	5	4	23	6	0
08-09	100	16	14	23	6	3	23	19	1
09-10	115	21	20	37	2	3	18	20	0
Average	**99**	**20**	**20**	**31**	**7**	**8**	**18**	**14**	**0**

For the subset of theses supervised by civil engineering faculty, a separate spreadsheet file was created for each of the 65 faculty members who have supervised 1148 theses in the 2004-2010 period and were not retired as of the spring semester of 2011. The file included the title and year of each supervised thesis and was sent with a personalized e-mail to each faculty member. The e-mail referred to the writing of the present article and asked each faculty to mark in the appropriate column of the spreadsheet if material from a thesis was presented at a conference or published in a journal, Greek or international or if the thesis was awarded a distinction, such as a NTUA thesis award or any other prize given by professional associations at a national or international level.

Table 3 includes data that correspond to a sample size equal to about 1/3 of the faculty members (22 responses out of 65 requests) and the theses (366 out of 1148). It is apparent that a sizeable number of graduating students are coauthors of conference or journal publications that include material from their diploma thesis. Even with the 1/3 response rate, the percentage of the 1148 diploma theses that contributed material to papers in international conferences and journals is 6.5% and 4%, respectively. This recognition attests to both the dedicated supervision of the civil engineering faculty and the talent of the students, which have entered the civil engineering program after having excelled in very competitive university entry examinations. At the same time, the importance of the 5-year integrated curriculum, which enables many students to mature and be productively involved in research on their last year, should not be overlooked. These very encouraging data also strengthen the belief that diploma thesis is a valuable element of the civil engineering curriculum at NTUA. What is more, they indicate that diploma thesis preparation is worth to be supported and improved further.

Table 3. Publications and distinctions related to 366 diploma theses completed from 2003-2004 to 2009-2010 and supervised by civil engineering faculty.

Number of publications and distinctions				
Conferences		Journals		Awards
Greek	International	Greek	International	
63	76	5	49	10

3.2 Further work

To further improve average thesis quality, the School of Civil Engineering has submitted a proposal to secure funds for the development of three web-based modules supporting thesis writing, with the collaboration of a language and information specialist. The three modules will address 1) technical writing, 2) expectations for a NTUA thesis (goal, audience, abstract writing, structure of thesis, use of tables, use of figures, format, references, glossaries with key terms) and 3) systematic literature searches (databases, deontological issues) & technical terminology (glossaries, multilingual resources). While the first module will be to a large extent specific to the Greek language, the other two modules are of broad relevance and will be made available in English as well. The developed modules will build on material from existing technical and science writing guides in Greek and English (e.g. Agioutantis and Mertikas, 2003; Montgomery, 2003). The first two modules will follow the approach adopted by Montgomery (2003), whereby excerpts from texts are presented at several subsequent editing stages. To this end, authentic texts written by civil engineering students have been collected; module users will first be given an opportunity to comment on them and suggest changes, before they are given access to the edited versions.

4. DISCUSSION

In the absence of systematic assessment data, this section gives some anecdotal evidence of the impact of the two educational activities presented herein, together with some supporting evidence from the literature. On the part of the students, the first author has been recipient of numerous comments regarding the value students themselves give to their experience of the field trip. Many students have commented that their resolve to become geotechnical engineers has its origins in the geoengineering field trip. Other comments highlight how stimulating is for them to approach real civil engineering as active participants instead of as passive onlookers. Among the most telling comments is the following: “when we returned to Athens, if only I could take a shower, I would be ready to start the trip all over again”.

Another feature that contributes to the value of the experiences is their research element, direct or indirect. The debate concerning the research-teaching relationship (i.e. whether research activities of faculty members add value to their teaching) already had a long history, before Prince et al. (2007) showed that, whereas research has clearly the potential to support teaching, data collected so far do not substantiate this broad claim. Regarding the possibility of bringing research into the classroom, Prince et al. (2007) question the potential of integrating research content into instruction. However, they are very positive about the potential of introducing elements of the research process in instruction. Accordingly, they highlight inductive teaching as an instructional strategy that emulates research: such was the approach for the visit at the Malpasset Dam locale described in Section 2.4. When it comes to evidence substantiating the various claimed gains from the research-teaching connection, Prince et al. (2007) found that currently only undergraduate research can be supported by several documented educational benefits.

5. CONCLUDING REMARKS

In breaking with tradition of highlighting innovations in education, this article presented two lasting components of a civil engineering program deemed by the authors of unique educational value because of their “Advanced Personalized Learning” aspect. Although no direct assessment has been made of skills developed by the students as a consequence of the two learning experiences, the hypothesized value is consistent with literature findings that show concrete gains for undergraduate students engaged in research or research-like experiences. At a conceptual level, the article takes the discussion on distinguishing logistical from pedagogical contributions of instructional technology one step further: recognizing the forces for change of engineering curricula, it starts delineating the dividing line which instructional technology cannot cross (as of yet). At a practical level, the article offers material for a geoengineering field trip that can readily be adapted by institutions in many European countries and provides motivation for the development of educational material for undergraduate thesis preparation.

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THE VISUAL IMPACT ISSUE IN THE CIVIL ENGINEERING CURRICULUM

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EXTENDED ABSTRACT

In 2000, the EU released the "European Landscape Convention". In February of 2008 the EU Committee of Ministers issued a more comprehensive document developing the guidelines for the implementation of the European Landscape Convention. In terms of the civil engineering infrastructures design, this document consolidates the need to know how to assess the visual intrusion that such design is going to produce on the landscape. This task is integrated within the corresponding Environmental Impact Assessment.

When a civil engineering infrastructure is projected, its effect can be predicted and expressed as the result of having analysed two essential factors (landscape and population) and having combined two assessments (one subjective, the other objective). They tend to be called visual intrusion intensity (the former) and visual impact magnitude (the latter). It is common to assist the intensity assessment with computer-graphic simulators, and more or less sophisticated virtual reality, as well as to formulate the magnitude with numeric indicators, derived from a calculation process which does not differ too much from the ones used to study other elements of the project.

At the Civil Engineering School of Santander, the assessment of visual impact has been a matter of research since the year 2000, and it has been a post-graduate master level course since the year 2006. The purpose of this study is to describe the scientific, technical and technological scope of its content, outlining its most noteworthy educational elements and forms.

The study will also briefly refer the proprietary tools developed to evaluate visual impact, both in their numeric and in their graphic aspects.

KEYWORDS

VIA, Visual Impact Assessment, LIA, Landscape Impact Assessment, EIA, Environmental Impact Assessment, MOYSES® v4.0, CANTAVIA® v1.0.

1. INTRODUCTION.

A study on the environmental impact produced by a civil infrastructure construction should incorporate an assessment regarding the visual aspect. This assessment should prevent and take into account the effects of this projected construction on the landscape and on the population living (or travelling) more or less nearby. This can be carried out from several different approaches; the most common may be explored using acronyms that have quite a precise technical meaning. This is the case with VIA (Visual Impact Assessment), LIA (Landscape Impact Assessment), LC (Landscape Character), LVIA (VIA + LIA) and CLVIA (Cumulative Landscape and Visual Impact Assessment) [Hutton 1998], [SNH2002], [SNH2005], [SNH2009]. Below is a detailed summary of their general characteristics, mainly extracted from [Hutton 1998].

1.1. Visual assessment: Landscape and population.

The analysis of the visual effect that an infrastructure may cause on a landscape requires a previous categorisation of the landscape value on the site where the construction is undertaken, and also of the area of visual influence (so-called "view-shed"). This area may have a magnitude of tens of kilometres (in the case of wind farms) or much lesser distances (in the case of industrial development zones, for example). In any case, it is clear that to know this effect, there must be some previous sort of qualitative classification of the landscape. The most common is the so-called Landscape Units Map, which sub-divides the territory into a mosaic of zones which are characterised by means of a qualitative-type visual quality index (from 0-very low to 5-very high or similar). The way these maps are obtained (which has more to do with geomorphological, biological, and patrimonial features) pertains to the field of activity called "landscape impact assessment" (LIA), the details of which are beyond the scope of the purpose outlined in this communication.

Having the landscape units map available, the analysis of the visual effect that an infrastructure may have on the population observing the construction, and the physical changes it produces on its site is what is known as the "visual impact assessment" (VIA).

1.2. Visual impact assessment: fundamental problems and objectives.

The visual impact assessment (that, by the way, may be negative or positive) involves always an answer to 4 main problems:

- The technological problem of how to properly visualize its effect just when construction has not yet been undertaken,
- The technical problem of how to reliably assess this effect,
- The administrative problem of how to adapt that assessment to the environmental planning in force,
- The social problem of how to convey that assessment to the population, a task that proves to be the most controversial and delicate of all.

The basic functions of a study on visual impact are ordered according to these fundamental objectives:

- The organisation of the spatial and temporal data necessary to carry it out, on a local and regional level,
- A clear identification of different types of impacts.

- The prediction itself of the impacts.
- The clear quantitative and qualitative expression of them.
- A clear and accessible communication of these impacts.

1.2. Studies on Landscape Integration in Spain.

Spain has signed the European Landscape Agreement and, as a result, environmental legislation obliges very diverse types of infrastructure projects to incorporate in the environmental impact study a chapter dedicated to landscape. Nonetheless, there is not a very wide-reaching specific legislation concerning the matter. Currently, only three regional administrations (Catalonia, Valencia and Galicia) have developed a landscape law, an essential instrument in order to be able to properly develop a visual impact assessment.

The region of Valencia has approved a Landscape Regulation [CV 2006] in 2006. This contribution is supported by this regulation, because it is the one that this team has dealt with the most often and in the most depth. Its regulatory development creates the concept of Landscape Integration Study (LIS) as the main technical vehicle of instrumentation for visual impact assessment. Its most essential characteristics are described below.

1.2.1. What is the purpose of a LIS? Objective and determinations.

The objective of a LIS is to predict and assess the magnitude and importance of the effects that new actions may produce on the landscape's character and in its perception, as well as how to determine strategies to avoid impacts, or to mitigate possible negative effects. This objective has two fundamental expressions:

a) The Landscape Integration Assessment of an action, which analyses and assesses the capacity or fragility of a landscape to adapt to the changes produced by the action without losing its value or landscape character.
b) The Visual Integration Assessment of an action, which analyses and assesses the changes in the composition of views toward a landscape as the result of the implementation of an action, the population's response to these changes and the effects on the visual quality of the existing landscape.

1.2.2. What does a LIS detect? Causes of Landscape intrusion.

An action or a infrastructure is not integrated into the landscape, and consequently produces a landscape and visual impact when one or several of the following circumstances occurs:

a) It does not fulfil the regional or national Landscape Integration Standards,
b) It blocks or generates an adverse effect on some Landscape Resource,
c) It creates blinding or illumination which affects visual resources,
d) It reduces the integrity in the perception of a cultural heritage element, or negatively affects its historical meaning,
e) It differs and contrasts significantly with the environment or the surroundings where it is located, and reduces the visual value of the landscape due to its extension, volume, composition, type, texture, colour, shape, etc.
f) It dominates, negatively changing the composition of the landscape or its elements perceived from a Relevant Observation Point.

1.2.3. What range does a LIS have? Territorial scope.

The range in distance of a visual intrusion has been a topic of reflection and controversy. For significant impacts (electrical line towers, wind power towers), the most used references are due to Bishop [Shang 2000], which establishes three different thresholds distance values, corresponding to the average distance where (i) the perception of a shape, (ii) its recognition or (iii) its possible visual intrusion is produced. It is this threshold of type (iii) that comes to play in our problem. Taking into account this distance threshold, a LIS will take into account, for each plan, project or action, the complete Landscape Unit or Units affected by the view-shed of the action, both in its construction and exploitation phases.
In this regard, the view-shed is understood as the part of the territory from where the action is visible, and seen spatially as a unit generally defined by terrain and distance. The view-shed may contain a part of a Landscape Unit, a complete Unit or several Landscape Units.

1.2.4. What does the Landscape Integration assess? Assessment criteria.

The assessment implies classification of the importance of impacts as a combination of the magnitude of the impact and sensitivity of the landscape. The potential of corrective measures must also be identified. In the assessment, the importance of landscape impact will be predicted before and after applying corrective measures.

2. ELEMENTS IN THE VISUAL IMPACT ASSESSMENT.

2.1. Visual Impact assessment Technologies and Techniques.

Although other assisting tools have been tested and reported, the ones most frequently used rely on GIS technology to assess resources by recreating hypothetical situations in the territory. It is recommended to know the description offered by [Turnbull 1987]. In general, there are three types of analysis to carry out: a local landscape analysis, a territorial analysis and an analysis from previously selected points of view:

- The local analysis of the landscape studies the visual impacts from very specific locations from where one's gaze is directed toward very concrete, specific zones.
- The territorial analysis (the most common technique) is carried out by calculating Zones of Visual Influence (ZVI). The ZVIs are the result of the sum of several view-sheds. The observer sets a number of vantage points, a view-shed is calculated for each one of them and the aggregation of these view-sheds makes up the ZVI, which is normally represented with a coloured map marking visibility intensity. See figure 1.
- The Viewpoint Analysis makes use of certain critical points of view previously selected, and from where the alteration in landscape may be perceived by a maximum of people and with very notable effects. A complete presentation of the method may be found in [Otero 2004].

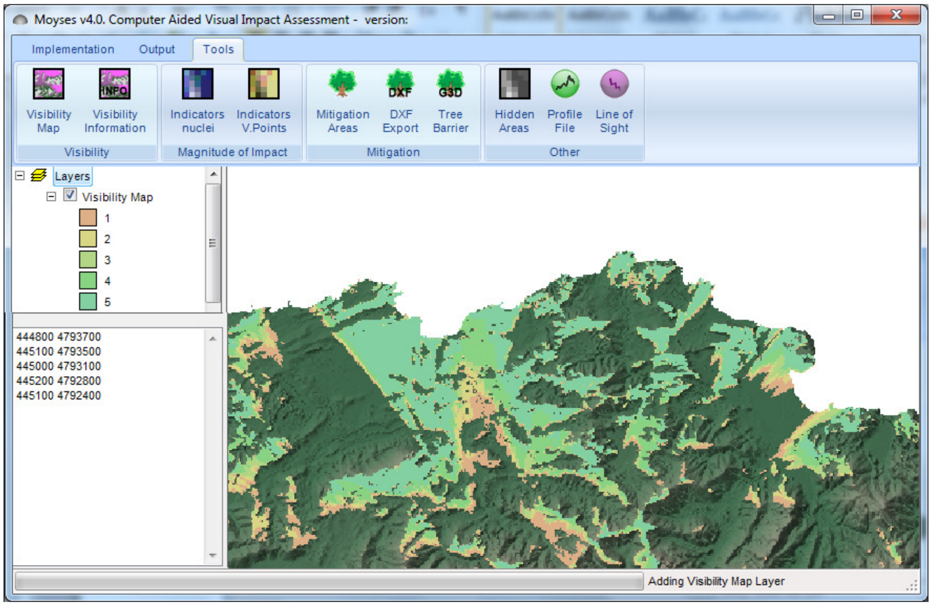
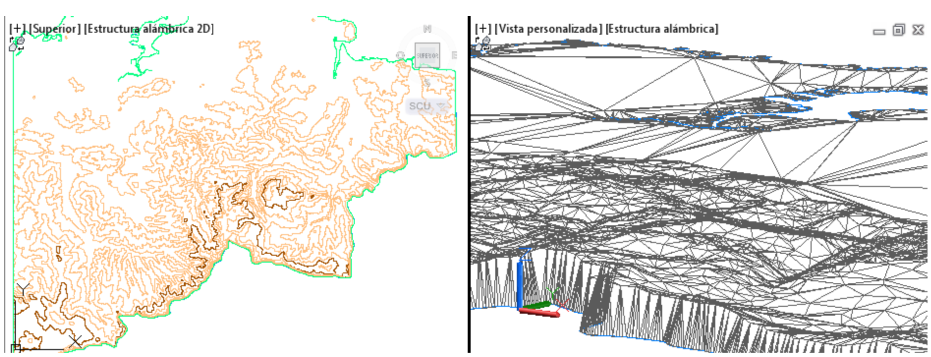


Figure 1: ZVI made by the aggregation of 5 view-sheds.

Along with the GIS techniques, simulated results based on graphic computation offer several techniques (see fig. 2):

- Wire-frame: the terrain is presented as a mesh (regular or not, with triangles where only their vertexes and sides are represented).
- Surface model: the terrain is also represented by triangular faces, in such a way that it is feasible to apply hidden lines and faces removal algorithms, or rendering operations.
- Combination of surface model with orthophotography: this is the most common technique nowadays. A model of the terrain is combined with aerial images of the ground, applied as texture. The result is very descriptive and may be explored in real time, flying or moving on the ground.
- Image processing: it merges real photographic images with other virtual ones (many times extracted from the previously described systems) to present the results hoped to be produced via manual manipulation. It is quite an artisan technique, and very controversial, but proves to be necessary in some of the assessment phases.



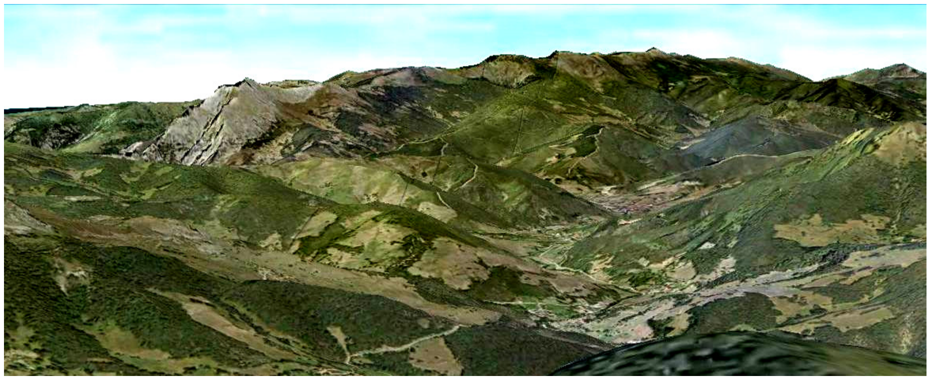


Figure 2: Simulated results based on graphic computation

2.2. Resumed work flow in a Landscape Integration Study.

The following sequence orders the typical work flow in an LIS:

- Identify the vantage points, the Landscape Resources visually affected and the scenic routes (roads with exceptional landscape value).
- Select viewpoints and visual itineraries of greatest public affluence which will include, in addition to others, the following: main communication roadways, population nuclei, principal recreational, tourist and massive affluence areas, and panoramic viewpoints.
- Obtain the view-shed for each viewpoint selected, marking short, medium and long distances from the observation point, determining the number of potential observers of the landscape being studied, but differentiating their proportion in relation to the following categories: residents, tourists and itinerants. Also the estimated duration of observation in the case of scenic routes or itineraries.
- The Observation Points will be classified as principal and secondary, according to the number of potential observers, the distance and duration of the view.

According to the level of importance, zones with maximum visibility, medium visibility, low visibility and those not visible or shadow zones will be obtained. Maximum visibility zones will be those perceptible from some principal observation point. Medium visibility zones will be those perceptible from more than half of the secondary observation points, and low visibility will be the ones visible from less than half of them.

3. THE CIVIL ENGINEERING SCHOOL COURSE.

3.1. Master's Degree in Research in Civil Engineering.

Since the year 2007, training PhD students at the Civil Engineering school of Santander is undertaken with a PhD programme in Civil Engineering, which includes a preparatory phase (which essentially takes the form of a master of science degree in civil engineering, with 60 ECTS), followed by a doctorate phase, wherein the student prepares his/her doctorate thesis. Any qualified member at the Civil Engineering School of Santander may supervise doctorate students in this programme, which is a compulsory re-formulation of the one created in 2005 with the name Doctorate Programme in the "Development and application of Models in Civil Engineering".

The subject of "Computer Graphics Applied to Visual Impact Modelling" (3 ECTS) is offered in the master level and has been in force since the year 2006. At the beginning, the weight of the purely graphic and descriptive component was greater, and this is why the name maintains the initial denomination of Computer Graphics. However, evolution and experience have shown that a large part of the knowledge summarised in the previous sections constitutes a matter to learn and work. The most relevant aspects of the syllabus and the individual project work proposed in this course are described below.

3.2. Computer Graphics Applied to Visual Impact Modelling Course.

The course has an eminently instrumental and practical character. In fact, of a total of the 3 ECTS, only 4 hours are dedicated to conventional theoretical sessions; 20 hours are developed in the laboratory, and 45 are personal work that, in reality, is carried out almost entirely in the course laboratories, since part of the necessary software can be exclusively used there. At the moment, this is possible because only 20 students by year undertake the master. The official documentation [MIIC 2011] of the subject presents these educational features:

- Specific competences
    - Knowing the technologies, tools and techniques in the field of Visual Impact produced by engineering infrastructures and constructions, especially related to civil engineering.
    - Being capable of identifying, measuring, stating, analysing, assessing, modelling, and scientifically and technically describing a Visual Impact problem within the scope of engineering.
- Results of learning in the course
    - The student will model, assess and express the visual impact of human actions, using computer graphic design tools.
- Course objective
    - To develop the methodological bases to begin the instrumental training of a researcher in the subject matter indicated in the title.
- Course programme: the topics and their distribution in classes of the diverse modalities are described next:

Table 1: Course programme

LESSON	THEORY	LAB	TUTORIAL	EVALUATION	GROUP WORK	INDIVIDUAL WORK
Computer Graphics (CG). Fundamentals. CG Standards.	1h.	0				
CAD Systems. The Advanced Program Interface (API) of a CAD system	1h.	2h.				
Civil Engineering CAD Systems. The API of a Civil Eng.CAD system		7h.				
GIS for VIA and LIA		2h.				
Tools of Virtual Reality for Civil Engineering	2h.	3h.				
VIA in Civil Engineering projects and works		6h.				
FINAL PROJECT			3h.	3h.	15h.	30h.
TOTAL	4h.	20h.	3h.	3h.	15h.	30h.

- Objectives and indicators of final course project: the detailed objectives as well as the elementary results to be achieved are shown in the table below. The final evaluation requires a brief presentation and defence.

Table 2: Objectives and indicators

OBJECTIVE	INDICATORS
Graphic data capture	a. Altimetry (mdt) b. Planimetry (nuclei, motorways, forests, viewpoints, landscape itineraries)
Computer-assisted civil engineering systems.	a. Alignments b. Profiles c. Cross sections d. Corridors
Preparations previous to visual impact assessment.	a. Assess population nuclei affected by the impact b. Classify them by distance (short, medium or long). c. Make a table of affected population. d. Assess motorway sections affected by the impact. e. Classify them by distance (short, medium or long).
Visual Impact Assessment	a. Practise defining a visual scope with sections radiation. b. Definition of a view-shed: spatial analysis
Simulation: Pre-processed.	a. Create mdt in tiff format with 5m pixel. b. Select adequate photos for covering. c. Shade the road zone in AutoCAD with MPOLYGON type entities d. Export the previous entities to shapefile e. Export population nuclei to shapefile. f. Export motorways to shapefile
Simulation. Project creation	a. Create the project. b. Load the terrain c. Load the photos (or part of them) d. Load the shapefiles e. Create vectorial layer groups. Import vectorial layers f. Load toponyms g. Create places category h. Incorporate places
Visibility results.	a. Create infos category b. Put various information about the roadway c. Create views d. From visible population nuclei to roadway info e. From first order visible roadway stretches to roadway info.
Semi-automatic generation of computer graphics	a. Capture computer graphics from the simulator b. Capture real photographs c. Filter elements and superimpose

4. THE TOOLS CREATED FOR LEARNING. (MOYSES® AND CANTAVIA®).

Supporting the Computer Graphics Applied to Visual Impact Modelling course, there is a research and development activity which was initiated 11 years ago. During this time the team teachers in charge of this subject have collaborated with the regional administration in the region of Cantabria, the construction company DRAGADOS, the Companies GENERCAN and E.ON-Renewable Energies, and with the national Ministry of Development. As a result of the work contracted or subsidised by these companies and entities, two internally developed applications are now available:

- MOYSES: Modeller and Simulator for the Evaluation of Visual Impact.
- CANTAVIA: Cantabrian Visual Impact Assessment.

The first of the applications supports the greater part of the specific GIS calculation process (indicators, ZVI, Viewpoints, View-sheds, etc.), while CANTAVIA is the 3D interactive simulator developed to incorporate any project in the Cantabria region territory

(Spain). Both elements could be the topic of specific communication to EUCEET. In any case, figures 3 and 4 give a first idea of their most noteworthy characteristics.

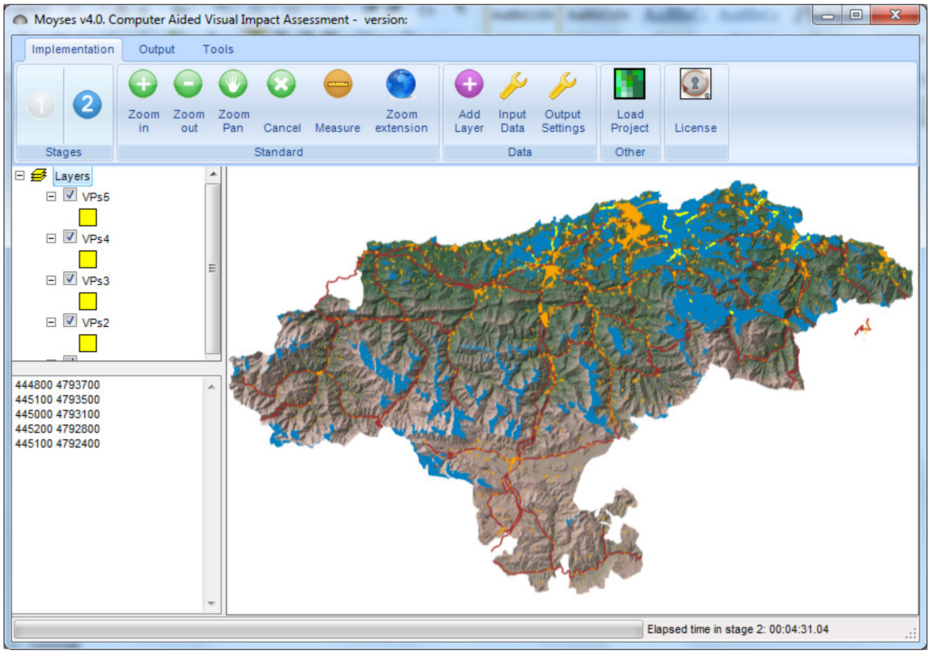


Figure 3: Application Moyses v4.0. On-screen, the result of calculating visual scopes.

Figure 4: general view of CANTAVIA

5. CONCLUSIONS.

Visual impact assessment, as an integral part of environmental impact assessment, is compulsory and requires professional training; this training can become a specific professional competency. In regards to civil project and construction, it again proves quite useful that the civil engineer (and no other specialists) is the appropriate professional to carry out (or to lead and supervise) the VIA study into a project-planning.

As has occurred on many occasions in the past, this implies reaction capacity on the educational sector's part to be able to offer this training in reasonable quality and opportunity conditions. The annual EUCEET 2011 conference is an appropriate occasion for the Civil Engineering School of Santander to present how they are carrying this out. In the document, an effort has been made to present the discipline from its foundation to its current development in a summarised format.

ACKNOWLEDGEMENTS.

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CANTAVIA v1.0. (2011) was partially funded by the contract ref: UC-24.2846.2846 with GENERCAN (Department of Industry of the Government of Cantabria).

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INCORPORATION OF NANOTECHNOLOGY IN THE CURRICULUM OF CIVIL ENGINEERING EDUCATION

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EXTENDED ABSTRACT

Nanotechnology and nanoscience are scientific and technological fields that have attracted considerable interest in the last decade. Both deal with the science and technology at a scale smaller than 100nm (1nm=10^{-9}m). Due to their reduced size, nanomaterials properties vary considerably from those of bulk materials and thus they present exceptional mechanical, optical, magnetic and electric properties (Schaefer 2010). Applications to everyday life are increasing as well as the domains of applications.

Civil Engineering is not excluded from applications of nanotechnology. Applications include super-hydrophobic surface treatment in order to increase materials durability, self healing materials in order to reduced crack propagation, Micro-Electro-Mechanical Systems (MEMS) and Nano-Electro-Mechanical Systems (NEMS) for monitoring of structures with non-destructive methods, nano-cement and nano-steel for increased strength and durability, just to mention a few (Nanoforum Report 2006, Sobolev et al. 2006). Nanotechnology applications seem also very promising in environmental applications, a field in which Civil Engineers are increasingly involved (Observatory Nano 2010). The financial interest is demonstrated by the increased amount of budgets invested in nanotechnology research and development, a significant part of which is directed to the domain of tailor-made materials properties, while the scientific interest is demonstrated by the increasing rate of scientific publications, which originate from the fields of physics, chemistry and materials science and seem to involve an increasing number of civil engineers (Economidis 2010).

The need for better understanding of materials properties at the nanoscale and their use in application in engineering and more specifically in Civil Engineering is a special concern (ASCE 2007, Kim et al. 2006). It is also demonstrated by actions taken by the National Science Foundation (NSF) in the United States (US) for Civil Engineering Departments to introduce nanotechnology courses in their curriculum (Zheng et al. 2010).

In the present paper we discuss the need for the introduction of nanoscience and nanotechnology courses with relation to the syllabus as well as to pedagogical points where attention should be paid in order to achieve the best output. Understanding the difference of behaviour of nanomaterials and their importance on materials' behaviour will provide future Civil Engineers with advanced skills that will enable them to adopt emerging technologies and formulate innovative solutions to complex problems. Such skills will provide students with additional professional opportunities and competitiveness in the international economic and scientific environment.

KEYWORDS

Nanoscience, Nanotechnology, Civil Engineering Education, Civil Engineering curriculum.

1. INTRODUCTION

Nanotechnology and nanoscience deal with the science and technology at a scale smaller than 100nm (1nm=10^{-9}m). Due to their reduced size nanomaterials' properties vary considerably from that of bulk materials and thus they present exceptional mechanical, optical, magnetic and electrical properties (Schafer 2010). Due to these reasons these fields have attracted considerable interest in the last decade. The first mention to the evolution that would come is attributed to the Nobel Laureate Richard Feynman who mentioned "there is plenty of space at the bottom" in a lecture that gave on December 29th 1959 at the annual meeting of the American Physical Society at the California Institute of Technology (Feynman 1960).

The basic interest in nanotechnology was initially limited to research labs mainly of physics and chemistry and more lately to that of materials science. However, applications to everyday life are increasing as well as the domains of applications. Civil Engineering is not excluded from applications of nanotechnology since many branches are involved such as cement and concrete (Antonivic et al. 2010, Ge and Gao 2008), coating materials for construction production, health monitoring of structures etc (Lynch et al. 2009). Applications include super-hydrophobic surface treatment in order to increase materials durability, self healing materials in order to reduced crack propagation, Micro-Electro-Mechanical Systems (MEMS) and Nano-Electro-Mechanical Systems (NEMS) for monitoring of structures with non-destructive methods, nano-cement and nano-steel for increased strength and durability, just to mention a few (Nanoforum Report 2006, Sobolev et al. 2006). Nanotechnology applications seem also very promising in environmental applications, a field in which Civil Engineers are increasingly involved (Observatory NANO 2010).

The financial interest is demonstrated by the increased amount of budgets invested in nanotechnology research and development, a significant part of which is directed in the domain of tailor-made materials properties, while the scientific interest is demonstrated by the increasing rate of scientific publications which go out from the fields of physicists, chemists and materials scientists and seems to involve an increasing number of civil engineers (Economidis 2010, Lux 2004, Moradi 2005). We must mention here that nanotechnology constitutes a priority research files in US, Europe but also in Greece.

The need for better understanding of materials properties at the nanoscale and their use in applications in engineering and more specifically in Civil Engineering is a special concern (Kim et al. 2006, ASCE 2007). It is also demonstrated by actions taken by the NSF in the United states for Civil Engineering Departments to introduce nanotechnology courses in their curriculum (Kim et al. 2010), but also by the National Nanotechnology Initiatives (NNI 2011) and several actions realized in Europe.

In the present paper we discuss the need for the introduction of nanoscience and nanotechnology courses with relation to the syllabus as well as to pedagogical points where attention should be paid in order to achieve the best output. We present some cases of introduction of nanotechnology courses in the curriculum of Civil Engineering Departments in the US and Europe and then we present our proposal for the introduction of such courses in the case of Greece.

2. CIVIL ENGINNERING AND NANOTECHNOLOGY

Civil engineering is directly related to construction and thus to construction materials, the most representative of which are cement, concrete and steel as well as coatings.

Monitoring of structure health which may be critical in several constructions and solutions for healing or preventing damage are also of interest for Civil Engineers. Nanotechnology is related to the development of materials since at this scale materials present different properties from the classical macroscopic materials and their properties as we know them. This different and sometimes extraordinary behaviour originates from the fact that at the nanoscale the ratio of surface atoms to volume atoms becomes important. Taking advantage of this particularity novel materials containing nanoparticles have been developed for civil engineering applications. In the following we discuss briefly such applications concerning construction materials and health monitoring.

2.1 Construction Materials

2.1.1. Concrete

This is the most widely used material in constructions. Although the macroscopic behaviour of concrete has been extensively studied its properties and behaviour at the micro and nano-scale are not fully understood. Processes that are important in the case of concrete include hydration and the alkali-silicate reaction (Balaguru 2005). The study and understanding of the structure and behaviour at the micro/nano-scale is necessary for improving concrete properties and avoiding several problems like alkali-silicate reaction. Li (2003) found that the addition of nano-SiO_2 significantly increases its compressive behaviour. It has been shown that the inclusion of nano polycarboxylates into concrete permits consolidation without need for vibration, resulting in a significant labour cost reduction (Nanoforum Report 2006).

Carbon nanotubes (CNTs) are among the strongest fibers and are very promising for the production of high-performance materials. They have five times the Young’s modulus and eight times the strength of steel while their density is six times smaller than that of steel. Studies have indicated that the distribution of CNTs across cement grains can improve the mechanical behaviour of the cement-CNTs composite (Makar and Beaudoin 2003).

2.1.2. Steel

Steel is another major construction material and is present in nearly all structures. Properties of significant importance are strength and corrosion resistance. In the US new low carbon high-performance steel for bridges has been developed (Kuennen 2004). This new kind of steel presents higher corrosion-resistance and weld ability through the incorporation of copper nanoparticles in the steel grain boundaries.

MMFX2 is a nanostructured steel produced by MMFX Steel Corp (2010) which compared to conventional steel has a different microstructure which results in three times larger strength, along with larger ductility, toughness and corrosion resistance. Stainless steel presents a high cost thus it is employed in high risk environments. The new MMFX2 steel has a lower cost while presenting a similar corrosion behavior like that of stainless steel and thus it would constitute a serious alternative (MMFX Steel Corp 2010).

2.1.3. Coatings

There are several types of coatings that have been developed for certain purposes. In fact the materials contain certain types of nanoparticles that produce the desired effects. These are coatings that due to their hydrophobic behaviour push away water. Hydrophobic coatings are commercially available (see for example NanoPhos 2011). Another class of coatings is containing titanium dioxide nanoparticles which is employed in glazing coatings. Due to the sterilizing and fouling properties of titanium dioxide organic dirt is disintegrated through a catalytic reaction (Arafa et al. 2005). Other applications of coating include anti-graffiti paints, anti-reflection coatings on glass etc.

2.1.4. Self healing materials

Cracks are a major concern for nearly all constructions. Research has been performed on the use of microencapsulated healing agents (Kuennen 2004). The idea is that when the crack breaks the microcapsule a healing agent is released in the crack region and the resulting polymerization bonds the two crack faces. This approach can be applied in cases such as bridge piers and columns (Mulenga and Robery 2010).

Vernet (2004) has investigated the effect of a high percentage of anhydrous material which remains after the reaction with the water in the initial mix. This anhydrous fraction can act as a source for further hydration which is exposed when a micro-crack develops. If the sample is soaked in water hydration can start again on the cracks and the new formed hydrates could rapidly fill the cracks.

2.2 Structure Health Monitoring

Several ideas have been proposed and examined for the structure health monitoring of structures including micro-sensors, Micro-Electro-Mechanical Systems (MEMS) and Nano-Electro-Mechanical Systems (NEMS) as well as structural components with special properties.

There are cases where thin films are assembled at the nano-scale with the use of single wall carbon nanotubes (SWNT) and polyelectrolytes (PE) in order to create a homogeneous composite with exceptional mechanical strength and with electrical conductivity that varies in response to stimulus such as strain and tearing. Thus this film can play the role of distributed sensing all over the structure (Lynch et al. 2009).

Another kind of applications are piezoelectric materials which can be bonded to the structure. It seems that the best way is not to use adhesives in order to bond the sensors to the structure but to fabricate the sensors directly onto the structure. A characteristic example are piezoelectric paints made from piezoelectric powders which can easily be applied on large structures without affecting the mechanical properties (Zhang 2006).

MEMS and NEMS sensors have been developed and employed in construction in order to monitor or/and control structure performance. Due to their small size they can be embedded into the structure during the construction phase. Use of such sensors can provide access to measurements of several critical quantities such as temperature, pressure, stress and strain (Saafi 2006). An example of incorporation of such sensors is *Intellirock:* a wired sensor (Engius 2005) that is embedded in concrete to measure its temperature during the curing process. Such technology has been used in highway projects allowing for faster and lower cost contraction. MEMS/NEMS sensors can be embedded into highways or cover an entire bridge for monitoring deterioration, and allowing for control before they are apparent to human inspectors. The Golden Gate Bridge now has an experimental sensor network of approximately 200 small MEMS sensors. Each sensor can measure movement due to traffic, wind, or seismic loads and all sensor readings are correlated, to create a 3-dimensional picture which may indicate structural abnormalities (Nano@PennState 2011).

4. SOME EXAMPLES OF INTRODUCTION OF NANOTECHNOLGY IN THE CURRICULUM APPLICATION OF CIVIL ENGINEERING

From the above not exhaustive presentation of applications it becomes obvious that nanotechnology is going to affect the future Civil Engineers. Thus it is necessary that the curriculum provides them at least with the basis of being able to understand the applications but also to be involved in the development of new products and processes based on nanotechnology. Thus, it seems necessary to introduce nanotechnology related courses in the curriculum; otherwise our future students will be nano-illiterate. This will also help them to collaborate with scientists and engineers from other domains that can be implicated in the construction development like materials scientists, electrical and electronic engineers. In the framework of international mobility, knowledge of nanotechnology and its possible l applications will also be of help. The objectives should be to obtain fundamental knowledge of nanoscience and nanotechnology, increase awareness of the possibilities that nanoscience and nanotechnology offer to civil engineering.

How can one introduce in the curriculum the courses and what kind of courses? One approach is to use specific civil engineering courses like a course in "Construction Materials" or "Advanced Construction Materials". Such an approach has been employed in the Jackson State University in 2007 and 2008, the University of Oklahoma in 2007 and the University of Houston in 2008 (Zheng et al. 2011) where a course "Construction Materials and Lab" was implemented. This new course module included four lecture modules, four lab modules, two seminars by industry people and a co-curricular project. The course focused on four domains a) improved construction materials, b) sensing technology c) smart materials d) creativity strategies and innovative designs. The co-curricular project is formulated and implemented based on a problem-based learning pedagogy (Barrows 1996) and a self-regulated learning cognitive model (Zimmerman 1990). In the frame of the project students are asked to identify existing problems in civil engineering and propose innovative solution to them at their own choice by applications of nanotechnology. Zheng et al. (2011) performed a survey that shows that the four most interesting module topics ranked by students were:

1. Microfiber reinforced concrete
2. Nanotechnology application for civil engineering
3. Nanocoatings for infrastructure
4. Smart materials and application

While the four most practical module topics from the University of Oklahoma were:

1. Microfiber reinforced concrete
2. Wireless data acquisition and processing
3. Nanotechnology application for civil engineering
4. Nanocoatings for infrastructure

The lowest-ranked module is the module of innovative design and creative strategies. For full details the reader can consult (Zheng et al. 2011). Representative projects of students realized in the frame of the course are: "Warm in winter and cool in Summer: Nano-enhanced Home through the use of Nano-Particle Additives and Nanocoatings for enhancing Insulating factors of Construction Materials", "Smart suspension bridges through the use of smart-material cables both as structural members and actuators to support bridges under traffic loads and control bridge movement under wind loads".

It must be mentioned that this effort was supported by the Division of Engineering Education and Centers of the National Science Foundation. Under the action Nanotechnology Undergraduate Education (NUE) in Engineering NSF has already funded 39 such actions and there are new calls for 2011 (NSF 2011).

We must also stress the importance given to nanotechnology education in the USA, even at the secondary education level and which is shown by the funding of the National Nanotechnology Initiative (NNI) which is more than one million dollars per year (NNI 2011).

A course of “Nanotechnology and Nanomaterials Fundamentals” (code CE/ME 486/686 MNT 730) (North Carolina 2011) was introduced is the Department of Civil Engineering of North Dakota State University. This course covers principles of nanotechnology and nanomaterials and develops a framework for their understanding. In the frame of the course the basic tools of nanotechnology: nanoscale characterization, physics and materials design are also discussed in the context of current technological advances.

The USA is not the only country to introduce nanotechnology courses in the Civil Engineering Curricula. The renown French École des Ponts ParisTech (Ecoles des Ponts et Chausses) has also introduced a course Concerning nanomaterials which is mainly related to mechanical properties, point and line defect, fatigue and fracture, fracture modes, Hall petch effect, as well as with fabrication procedures (Ponts 2011).

Instruction of nanoscience and nanostructure is also a concern for other engineering disciplines like Electrical, mechanical, computer and chemical engineering (Kim et al 2006, Malsch 2007).

5. SUGGESTIONS FOR GREECE

Given the fact that our aim is to maintain the competitiveness of our graduates both at home and abroad, there is a dual goal that we must achieve. An engineer has to be an expert of a specific field (in our case civil engineering) with solid background, but he/she must also have the ability of interdisciplinary understanding and collaboration. There is a question on how to introduce new course material in a quite loaded curriculum and how to attract the interest of students. We identify and propose two general strategies that one could follow in order to achieve this goal.

The first one would consist of enriching an existing course appropriate for presenting nanotechnology applications, with notions of nanoscience and nanotechnology. Such courses could be the General Physics courses and courses related to Construction Materials and Materials Behaviour. In this frame one could include additional information about what happens when things get very small at the nanoscale, and how nanoparticles can affect the macroscopic properties of the materials. Of course, with such a choice one does not have enough time to cover all the subjects. Elective project works where the students would study subjects related to nanotechnology and its applications in bibliographic sources, and on the internet could be an option.

The author has applied this principle in an experimental trial in the frame of the course “General Physics II” taught in the first year of Civil Engineering at the University of Thessaly (Volos, Greece) during the 2011 spring semester, and found that students were particularly motivated. The students were electively assigned projects (they had a choice from a subject pool, but they had also the possibility to suggest another subject) at the beginning of the semester and were asked to prepare a report as well as to make a presentation in front of the class, so that their colleagues could have information and ask questions. The projects covered construction materials, self-cleaning materials, specific glasses, but also more general application like hydrophobic surfaces. The first impression is that the rest of the students were particularly interested in these new developments of technology. Similar techniques can be applied to other courses like Construction Materials, Structural Dynamics but also environmental courses since nanotechnology has applications in environmental remediation, water cleaning etc. The use of Information and Communication Technologies could also be of help, since one could provide additional material and presentations for self-study as well as access to virtual and remote labs in order to overcome the problem of additional cost (Karakasidis 2009).

The other strategy would be to offer a specific new course that would describe what nanoscience is and what are the current applications or the applications to come in the field of Civil Engineering. This could be an elective course so that the curriculum is not overloaded with an additional compulsory course, while the students who are interested in new horizons could have the possibility to cover their need. One could even think that in a School of Engineering with several engineering disciplines such as Mechanical, Electrical, Architectural etc, a general elective course about nanoscience/nanotechnology and their applications in all engineering fields could be a very interesting solution, since it would further provide interdisciplinarity not only through the course content itself but also through the interaction of students who would attend the course and come from different fields. Group projects as part of the course with members from different disciplines would also be a very interesting approach which would contribute a) work in groups b) interdisciplinarity, a situation that students will face once they graduate and they are going to enter the work market in homeland or abroad. This experience would also be an asset if they decide to follow a research or consulting career. A course like this would comprise a) structure of matter b) atomic structure c) some notions of statistical physics and the link of microscopic properties to macroscopic properties d) how the size of materials can affect their properties and how surface effects become important e) representative examples of the variation of mechanical, optical and electrical properties of materials as compared to bulk materials and f) some notions of atomistic modelling.

Of course one also could think of a compulsory course but this would be perhaps more difficult at the given stage. However, such a solution, if designed in collaboration with all the sections of the department, would expose all the students to the new knowledge and its possible applications. In all these cases, however, care should be taken in order to make students sensible to eventual Risks of Nanotechnology both at health but also social level (NSET Subcommittee 2011).

If one would like to go further, one could provide also insight into methods to model materials and phenomena at the nanoscale, where the continuum approach fails and appropriate methods are necessary such as Molecular Dynamics (Haile 1997) for atomistic modelling, Dissipative Particle Dynamics (Español and Warren 1995, as well as Kasiteropoulou et al. 2011a,b and references there in) for mesoscale modelling or multiscale modelling (Karakasidis and Charitidis 2007). However, this would be more appropriate perhaps at a postgraduate or doctoral level. The experience of the author during the last four years with the supervision of PhD students form Greek Engineering Departments (Civil and Electrical) in nanotechnology-related research (nano and microfluidics), showed that although students need a time of familiarization with such methodologies and notions given their previous background where the atomistic world is completely absent, they can achieve significant results and perform high level research (Sofos et al. 2009, 2010, 2011, Kasiteropoulou et al. 2011a, 20011b). PhD students could also act as intermediate agents in order to diffuse the knowledge and culture to undergraduate or graduate students.

The Diploma Thesis would also be a great occasion for students to enhance their knowledge. Nowadays there are several Research Teams in Civil Engineering Departments in Greece that are working in the field of nanotechnology. Such examples are the Laboratory of Building Materials in Department of Civil Engineering of the Aristotle University of Thessaloniki, the Laboratory of Hydromechanics and Environmental Engineering and the Laboratory of Strength of Materials and Nanomechanics in the Department of Civil Engineering of the University of Thessaly in Volos, just to mention few of them. Diploma theses in such nanotechnology-related subjects would be particularly profitable for the students but also for the development of Research in the Departments, and it may lead to collaborations with other Science or Engineering Departments.

6. CONCLUDING SECTION

The contribution of the paper is to enhance and provoke the discussion about the need for incorporating Nanotechnology and Nanoscience in the Curriculum of Civil Engineering Departments, particularly in the case of Greece. We believe that such incorporation is feasible and each Department can choose the way that fits best in its existing Curriculum and Research Profile. Given that nanotechnology is a priority research field both at national and European level it would be a great opportunity to advance in this direction. This also would increase the open mindedness of our students as well as their capacity for interdisciplinary collaboration, a quality that is currently necessary at the international level for work in the market or in the research domain. It seems that the enrichment of appropriate existing courses with nanotechnology notions and the introduction of elective courses, along with practice through the realization of course projects or Diploma Theses, constitute the most appropriate solution for the introduction of Nanotechnology in the curriculum, at least for the Greek Civil Engineering Departments.

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HOW TO WORK WITH CURVED STRUCTURES; THEORY

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EXTENDED ABSTRACT

Teaching of structural mechanics – or mechanics generally - is traditionally an extremely challenging task. Curved structures particularly have proven to be frightening for the students. For “straight” structural members the basis unit vectors applied can be kept as constants. Usually simple figures describing a material element in the original and in the deformed state produce rather straightforwardly the required strain expressions. Similarly, simple free body diagrams for the material element are enough to give the local equilibrium equations and the traction boundary conditions.

Curved structures need to be described initially in curvilinear coordinates. The unit basis vectors are then no more constants but depend on the position. This is one major complication as compared to the straight case. Perhaps a still more serious difficulty concerns the use of figures and diagrams to produce the strains and equilibrium equations. The figures and diagrams tend to become so involved that a doubt about the correctness of the deductions can easily emerge in the mind of the student. A general unifying background theory is easily lost as more or less ad hoc figures are employed in each new structural case. Further, if large deformation problems are considered, correct deductions in this way are in practice out of the question. Of course, tensor calculus in curvilinear coordinates solves these problems elegantly, but this approach is quite too demanding in time and effort to be used in basic structural mechanics courses.

An approach which produces the relevant expression in curvilinear orthogonal coordinates without tensor calculus is described in the paper. The approach is called “the method of local Cartesian frame”. The main idea is: if we have an expression valid in rectangular Cartesian coordinates, a corresponding expression for curvilinear orthogonal coordinates can be formed in simple steps. Explaining the steps to the students does not demand too much effort. A general theory is described in the paper. For instance gradient and divergence expression and general small deformation strain expressions in two dimensions are developed. No figures describing the material element in the initial and deformed state are used. Again, such figures are fine in simple straight structure applications but are, in our opinion, not convincing enough in curved cases.

The equilibrium equations for curved structures are not derived here directly by the method of local Cartesian frame although this can be done. Alternatively, after the strains have been arrived at, the principle of virtual work is used for this purpose. The importance of the principle of virtual work in structural mechanics cannot be overemphasized. It unifies analytical and numerical approaches - especially the finite element method. Here with curved structures it is employed to derive the local equilibrium equations and traction boundary conditions. The invariance properties of the internal and external virtual work are employed when using the method of a local Cartesian frame. Integration by parts operations are needed in the manipulations. No free body diagrams are applied.

KEYWORDS
Teaching Techniques for Mechanics, Curved Structures, The Method of Local Cartesian Frame, Principle of Virtual Work.

1. INTRODUCTION

Education processes are – nowadays particularly – under strong development. The challenges are obvious because the interest towards theoretical studies has decreased rapidly. One reason for this is the highly developed numerical technique and computers with versatile possibilities in structural analysis. Though the profits achieved, its almightiness gives a signal that theoretical capability belongs nowadays to the computers only. This will ruin the interest to study theoretical subjects destroying at the same time the general development of mathematical thinking and manual problem solving as well.

This has forced teachers to think also the methodology applied in teaching. Structural analysis has been too method oriented so far. University studies have included tens of different strategies to solve a single problem. In addition, all the areas of mechanics have been far too split, and no common 'red line' for the analysis in general does exist.

There is clearly a lack of common mathematical tools for structural analyses. These should be mathematically exact supported on very basic mathematics only, and they should be usable in all areas of mechanics. When getting familiar with these tools in basic courses already, a student does not loose his interest when the problems become more complicated. Applying the differential geometry and its figures is graphic and works well with simple structures, but when the structures considered are more complicated or in non-linear analyses they will lose their usability.

Structural mechanics is actually a strong combination of mechanics and mathematics. The problem is how to succeed to put more emphasis on the part of mechanics and push the mathematics – which has nowadays a very limited popularity in various university syllabuses – more to the background. Solving different complicated partial or ordinary differential equations belongs to the pure mathematics though it often takes the biggest part of the attention in various courses of mechanics. The procedures looked for are concentrating on the mechanics, and the mathematics is aimed to play the side role only. The goal is to find out a mathematical tool which could be applied to any structural problem in any geometry – including curvilinear structures. In this way, we will have a lot more time in getting familiar with the problems of pure mechanics.

We are proposing in this paper a combination of methods to be applied when building up a model for a generic structure. The procedure consists of a method of local Cartesian frame and the principle of virtual work. These form up together a simple logical way to handle any type of structural task.

2. MATHEMATICAL BACKGROUND AND GEOMETRY DESCRIPTION

In this chapter, some basic formulas dealing with orthogonal curvilinear coordinates are reviewed. The presentation is given in two dimensions as the main points can be seen already in this case.

The starting point when looking for new ways to approach a generic structural problem is, at first, to realize the fact that the geometry and also the deformation are actually vector quantities, and try to find suitable ways to exploit it. The geometry of any structure can always be fixed by a position vector $\mathbf{r}$ the origin of which is placed at the origin of any global Cartesian coordinate system x, y. The curvilinear geometries are defined by local curvilinear coordinates, α, β, coinciding with the geometry of the body, or characteristic lines of the structure considered.

The meaning of this vector is great. It includes a lot of important information and defines the space where the kinematics and boundary conditions are most naturally given. The fact, that this particular vector includes in addition all the information needed to define any differential operator in the differential equation to be solved, is a huge profit. And these operators are defined in any arbitrary coordinate curvilinear system α, β, which has not been emphasized too much usually anywhere.

A rectangular Cartesian coordinate system x, y with unit base vectors $\mathbf{i}, \mathbf{j}$ and a curvilinear orthogonal system α, β with unit vectors $\mathbf{e}_\alpha, \mathbf{e}_\beta$ are considered (Figure 1).

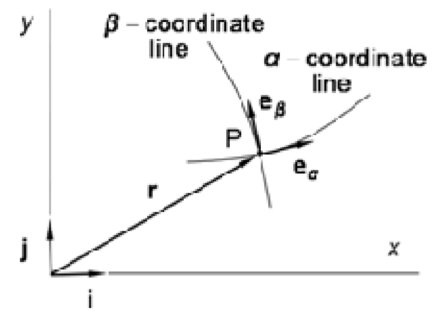

Figure 1: Two coordinate systems.

The coordinates fixing the position vector are connected by

$$x = x(\alpha, \beta), \; y = y(\alpha, \beta). \tag{1}$$

The position vector **r** can be expressed as

$$\mathbf{r} = \mathbf{r}(\alpha, \beta) = x(\alpha, \beta)\mathbf{i} + y(\alpha, \beta)\mathbf{j} \tag{2}$$

or alternatively as

$$\mathbf{r} = \mathbf{r}(\alpha, \beta) = r_\alpha(\alpha, \beta)\mathbf{e}_\alpha(\alpha, \beta) + r_\beta(\alpha, \beta)\mathbf{e}_\beta(\alpha, \beta). \tag{3}$$

with

$$\mathbf{r}_\alpha(\alpha, \beta) = \mathbf{r}(\alpha, \beta) \cdot \mathbf{e}_\alpha(\alpha, \beta), \quad \mathbf{r}_\beta(\alpha, \beta) = \mathbf{r}(\alpha, \beta) \cdot \mathbf{e}_\beta(\alpha, \beta) \tag{4}$$

The partial derivatives $\partial \mathbf{r} / \partial \alpha$ and $\partial \mathbf{r} / \partial \beta$ of the position vector **r** with respect to the curvilinear coordinates are tangent vectors to the corresponding coordinate lines and one can thus write

$$\frac{\partial \mathbf{r}}{\partial \alpha} = h_\alpha \mathbf{e}_\alpha, \; \frac{\partial \mathbf{r}}{\partial \beta} = h_\beta \mathbf{e}_\beta, \tag{5}$$

where the scale factors $h_\alpha = |\partial \mathbf{r} / \partial \alpha|$, $h_\beta = |\partial \mathbf{r} / \partial \beta|$ are obtained from

$$h_\alpha = \left[\left(\frac{\partial x}{\partial \alpha} \right)^2 + \left(\frac{\partial y}{\partial \alpha} \right)^2 \right]^{1/2}, \quad h_\beta = \left[\left(\frac{\partial x}{\partial \beta} \right)^2 + \left(\frac{\partial y}{\partial \beta} \right)^2 \right]^{1/2}. \tag{6}$$

These are arrived at by differentiating expression (2) where the Cartesian unit vectors are constants. The derivatives of the unit vectors are also needed. There is obtained

$$\frac{\partial \mathbf{e}_\alpha}{\partial \alpha} = -\frac{1}{h_\beta}\frac{\partial h_\alpha}{\partial \beta}\mathbf{e}_\beta , \quad \frac{\partial \mathbf{e}_\alpha}{\partial \beta} = \frac{1}{h_\alpha}\frac{\partial h_\beta}{\partial \alpha}\mathbf{e}_\beta ,$$
$$\frac{\partial \mathbf{e}_\beta}{\partial \alpha} = \frac{1}{h_\beta}\frac{\partial h_\alpha}{\partial \beta}\mathbf{e}_\alpha , \quad \frac{\partial \mathbf{e}_\beta}{\partial \beta} = -\frac{1}{h_\alpha}\frac{\partial h_\beta}{\partial \alpha}\mathbf{e}_\alpha . \tag{7}$$

These are found by manipulations of the equation arrived at from further differentiation of the first and second equation (5) with respect to β and α, respectively.

The polar coordinates $\alpha \triangleq r$, $\beta \triangleq \theta$ (Figure 2) are employed here and in the following as a simple specific illustrative example case.

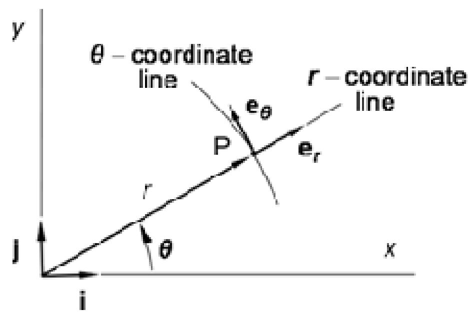

Figure 2: Polar coordinate system.

From Figure 2,

$$x = r\,cos\theta , \quad y = r\,sin\theta . \tag{8}$$

Corresponding to (2) and (3), we have

$$\mathbf{r}(r,\theta) = r\,cos\theta\,\mathbf{i} + r\,sin\theta\,\mathbf{j} \tag{9}$$

and

$$\mathbf{r}(r,\theta) = r\mathbf{e}_r(\theta) + 0\cdot\mathbf{e}_\theta(\theta). \tag{10}$$

The scale factors (6) are

$$h_r = \left[cos^2\theta + sin^2\theta\right]^{1/2} = 1, \quad h_\theta = \left[r^2 sin^2\theta + r^2 cos^2\theta\right]^{1/2} = r \tag{11}$$

and the derivatives (6) are

$$\frac{\partial \mathbf{e}_r}{\partial r} = \mathbf{0}, \quad \frac{\partial \mathbf{e}_r}{\partial \theta} = \mathbf{e}_\theta , \quad \frac{\partial \mathbf{e}_\theta}{\partial r} = \mathbf{0}, \quad \frac{\partial \mathrm{e}_\theta}{\partial \theta} = -\mathbf{e}_r . \tag{12}$$

In this simple application, the derivatives (12) can also be found directly by inspection without the use of the general expressions (7).

3. HOW TO CALCULATE DERIVATIVES IN CURVILINEAR COORDINATES

Any problem of mechanics ends up to various ordinary or partial differential equations. Therefore, the concept of differentiation must be well-understood, particularly when considering differentiation in curvilinear coordinates which has proven to be rather difficult to handle traditionally. A derivative or gradient measures the change of the function considered. To have a fixed frame with respect to which the measurement will be done, we can apply a local Cartesian frame, and orientate its unit base vectors to coincide with the unit vectors of the curvilinear system at the point where the results will be reached. A curvilinear coordinate do not form a proper system to work as such because the direction of its unit vectors are changing from point to point. The idea is to perform the mathematical operations in these locally defined orthogonal rectilinear coordinates where all the well known rules are valid, and consider finally the result at the single point where the coordinates are equal. In this way, we can bypass all the operations in curvilinear coordinates.

An auxiliary local Cartesian coordinate system X, Y — or shortly a local Cartesian frame — with unit base vectors $\mathbf{e}_X$, $\mathbf{e}_Y$ is made use of with its origin at a generic point P and its axes tangent to the α-, β-coordinate lines (Figure 3). This local frame can be brought to any point P but it is very important to stress to the students that *during a specific derivation of a result, the frame is considered fixed* so that the unit vectors $\mathbf{e}_X$ and $\mathbf{e}_Y$ are constants with respect to differentiation.

At the local origin — and not elsewhere in general —

$$\mathbf{e}_X = \mathbf{e}_\alpha\,, \quad \mathbf{e}_Y = \mathbf{e}_\beta \tag{13}$$

When applying this method, a rule between differentiation in the local Cartesian and curvilinear coordinates will be needed. This is easy to build up by applying the well known chain rule which will be simplified in orthogonal systems to a diagonal form to give

$$\frac{\partial}{\partial X} = \frac{1}{h_\alpha}\frac{\partial}{\partial \alpha} \quad , \quad \frac{\partial}{\partial Y} = \frac{1}{h_\beta}\frac{\partial}{\partial \beta} \; . \tag{14}$$

These are the formulas which are employed repeatedly in the applications to follow. Relations (13) should be obvious from Figure 3. Further, the first formula (14), for instance, can be clarified as follows. From (5) due to an increment $\mathrm{d}\alpha$, the position vector obtains the increment $\mathrm{d}\mathbf{r} = h_\alpha \mathbf{e}_\alpha \mathrm{d}\alpha = h_\alpha \mathrm{d}\alpha \mathbf{e}_\alpha$ which equals $\mathrm{d}X\mathbf{e}_X = \mathrm{d}X\mathbf{e}_\alpha$ so $\mathrm{d}X = h_\alpha \mathrm{d}\alpha$.

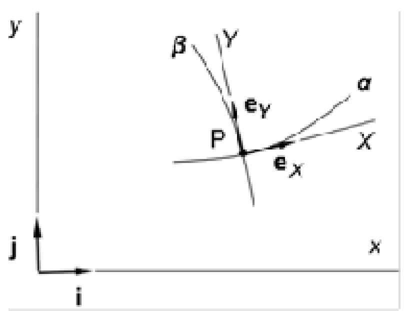

Figure 3: The local frame.

The local frame can be considered as a tool which is taken temporarily in use and then discarded as its function has been fulfilled. We will call this kind of application of the local frame as *the method of local Cartesian frame*.

2.2 Displacement field

Another important vector is the displacement vector defining the kinematics chosen for the structure considered. This theme, the role of which is strongly undervalued in teaching, is the kinematics. It is an extremely powerful tool. Usually, it will not be explained explicitly, that the difference between various beam, plate and shell theories is hiding in the kinematics adopted. The kinematics is the way to define the whole problem to be solved. It is also worth noticing that it is a tool controlled by the analyzer himself. The geometry, loading, the accuracy looked for, are the factors to be taken into account, when choosing proper kinematics,

The displacement field ***u*** has the alternative representations

$$\begin{aligned} \mathbf{u} &= u\mathbf{i} + v\mathbf{j}, \\ &= u_X\mathbf{e}_X + u_Y\mathbf{e}_Y, \\ &= u_\alpha\mathbf{e}_\alpha + u_\beta\mathbf{e}_\beta. \end{aligned} \tag{15}$$

Where, for example

$$u = \mathbf{u} \bullet \mathbf{i},\ v = \mathbf{u} \bullet \mathbf{j}, \text{ and } u_X = \mathbf{u} \bullet \mathbf{e}_X,\ u_Y = \mathbf{u} \bullet \mathbf{e}_Y \tag{16}$$

The well-known expressions for small strain components in Cartesian coordinates are

$$\begin{aligned} \varepsilon_x &= \frac{\partial u}{\partial x}, \\ \varepsilon_y &= \frac{\partial v}{\partial y}, \\ \gamma_{xy} &= \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}. \end{aligned} \tag{17}$$

It is very useful to write the definitions by applying the vector presentation of the displacement field by replacing the components (16) into the definitions (17), which yields

$$\begin{aligned} \varepsilon_x &= \frac{\partial u}{\partial x} = \frac{\partial \mathbf{u}}{\partial x} \bullet \mathbf{i}, \\ \varepsilon_y &= \frac{\partial v}{\partial y} = \frac{\partial \mathbf{u}}{\partial y} \bullet \mathbf{j}, \\ \gamma_{xy} &= \frac{\partial u_x}{\partial y} + \frac{\partial u_y}{\partial x} = \frac{\partial \mathbf{u}}{\partial y} \bullet \mathbf{i} + \frac{\partial \mathbf{u}}{\partial x} \bullet \mathbf{j}, \end{aligned} \tag{18}$$

Here, we have taken into account that the base vectors are constant with respect to differentiation. Similarly, in the local frame we have the linear strains components

$$\begin{aligned} \varepsilon_X &= \frac{\partial u_X}{\partial X} = \frac{\partial \mathbf{u}}{\partial X} \bullet \mathbf{e}_X, \\ \varepsilon_Y &= \frac{\partial u_Y}{\partial Y} = \frac{\partial \mathbf{u}}{\partial Y} \bullet \mathbf{e}_Y, \\ \gamma_{XY} &= \frac{\partial u_X}{\partial Y} + \frac{\partial u_Y}{\partial X} = \frac{\partial \mathbf{u}}{\partial Y} \bullet \mathbf{e}_X + \frac{\partial \mathbf{u}}{\partial X} \bullet \mathbf{e}_Y. \end{aligned} \tag{19}$$

or correspondingly non-linear ones

$$\begin{aligned} \varepsilon_X &= \frac{\partial \mathbf{u}}{\partial X} \bullet \mathbf{e}_X + \frac{1}{2}\frac{\partial \mathbf{u}}{\partial X} \bullet \frac{\partial \mathbf{u}}{\partial X}, \\ \varepsilon_Y &= \frac{\partial \mathbf{u}}{\partial Y} \bullet \mathbf{e}_Y + \frac{1}{2}\frac{\partial \mathbf{u}}{\partial Y} \bullet \frac{\partial \mathbf{u}}{\partial Y}, \\ \gamma_{XY} &= \frac{\partial \mathbf{u}}{\partial Y} \bullet \mathbf{e}_X + \frac{\partial \mathbf{u}}{\partial X} \bullet \mathbf{e}_Y + \frac{\partial \mathbf{u}}{\partial X} \bullet \frac{\partial \mathbf{u}}{\partial Y}. \end{aligned} \tag{20}$$

When applying now the differentiation rules (14), and consider the result at the origin, we get

$$\varepsilon_X = \varepsilon_\alpha = \frac{\partial \mathbf{u}}{h_\alpha \partial \alpha} \bullet \mathbf{e}_\alpha + \frac{1}{2} \frac{\partial \mathbf{u}}{h_\alpha \partial \alpha} \bullet \frac{\partial \mathbf{u}}{h_\alpha \partial \alpha},$$
$$\varepsilon_Y = \varepsilon_\beta = \frac{\partial \mathbf{u}}{h_\beta \partial \beta} \bullet \mathbf{e}_\beta + \frac{1}{2} \frac{\partial \mathbf{u}}{h_\beta \partial \beta} \bullet \frac{\partial \mathbf{u}}{h_\beta \partial \beta}, \tag{21}$$
$$\gamma_{XY} = \gamma_{\alpha\beta} = \frac{\partial \mathbf{u}}{h_\beta \partial \beta} \bullet \mathbf{e}_\alpha + \frac{\partial \mathbf{u}}{h_\alpha \partial \alpha} \bullet \mathbf{e}_\beta + \frac{\partial \mathbf{u}}{h_\alpha \partial \alpha} \bullet \frac{\partial \mathbf{u}}{h_\beta \partial \beta}.$$

The fact which is now important to notice is that the kinematics is given in curvilinear coordinates, including the unit vectors $\mathbf{e}_\alpha$ and $\mathbf{e}_\beta$ which are not constant with respect to differentiation, and their derivatives according to rule (7) have to be taken into account.

All the strain components can now be calculated very mechanically, independently of how complicated the kinematics or the structure under consideration is.

3.1 The gradient

The gradient and the divergence expressions in curvilinear coordinates are derived here as examples of the use of the method of local Cartesian frame. Further, the divergence expression is needed in the derivation of the integration by parts formula.

In Cartesian coordinates the definition the gradient of a scalar f is

$$\operatorname{grad} f \equiv \nabla f = \frac{\partial f}{\partial x}\mathbf{i} + \frac{\partial f}{\partial y}\mathbf{j} \tag{22}$$

or using the local frame

$$\operatorname{grad} f = \frac{\partial f}{\partial X}\mathbf{e}_X + \frac{\partial f}{\partial Y}\mathbf{e}_Y . \tag{23}$$

Thus, at the local origin due to (13) and (14)

$$\operatorname{grad} f = \frac{1}{h_\alpha}\frac{\partial f}{\partial \alpha}\mathbf{e}_\alpha + \frac{1}{h_\beta}\frac{\partial f}{\partial \beta}\mathbf{e}_\beta . \tag{24}$$

This is the standard mathematics formula for the gradient in curvilinear coordinates.
In polar coordinates, due to (12), we get

$$\operatorname{grad} f = \frac{1}{h_r}\frac{\partial f}{\partial r}\mathbf{e}_r + \frac{1}{h_\theta}\frac{\partial f}{\partial \theta}\mathbf{e}_\theta = \frac{\partial f}{\partial r}\mathbf{e}_r + \frac{1}{r}\frac{\partial f}{\partial \theta}\mathbf{e}_\theta . \tag{25}$$

3.2 The Divergence

For a vector **F** we have the alternative representations

$$\begin{aligned} \mathbf{F} &= F_x(x,y)\mathbf{i} + F_y(x,y))\mathbf{j}, \\ &= F_X(X,Y)\mathbf{e}_X + F_Y(X,Y)\mathbf{e}_Y , \\ &= F_\alpha(\alpha,\beta)\mathbf{e}_\alpha(\alpha,\beta) + F_\beta(\alpha,\beta)\mathbf{e}_\beta(\alpha,\beta) . \end{aligned} \tag{26}$$

Again it is emphasized that although point P for the origin of the X,Y-system can be anywhere, during the following steps, it and the directions of the X- and Y-axes are fixed.

In Cartesian coordinates the definition for the divergence is

$$\mathrm{div}\mathrm{F} \equiv \nabla \bullet \mathbf{F} = \frac{\partial F_x}{\partial x} + \frac{\partial F_y}{\partial y} = \frac{\partial F_X}{\partial X} + \frac{\partial F_Y}{\partial Y}. \tag{27}$$

Now

$$F_X = \mathbf{F} \bullet \mathbf{e}_X, \quad F_Y = \mathbf{F} \bullet \mathbf{e}_y \tag{28}$$

so

$$\frac{\partial F_X}{\partial X} = \frac{\partial}{\partial X}(\mathbf{F} \bullet \mathbf{e}_X) = \frac{\partial \mathbf{F}}{\partial X} \bullet \mathbf{e}_X, \quad \frac{\partial F_Y}{\partial Y} = \frac{\partial}{\partial Y}(\mathbf{F} \bullet \mathbf{e}) = \frac{\partial \mathbf{F}}{\partial Y} \bullet \mathbf{e}_Y \tag{29}$$

as in the local frame $\mathbf{e}_X$ and $\mathbf{e}_Y$ are constants. Thus,

$$\mathrm{div}\mathbf{F} = \frac{\partial \mathbf{F}}{\partial X} \bullet \mathbf{e}_X + \frac{\partial \mathbf{F}}{\partial Y} \bullet \mathbf{e}_Y. \tag{30}$$

This type of representation is suitable for the method of local Cartesian frame. At the local origin due to formulas (13) and (14)

$$\mathrm{div}\mathbf{F} = \frac{1}{h_\alpha}\frac{\partial \mathbf{F}}{\partial \alpha} \bullet \mathbf{e}_\alpha + \frac{1}{h_\beta}\frac{\partial \mathbf{F}}{\partial \beta} \bullet \mathbf{e}_\beta. \tag{31}$$

Employing the last form (26), we obtain

$$\frac{1}{h_\alpha}\frac{\partial \mathbf{F}}{\partial \alpha} \bullet \mathbf{e}_\alpha = \frac{1}{h_\alpha}\left[\frac{\partial}{\partial \alpha}\left(F_\alpha \mathbf{e}_\alpha + F_\beta \mathbf{e}_\beta\right)\right] \bullet \mathbf{e}_\alpha = \frac{1}{h_\alpha}\left(\frac{\partial F_\alpha}{\partial \alpha} + \frac{F_\beta}{h_\beta}\frac{\partial h_\alpha}{\partial \beta}\right). \tag{32}$$

Use have been made of expressions (7) and of the properties of the scalar product. Similarly,

$$\frac{1}{h_\beta}\frac{\partial \mathbf{F}}{\partial \beta} \bullet \mathbf{e}_\beta = \frac{1}{h_\beta}\left(\frac{\partial F_\beta}{\partial \beta} + \frac{F_\alpha}{h_\alpha}\frac{\partial h_\beta}{\partial \alpha}\right) \tag{33}$$

and thus

$$\begin{aligned} \mathrm{div}\,\mathbf{F} &= \frac{1}{h_\alpha}\frac{\partial F_\alpha}{\partial \alpha} + \frac{1}{h_\alpha h_\beta}\frac{\partial h_\alpha}{\partial \beta}F_\beta + \frac{1}{h_\beta}\partial\frac{\partial F_\beta}{\partial \beta} + \frac{1}{h_\alpha h_\beta}\frac{\partial h_\beta}{\partial \alpha}F_\alpha \\ &= \frac{1}{h_\alpha h_\beta}\left[\frac{\partial}{\partial \alpha}\left(h_\beta F_\alpha\right) + \frac{\partial}{\partial \beta}\left(h_\alpha F_\beta\right)\right], \end{aligned} \tag{34}$$

agreeing with the standard formula given in the literature. In polar coordinates (34) takes the form

$$\mathrm{div}\,\mathbf{F} = \frac{1}{r}\left[\frac{\partial}{\partial r}(rF_r) + \frac{\partial}{\partial \theta}(F_\theta)\right] = \frac{\partial F_r}{\partial r} + \frac{F_r}{r} + \frac{1}{r}\frac{\partial F_\theta}{\partial \theta}. \tag{35}$$

4. PRINCIPLE OF VIRTUAL WORK

The principle of virtual work has a central role in teaching structural mechanics. It can be employed in analytical applications but it also forms the starting point for numerical methods, especially the finite element method. It is thus a unifying principle which should be clearly understood by the student. It is well-known that the method can be used to derive equilibrium equations in a systematic way. Here, this idea is employed in connection with the method of local Cartesian frame.

The principle of virtual work can be expressed as

$$\delta W^i + \delta W^e = 0 . \tag{36}$$

Here for a two-dimensional continuum (and small strains) the virtual work of internal forces

$$\delta W^i = -\int_A \left(\sigma_x \delta\varepsilon_x + \sigma_y \delta\varepsilon_y + \tau_{xy} \delta\gamma_{xy} \right) \mathrm{d}A \tag{37}$$

and the virtual work of external forces, correspondingly

$$\delta W^e = \int_A \left(f_x \delta u + f_y \delta v \right) \mathrm{d}A + \int_{s_t} \left(t_x \delta u + t_y \delta v \right) \mathrm{d}s \tag{38}$$

The virtual strains are obtained by variation of the general strain-displacement relations:

5.1 One dimension

Integration by parts is an important mathematical manipulation which is needed in structural mechanics especially in connection with the principle of virtual work.
The starting point is the relation

$$\int_a^b \frac{\mathrm{d}u}{\mathrm{d}x} \mathrm{d}x = \left[u \right]_a^b \tag{39}$$

for an arbitrary (smooth) function $u(x)$. Inserting $u = fg$, where $f(x)$ and $g(x)$ are two functions, produces with some arrangement the integration by parts formula

$$\int_a^b \frac{\mathrm{d}f}{\mathrm{d}x} g \,\mathrm{d}x = \left[fg \right]_a^b - \int_a^b f \frac{\mathrm{d}g}{\mathrm{d}x} \mathrm{d}x . \tag{40}$$

5.2 Two dimensions

The starting point is the Gauss formula which is in two dimensions

$$\int_A \nabla \bullet \mathbf{F} \mathrm{d}A = \int_s \mathbf{F} \bullet \mathbf{n} \mathrm{d}s . \tag{41}$$

The meaning of the notations is obvious. In Cartesian coordinates (41) obtains the form

$$\int_A \left(\frac{\partial F_x}{\partial x} + \frac{\partial F_y}{\partial y} \right) \mathrm{d}x \mathrm{d}y = \int_s (F_x n_x + F_y n_y) \mathrm{d}s \tag{42}$$

and in curvilinear coordinates ($\mathrm{d}A = \mathrm{d}X \mathrm{d}Y = h_\alpha \mathrm{d}\alpha \, h_\beta \mathrm{d}\beta = h_\alpha h_\beta \mathrm{d}\alpha \, \mathrm{d}\beta$ and $\nabla \bullet \mathbf{F}$ is obtained from (31)):

$$\int_{\alpha,\beta}\left[\frac{\partial}{\partial\alpha}(h_\beta F_\alpha)+\frac{\partial}{\partial\beta}(h_\alpha F_\beta)\right]\mathrm{d}\alpha\,\mathrm{d}\beta=\int_s(F_\alpha n_\alpha+F_\beta n_\beta)\mathrm{d}s\,. \tag{43}$$

The α,β notation is used to indicate that the area integral is to be taken in the α,β-plane. Defining temporarily functions u and v by $u=h_\beta F_\alpha$, $v=h_\alpha F_\beta$ gives the form

$$\int_{\alpha,\beta}\left(\frac{\partial u}{\partial\alpha}+\frac{\partial v}{\partial\beta}\right)\mathrm{d}\alpha\,\mathrm{d}\beta=\int_s\left(\frac{n_\alpha}{h_\beta}u+\frac{n_\beta}{h_\alpha}v\right)\mathrm{d}s\,. \tag{44}$$

Finally making the consecutive selections, $u=fg$ and $v=0$, $u=0$, where $f(\alpha,\beta)$ and $g(\alpha,\beta)$ are two functions, we arrive at the integration by parts formulas

$$\begin{aligned}\int_{\alpha,\beta} f\frac{\partial g}{\partial\alpha}\mathrm{d}\alpha\,\mathrm{d}\beta&=\int_s\frac{n_\alpha}{h_\beta}fg\,\mathrm{d}s-\int_{\alpha,\beta}\frac{\partial f}{\partial\alpha}g\,\mathrm{d}\alpha\,\mathrm{d}\beta\,,\\ \int_{\alpha,\beta} f\frac{\partial g}{\partial\beta}\mathrm{d}\alpha\,\mathrm{d}\beta&=\int_s\frac{n_\beta}{h_\alpha}fg\,\mathrm{d}s-\int_{\alpha,\beta}\frac{\partial f}{\partial\beta}g\,\mathrm{d}\alpha\,\mathrm{d}\beta\,.\end{aligned} \tag{45}$$

In polar coordinates $\mathrm{d}A=\mathrm{d}X\,\mathrm{d}Y=\mathrm{d}r\,r\,\mathrm{d}\theta=r\,\mathrm{d}r\,\mathrm{d}\theta$ and equations (46) obtain the forms

$$\begin{aligned}\int_{\mathrm{r},\theta} f\frac{\partial g}{\partial r}\mathrm{d}r\,\mathrm{d}\theta&=\int_s\frac{n_r}{r}fg\,\mathrm{d}s-\int_{\mathrm{r},\theta}\frac{\partial f}{\partial r}g\,\mathrm{d}r\,\mathrm{d}\theta\,,\\ \int_{\mathrm{r},\theta} f\frac{\partial g}{\partial\theta}\mathrm{d}r\,\mathrm{d}\theta&=\int_s n_\theta fg\,\mathrm{d}s-\int_{\mathrm{r},\theta}\frac{\partial f}{\partial\theta}g\,\mathrm{d}r\,\mathrm{d}\theta\,.\end{aligned} \tag{46}$$

5. CONCLUDING COMMENTS

Above, there are given all the mathematical tools needed to allow the application of the method of local Cartesian frame. Although most of the relevant formulas have probably been presented earlier to the students in some mathematics courses, it is certainly a good idea to go through these details again when teaching structural mechanics. As seen above, this does not demand too much effort. In our opinion this effort is more than paid back when applications with curved structures are encountered. The need to employ complicated strain deduction figures and free body diagrams disappears.

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HOW TO WORK WITH CURVED STRUCTURES; APPLICATIONS

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EXTENDED ABSTRACT

This is a companion paper to the one titled: How to work with curved structures; theory. The general theory is presented in the cited paper. In the present paper two specific example applications are given in detail. Provided that the main ingredients in the method of local Cartesian frame for curved structures are explained in the theory paper, we here just shortly describe the two applications.

The first application concerns the analysis of a circular disk. Polar coordinates are employed. The conventional procedure applied in textbooks in this case is again based on carefully drawn figures showing the initial and deformed geometry for a small material element. Deducing the relevant expressions from the figures demands rather careful interpretations. Our approach is based on the use of a local Cartesian frame. Further, after the strains have been determined, the local equilibrium equations and the traction boundary conditions are arrived at by employing the principle of virtual work. Integration by parts in two dimensions is needed in the manipulations. This part of mathematics may be somewhat unfamiliar to the students. However, in introducing the most important principle of virtual work in general, integration by parts must be mastered, so this should not be a grave problem.

The second application concerns the analysis of a circular beam in two loading cases. Emphasis is placed on the importance of the corresponding kinematic assumptions. The curvilinear coordinates are now the beam axis arc length and two rectangular axes perpendicular to the beam axis. To determine the strains correctly from figures describing the geometry in the original and in the deformed state seems to us as a nearly impossible task. The method of local Cartesian frame works easily. In the equilibrium equations derivation, which is based on the principle of virtual work, integration by parts is needed only in one dimension. This tool should be already rather familiar to the students.

The meaning of the papers considered, is not just to derive the basic equations of classical mechanics, but to derive them in a systematic way students can easier assimilate. According to the feedback of students, it is obvious that even the complicated equations of the shell theory have got a novel role, when the background of each term will get a clear physical meaning.

Other concepts based on various kinematical assumptions, such as sectorial coordinate with thin-walled structures, may be derived simply as well.

KEYWORDS

Teaching Techniques for Mechanics, Curved Structures, Circular disk, Circular beam

1. INTRODUCTION

This is a companion paper to the paper of this conference titled: How to work with curved structures; theory. This will be referred to hereon as the theory paper. The general theory is presented in the cited paper. In the present paper, two specific example applications are given in detail.

The first application concerns the analysis of a circular disk. Polar coordinates are employed. The second application concerns the analysis of a circular beam. The curvilinear coordinates are now the beam arc length parameter and two rectangular axes perpendicular to the beam axis.

We repeat from the theory paper the basic relations used in the method of local Cartesian frame:

$$\mathbf{e}_X = \mathbf{e}_\alpha , \quad \mathbf{e}_Y = \mathbf{e}_\beta \tag{1}$$

and

$$\frac{\partial}{\partial X} = \frac{1}{h_\alpha}\frac{\partial}{\partial \alpha} , \quad \frac{\partial}{\partial Y} = \frac{1}{h_\beta}\frac{\partial}{\partial \beta} . \tag{2}$$

The meaning of the notations are shown in Figure 1, and explained in the theory paper.

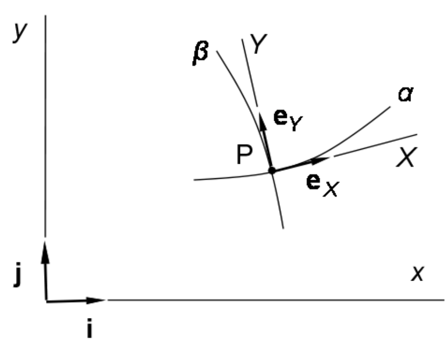

Figure 1: The local frame.

Additionally, we may need the derivatives of the unit vectors $\mathbf{e}_\alpha$ and $\mathbf{e}_\beta$ with respect to α and β. In connection with the principle of virtual work we will need also the integration by parts formulae. These both are derived in the theory paper. However, in what follows we will not represent general formulas for strains and general equilibrium equations, (Paavola and Salonen (2004)). Instead, in the two applications we will derive the necessary relations directly and not via general formulae.

2. CIRCULAR DISK
2.1 Polar coordinates

We consider a circular disk with a radius R (Figure 2). Polar coordinates r and θ are employed in the analysis. No dependence of the relevant quantities in the perpendicular direction to the disk is assumed.

We repeat here from the theory paper the relevant formulae in polar coordinates. The scale factors are $h_r = 1$, $h_\theta = r$. The counterparts of (1) and (2) are

$$\mathbf{e}_X = \mathbf{e}_r \,, \quad \mathbf{e}_Y = \mathbf{e}_\theta \tag{3}$$

and

$$\frac{\partial}{\partial X} = \frac{\partial}{\partial r} \,, \quad \frac{\partial}{\partial Y} = \frac{1}{r}\frac{\partial}{\partial \theta} \,. \tag{4}$$

Further, the derivatives of the unit vectors are

$$\frac{\partial \mathbf{e}_r}{\partial r} = \mathbf{0} \,, \quad \frac{\partial \mathbf{e}_r}{\partial \theta} = \mathbf{e}_\theta \,, \quad \frac{\partial \mathbf{e}_\theta}{\partial r} = \mathbf{0} \,, \quad \frac{\partial \mathbf{e}_\theta}{\partial \theta} = -\mathbf{e}_r \,. \tag{5}$$

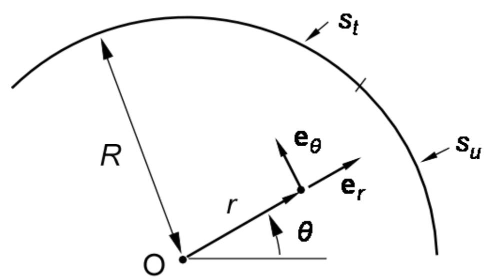

Figure 2: Part of a circular disk and notation.

2.2 Strains

The displacement field ***u*** has the alternative representations

$$\begin{aligned} \mathbf{u} &= u_X \mathbf{e}_X + u_Y \mathbf{e}_Y , \\ &= u_r \mathbf{e}_r + u_\theta \mathbf{e}_\theta \,. \end{aligned} \tag{6}$$

In the theory paper, the small strain expressions are derived in the local frame:

$$\begin{aligned} \varepsilon_X &= \frac{\partial u_X}{\partial X} = \frac{\partial \mathbf{u}}{\partial X} \bullet \mathbf{e}_X \,, \\ \varepsilon_Y &= \frac{\partial u_Y}{\partial Y} = \frac{\partial \mathbf{u}}{\partial Y} \bullet \mathbf{e}_Y \,, \\ \gamma_{XY} &= \frac{\partial u_X}{\partial Y} + \frac{\partial u_Y}{\partial X} = \frac{\partial \mathbf{u}}{\partial Y} \bullet \mathbf{e}_X + \frac{\partial \mathbf{u}}{\partial X} \bullet \mathbf{e}_Y \,. \end{aligned} \tag{7}$$

Thus, applying (3) and (4), at the local origin, the strain components are resolved:

$$\begin{aligned} \varepsilon_r &= \varepsilon_X = \frac{\partial \mathbf{u}}{\partial r} \bullet \mathbf{e}_r \,, \\ \varepsilon_\theta &= \varepsilon_Y = \frac{1}{r}\frac{\partial \mathbf{u}}{\partial \theta} \bullet \mathbf{e}_\theta \,, \\ \gamma_{r\theta} &= \gamma_{XY} = \frac{1}{r}\frac{\partial \mathbf{u}}{\partial \theta} \bullet \mathbf{e}_r + \frac{\partial \mathbf{u}}{\partial r} \bullet \mathbf{e}_\theta \,. \end{aligned} \tag{8}$$

The last form (6) is substituted in (8) and formulae (5) are used. We obtain in detail

$$\varepsilon_r = \left(\frac{\partial u_r}{\partial r} \mathbf{e}_r + \frac{\partial u_\theta}{\partial r} \mathbf{e}_\theta \right) \bullet \mathbf{e}_r = \frac{\partial u_r}{\partial r} \,,$$

$$\varepsilon_\theta = \frac{1}{r}\left(\frac{\partial u_r}{\partial \theta}\mathbf{e}_r + u_r\mathbf{e}_\theta + \frac{\partial u_\theta}{\partial \theta}\mathbf{e}_\theta - u_\theta\mathbf{e}_r\right)\bullet\mathbf{e}_\theta = \frac{1}{r}\left(u_r + \frac{\partial u_\theta}{\partial \theta}\right) \ , \tag{9}$$

$$\gamma_{r\theta} = \frac{1}{r}\left(\frac{\partial u_r}{\partial \theta}\mathbf{e}_r + u_r\mathbf{e}_\theta + \frac{\partial u_\theta}{\partial \theta}\mathbf{e}_\theta - u_\theta\mathbf{e}_r\right)\bullet\mathbf{e}_r + \frac{1}{r}\left(\frac{\partial u_r}{\partial r}\mathbf{e}_r + \frac{\partial u_\theta}{\partial r}\mathbf{e}_\theta\right)\bullet\mathbf{e}_\theta$$
$$= \frac{1}{r}\left(\frac{\partial u_r}{\partial \theta} - u_\theta\right) + \frac{\partial u_\theta}{\partial r}.$$

Based on classical approaches (Timoshenko and Goodier (1951, p. 65-66)), these results are obtained from a rather awkward differential geometry figure.

2.3 Equilibrium

The well-known general form of stress equilibrium equations for a continuum is $\mathrm{div}\,\boldsymbol{\sigma} + \mathbf{f} = \mathbf{0}$, where $\boldsymbol{\sigma}$ is the stress tensor and $\mathbf{f}$ the body force vector intensity (per volume). We could continue by using the method of local Cartesian frame and dyadic representation. A rather long manipulation is needed to give the final equilibrium equations. They are not given here. Further, the equation referred to is clearly not a suitable starting point for basic courses. The equation itself is probably not familiar and the manipulations needed are rather tedious even when the present polar coordinate case is considered. However, the principle of virtual work gives an alternative way to produce the equilibrium equations.

The principle of virtual work is applied for the equilibrium consideration, and it can be expressed as

$$\delta W^i + \delta W^e = 0 . \tag{10}$$

Here for a two-dimensional continuum (assuming small strains) the virtual work of internal forces is expressed by:

$$\delta W^i = -\int_A \left(\sigma_x\delta\varepsilon_x + \sigma_y\delta\varepsilon_y + \tau_{xy}\delta\gamma_{xy}\right)\mathrm{d}A \tag{11}$$

and the virtual work of external forces, correspondingly is,

$$\delta W^e = \int_A \left(f_x\delta u + f_y\delta v\right)\mathrm{d}A + \int_{s_t}\left(t_x\delta u + t_y\delta v\right)\mathrm{d}s \tag{12}$$

The virtual strains are obtained by variation of the general strain-displacement relations. Boundary s_t is that part of the total boundary where the traction $\mathbf{t}$ is given. Correspondingly, in Figure 2 the notation s_u refers to that part of the total boundary where the displacement $\mathbf{u}$ is given.

The integrands in (11) and (12) are because of their physical meaning, scalar quantities and therefore invariant with respect to coordinate transformations. With reference to polar coordinates, the following may be written:

$$\begin{aligned}
&\sigma_x\delta\varepsilon_x + \sigma_y\delta\varepsilon_y + \tau_{xy}\delta\varepsilon_{xy} = \sigma_X\delta\varepsilon_X + \sigma_Y\delta\varepsilon_Y + \tau_{XY}\delta\gamma_{XY} \\
&= \sigma_r\delta\varepsilon_r + \sigma_\theta\delta\varepsilon_\theta + \tau_{r\theta}\delta\gamma_{r\theta} \ , \\
&f_x\delta u + f_y\delta v = f_X\delta u_X + f_Y\delta u_Y = f_r\delta u_r + f_\theta\delta u_\theta \ , \\
&t_x\delta u + t_y\delta v = t_X\delta u_X + t_Y\delta u_Y = t_r\delta u_r + t_\theta\delta u_\theta \ .
\end{aligned} \tag{13}$$

Thus, the principle of virtual work obtains in polar coordinates the form

$$-\int_A \left(\sigma_r \delta\varepsilon_r + \sigma_\theta \delta\varepsilon_\theta + \tau_{r\theta}\delta\gamma_{r\theta}\right)\mathrm{d}A$$
$$+\int_A \left(f_r \delta u_r + f_\theta \delta u_\theta\right)\mathrm{d}A + \int_{s_t}\left(t_r \delta u_r + t_\theta \delta u_\theta\right)\mathrm{d}s = 0\,, \tag{14}$$

where the virtual strain components are expressed from (9)

$$\delta\varepsilon_r = \frac{\partial \delta u_r}{\partial r}\,,\;\; \delta\varepsilon_\theta = \frac{1}{r}\left(\delta u_r + \frac{\partial \delta u_r}{\partial \theta}\right),\;\; \delta\gamma_{r\theta} = \frac{1}{r}\left(\frac{\partial \delta u_r}{\partial \theta} - \delta u_\theta\right) + \frac{\partial \delta u_\theta}{\partial r}\,. \tag{15}$$

Upon substitution $\mathrm{d}A = r\,\mathrm{d}r\,\mathrm{d}\theta$ in Eqn. (14), the following simplifications are obtained:

first the form

$$-\int_{r,\theta}\left[r\sigma_r \frac{\partial \delta u_r}{\partial r} + \sigma_\theta\left(\delta u_r + \frac{\partial \delta u_\theta}{\partial \theta}\right) + \tau_{r\theta}\left(\frac{\partial \delta u_r}{\partial \theta} - \delta u_\theta\right) + r\tau_{r\theta}\frac{\partial \delta u_\theta}{\partial r}\right]\mathrm{d}r\mathrm{d}\theta$$
$$+\int_{r,\theta}\left(rf_r \delta u_r + rf_\theta \delta u_\theta\right)\mathrm{d}r\mathrm{d}\theta + \int_{s_t}\left(t_r \delta u_r + t_\theta \delta u_\theta\right)\mathrm{d}s = 0\,. \tag{16}$$

Then, using integration by parts (with the formulae derived in the theory paper):

$$\int_{\mathrm{r},\theta} f\frac{\partial g}{\partial r}\mathrm{d}r\,\mathrm{d}\theta = \int_s \frac{n_r}{r} f g\,\mathrm{d}s - \int_{\mathrm{r},\theta}\frac{\partial f}{\partial r} g\,\mathrm{d}r\,\mathrm{d}\theta\,,$$
$$\int_{\mathrm{r},\theta} f\frac{\partial g}{\partial \theta}\mathrm{d}r\,\mathrm{d}\theta = \int_s n_\theta f g\,\mathrm{d}s - \int_{\mathrm{r},\theta}\frac{\partial f}{\partial \theta} g\,\mathrm{d}r\,\mathrm{d}\theta\,. \tag{17}$$

These are applied to eliminate the derivatives on the virtual displacement components δu_r and u_θ. The result is

$$\int_{r,\theta}\left\{\left[\frac{\partial(r\sigma_r)}{\partial r} - \sigma_\theta + \frac{\partial \tau_{r\theta}}{\partial \theta} + rf_r\right]\delta u_r + \left[\frac{\partial \sigma_\theta}{\partial \theta} + \tau_{r\theta} + \frac{\partial(r\tau_{r\theta})}{\partial r} + rf_\theta\right]\delta u_\theta\right\}\mathrm{d}r\mathrm{d}\theta$$
$$+\int_{s_t}\left\{\left[t_r - n_r\sigma_r - n_\theta\tau_{r\theta}\right]\delta u_r + \left[t_\theta - n_\theta\sigma_\theta - n_r\tau_{r\theta}\right]\delta u_\theta\right\}\mathrm{d}s = 0 \tag{18}$$

It should be noted that the virtual displacement components are set to vanish on s_u, which explains why the line integral is only over s_t. The equilibrium equations are thus — after some minor development:

$$\frac{\partial \sigma_r}{\partial r} + \frac{1}{r}\frac{\partial \tau_{r\theta}}{\partial \theta} + \frac{\sigma_r - \sigma_\theta}{r} + f_r = 0\,,$$
$$\frac{1}{r}\frac{\partial \sigma_\theta}{\partial \theta} + \frac{\partial \tau_{r\theta}}{\partial \theta} + \frac{2\tau_{r\theta}}{r} + f_\theta = 0\,, \tag{19}$$

$$t_r = n_r\sigma_r + n_\theta\tau_{r\theta}\,,$$
$$t_\theta = n_\theta\sigma_\theta + n_r\tau_{r\theta}\,. \tag{20}$$

The traction boundary conditions simplify with the geometry of Figure 2 to

$$t_r = \sigma_r,\; t_\theta = \tau_{r\theta}\,. \tag{21}$$

as on the boundary $n_r = 1$ and $n_\theta = 0$.

Classically the equilibrium equations are obtained from a free-body diagram, e.g. Timoshenko and Goodier (1951, p.55-56). Our way of derivation cannot be considered particularly short. However, the steps used contain no arbitrariness. Further, similar manipulations must be performed in numerous applications of the principle of virtual work and this example case is a good demonstration exercise for the students.

3. CIRCULAR BEAM
3.1 Coordinate system

A circular plane beam is considered using the notation of Figure 3. The beam is assumed to be symmetrical in geometry and in material properties with respect to the xy-plane. The beam is clamped at $s=0$. As seen from the figure, here the y notation is used with two meanings; as a global coordinate and also locally at the beam cross-section, but this should not cause any confusion. Further, a local coordinate z (not shown in the figure) perpendicular to the xy-plane is needed. Compared to the theory part, where only the two dimensional case was treated, we here have one additional dimension. Additional notations γ and $\mathbf{e}_Z$ with obvious meanings are introduced. The curved beam axis is taken to be an α-coordinate line; here α is associated with the arc length s. The β- and γ-coordinate lines are straight and $\beta = y$ and $\gamma = z$. The local unit vectors $\mathbf{e}_s$, $\mathbf{e}_y$ and $\mathbf{e}_z$ form a right-handed triad.

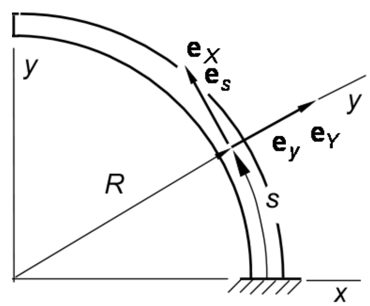

Figure 3: Circular beam.

The position vector of the beam axis is given by $\mathbf{r}_0 = R\mathbf{e}_y$ and that of the generic point P by

$$\mathbf{r}(s,y,z) = \mathbf{r}_0 + y\mathbf{e}_y + z\mathbf{e}_z = R\mathbf{e}_y + y\mathbf{e}_y + z\mathbf{e}_z = (R+y)\mathbf{e}_y + z\mathbf{e}_z . \tag{22}$$

The dependence on s comes through $\mathbf{e}_y$ which is not constant. From curve theory $\mathrm{d}\mathbf{r}_0/\mathrm{d}s = \mathbf{e}_s$ and by Frenet formulae,

$$\frac{\mathrm{d}\mathbf{e}_s}{\mathrm{d}s} = -\frac{1}{R}\mathbf{e}_y , \quad \frac{\mathrm{d}\mathbf{e}_y}{\mathrm{d}s} = \frac{1}{R}\mathbf{e}_s . \tag{23}$$

Differentiation of (22) gives

$$\begin{aligned} &\frac{\partial \mathbf{r}}{\partial s} = (R+y)\frac{\mathrm{d}\mathbf{e}_y}{\mathrm{d}s} = (R+y)\frac{1}{R}\mathbf{e}_s = \left(1+\frac{y}{R}\right)\mathbf{e}_s , \\ &\frac{\partial \mathbf{r}}{\partial y} = \mathbf{e}_y , \quad \frac{\partial \mathbf{r}}{\partial z} = \mathbf{e}_z . \end{aligned} \tag{24}$$

The scale factors are thus seen to be

$$h_s = \left|\frac{\partial \mathbf{r}}{\partial s}\right| = 1 + \frac{y}{R}, \quad h_y = \left|\frac{\partial \mathbf{r}}{\partial y}\right| = 1, \quad h_z = \left|\frac{\partial \mathbf{r}}{\partial z}\right| = 1. \tag{25}$$

Consequently, the counterparts of (1) and (2) are now

$$\mathbf{e}_X = \mathbf{e}_s, \quad \mathbf{e}_Y = \mathbf{e}_y, \quad \mathbf{e}_Z = \mathbf{e}_z \tag{26}$$

and

$$\frac{\partial}{\partial X} = \left(1 + \frac{y}{R}\right)^{-1} \frac{\partial}{\partial s}, \quad \frac{\partial}{\partial Y} = \frac{\partial}{\partial y}, \quad \frac{\partial}{\partial Z} = \frac{\partial}{\partial z}. \tag{27}$$

3.2 Displacement; general

We take here the Timoshenko type kinematic small displacement assumption where the beam material cross sections are assumed to move as rigid plates with no deformation in plate planes. The generic displacement vector of a generic point P becomes then

$$\mathbf{u}(s,y,z) = \left(u - y\theta_z - z\theta_y\right)\mathbf{e}_s + \left(v - z\theta_s\right)\mathbf{e}_y + \left(w + y\theta_s\right)\mathbf{e}_z. \tag{28}$$

Quantities u, v and w are the displacement components of the origin 0 of the cross-section and θ_s, θ_y and θ_z are the components of the cross-sectional rotation vector. Following certain notational convention, the component θ_y is defined as positive in the negative local y-axis direction.

3.3 Displacement; first case

To simplify the presentation we will consider here just two special cases. In the first case the loading consists of a point load P acting at the tip of beam and directed in the local positive y-axis direction. In the second case the tip load P acts in the local positive z – axis direction.

In the first case, due to the assumed symmetry, the displacement of point 0 must be in the xy-plane and the rotation vector must be perpendicular to the xy-plane. Thus, the only non-zero displacement components are u, v and the only non-zero rotation component is θ_z. Expression (28) simplifies to

$$\mathbf{u}(s,y) = \left(u - y\theta_z\right)\mathbf{e}_s + v\mathbf{e}_y. \tag{29}$$

3.4 Strains; first case

The relevant strain components are

$$\begin{aligned} \varepsilon_s &= \varepsilon_X = \frac{\partial \mathbf{u}}{\partial X} \bullet \mathbf{e}_X = \left(1 + \frac{y}{R}\right)^{-1} \frac{\partial \mathbf{u}}{\partial s} \bullet \mathbf{e}_s, \\ \gamma_{sy} &= \gamma_{XY} = \frac{\partial \mathbf{u}}{\partial Y} \bullet \mathbf{e}_X + \frac{\partial \mathbf{u}}{\partial X} \bullet \mathbf{e}_Y = \frac{\partial \mathbf{u}}{\partial y} \bullet \mathbf{e}_s + \left(1 + \frac{y}{R}\right)^{-1} \frac{\partial \mathbf{u}}{\partial s} \bullet \mathbf{e}_y. \end{aligned} \tag{30}$$

The derivatives

$$\begin{aligned} \frac{\partial \mathbf{u}}{\partial s} &= \left(\frac{\mathrm{d}u}{\mathrm{d}s} - y\frac{\mathrm{d}\theta_z}{\mathrm{d}s}\right)\mathbf{e}_s + \left(u - y\theta_z\right)\left(-\frac{\mathbf{e}_y}{R}\right) + \frac{\mathrm{d}v}{\mathrm{d}s}\mathbf{e}_y + v\frac{\mathbf{e}_s}{R}, \\ \frac{\partial \mathbf{u}}{\partial y} &= -\theta_z \mathbf{e}_s \end{aligned} \tag{31}$$

and substitution into (30) gives

$$\begin{aligned}\varepsilon_s &= \left(1+\frac{y}{R}\right)^{-1}\left(\frac{\mathrm{d}u}{\mathrm{d}s} - y\frac{\mathrm{d}\theta_z}{\mathrm{d}s} + \frac{v}{R}\right), \\ \gamma_{sy} &= \left(1+\frac{y}{R}\right)^{-1}\left(-\frac{u - y\theta_z}{R} + \frac{\mathrm{d}v}{\mathrm{d}s}\right) - \theta_z .\end{aligned} \tag{32}$$

To derive these exact results alternatively by some — however carefully drawn — figures is in our opinion practically impossible.

3.5 Equilibrium; first case

Again, the equilibrium equations are derived here by employing the principle of virtual work. The usual assumptions concerning stresses for plane beams is that only the components σ_s and τ_{sy} are non-zero. Thus, the virtual work of internal forces becomes

$$\delta w^I = \int_V \left(\sigma_s \delta\varepsilon_s + \tau_{sy}\delta\gamma_{sy}\right)\mathrm{d}V , \tag{33}$$

where the integration is over the volume of the beam. The volume element $\mathrm{d}V$ can be expressed here as

$$\mathrm{d}V = \mathrm{d}A\mathrm{d}X = \mathrm{d}Ah_s\mathrm{d}s = \mathrm{d}A\left(1+\frac{y}{R}\right)\mathrm{d}s , \tag{34}$$

where $\mathrm{d}A$ is beam cross-sectional area element. The virtual strain expressions are obtained by variations of Eqn. (32) and the virtual work expression becomes

$$\begin{aligned}\delta w^I &= -\int_s \left\{ \int_A [\sigma_s \left(1+\frac{y}{R}\right)^{-1}\left(\frac{\mathrm{d}\delta u}{\mathrm{d}s} - y\frac{\mathrm{d}\delta\theta_z}{\mathrm{d}s} + \frac{\delta v}{R}\right) \right. \\ &\left. + \tau_{sy}\left(1+\frac{y}{R}\right)^{-1}\left(\frac{\mathrm{d}\delta v}{\mathrm{d}s} - \frac{\delta u}{R} - \delta\theta_z\right)\right]\left(1+\frac{y}{R}\right)\mathrm{d}A\right\}\mathrm{d}s \\ &= -\int_s \left\{ \int_A \left[\sigma_s \left(\frac{\mathrm{d}\delta u}{\mathrm{d}s} - y\frac{\mathrm{d}\delta\theta_z}{\mathrm{d}s} + \frac{\delta v}{R}\right) + \tau_{sy}\left(\frac{\mathrm{d}\delta v}{\mathrm{d}s} - \frac{\delta u}{R} - \delta\theta_z\right)\right]\mathrm{d}A\right\}\mathrm{d}s .\end{aligned} \tag{35}$$

The inner integral is over the beam cross-section and the outer over the beam axis length.

In the conventional manner, the stress resultants consisting of the normal force, the shearing force and the bending moment are defined respectively by

$$N = \int_A \sigma_s \mathrm{d}A, \quad Q_y = \int_A \tau_{sy}\mathrm{d}A, \quad M_z = \int_A \sigma_s y\,\mathrm{d}A. \tag{36}$$

The virtual work of internal forces (35) becomes then

$$\delta w^I = -\int_s \left[N\left(\frac{\mathrm{d}\delta u}{\mathrm{d}s} + \frac{\delta v}{R}\right) - M_z\frac{\mathrm{d}\delta\theta_z}{\mathrm{d}s} + Q_y\left(\frac{\mathrm{d}\delta v}{\mathrm{d}s} - \frac{\delta u}{R} - \delta\theta_z\right)\right]\mathrm{d}s . \tag{37}$$

The virtual work of external forces is here just the virtual work of the vertical load:

$$\delta W^e = P\delta v\big|_{s=l} , \tag{38}$$

where $l = \pi R/2$. The virtual work equation becomes thus

$$-\int_s \left[N\left(\frac{\mathrm{d}\delta u}{\mathrm{d}s} + \frac{\delta v}{R}\right) - M_z \frac{\mathrm{d}\delta\theta_z}{\mathrm{d}s} + Q_y \left(\frac{\mathrm{d}\delta v}{\mathrm{d}s} - \frac{\delta u}{R} - \delta\theta_z\right)\right] \mathrm{d}s + P\,\delta v\big|_{s=l} = 0 . \tag{39}$$

To deduce the equilibrium equations, the derivatives on the virtual displacement quantities must be removed by integration by parts. The corresponding formula from the theory paper becomes with x replaced by s here

$$\int_0^l \frac{\mathrm{d}f}{\mathrm{d}s} g\,\mathrm{d}s = [fg]_0^l - \int_0^l f \frac{\mathrm{d}g}{\mathrm{d}s} \mathrm{d}s . \tag{40}$$

Equation (39) is found to transform to (note that due to the clamped beam end $\delta u = \delta v = \delta\theta_z = 0$ at $s = 0$)

$$\int_s \left\{ \left[\frac{\mathrm{d}N}{\mathrm{d}s} + \frac{Q_y}{R}\right]\delta u + \left[\frac{\mathrm{d}Q_y}{\mathrm{d}s} - \frac{N}{R}\right]\delta v - \left[\frac{\mathrm{d}M_z}{\mathrm{d}s} - Q_y\right]\delta\theta \right\} \mathrm{d}s$$
$$+ \left[-N\delta u + \left(-Q_y + P\right)\delta v + M_z \delta\theta \right]\Big|_{s=l} = 0 . \tag{41}$$

Thus, the field equilibrium equations are

$$\frac{\mathrm{d}N}{\mathrm{d}s} + \frac{Q_y}{R} = 0 , \quad \frac{\mathrm{d}Q_y}{\mathrm{d}s} - \frac{N}{R} = 0 , \quad \frac{\mathrm{d}M_z}{\mathrm{d}s} - Q_y = 0 \tag{42}$$

and the traction boundary conditions at $s = l$ are

$$N = 0 , \; Q_y = P , \quad M_z = 0 . \tag{43}$$

In this one-dimensional case the free body diagram approach can produce these relations relatively easily. The virtual work approach presented here may be considered as an alternative method to direct establishment of equilibrium equations, once again demonstrating to the students the importance of the principle of the virtual work.

3.6 Displacement; second case

Now due to the assumed symmetry, the displacement of point 0 must perpendicular to the xy-plane and the rotation vector must be in xy-plane. Thus, the only non-zero displacement component is w and the only non-zero rotation components are θ_s and θ_y. Expression (28) simplifies to

$$\mathbf{u}(s,y,z) = -z\theta_y \mathbf{e}_s - z\theta_s \mathbf{e}_y + (w + y\theta_s)\mathbf{e}_z . \tag{44}$$

3.7 Strains; second case

Due to the page limitations, the following presentation is outlined briefly. However, the steps needed are completely similar to those used in the first loading case. The relevant strain components are now

$$\begin{aligned}
\varepsilon_s &= \varepsilon_X = \frac{\partial \mathbf{u}}{\partial X} \bullet \mathbf{e}_X = \left(1 + \frac{y}{R}\right)^{-1} \frac{\partial \mathbf{u}}{\partial s} \bullet \mathbf{e}_s , \\
\gamma_{sy} &= \gamma_{XY} = \frac{\partial \mathbf{u}}{\partial Y} \bullet \mathbf{e}_X + \frac{\partial \mathbf{u}}{\partial X} \bullet \mathbf{e}_Y = \frac{\partial \mathbf{u}}{\partial y} \bullet \mathbf{e}_s + \left(1 + \frac{y}{R}\right)^{-1} \frac{\partial \mathbf{u}}{\partial s} \bullet \mathbf{e}_y , \\
\gamma_{sz} &= \gamma_{XZ} = \frac{\partial \mathbf{u}}{\partial Z} \bullet \mathbf{e}_X + \frac{\partial \mathbf{u}}{\partial X} \bullet \mathbf{e}_Z = \frac{\partial \mathbf{u}}{\partial z} \bullet \mathbf{e}_s + \left(1 + \frac{y}{R}\right)^{-1} \frac{\partial \mathbf{u}}{\partial s} \bullet \mathbf{e}_z .
\end{aligned} \tag{45}$$

By differentiating the displacement expression (44) with respect to s, y and z and substituting the results in (45) the following are obtained:

$$\begin{aligned}
\varepsilon_s &= -\left(1+\frac{y}{R}\right)^{-1} z\left(\frac{\mathrm{d}\theta_y}{\mathrm{d}s}+\frac{\theta_s}{R}\right), \\
\gamma_{sy} &= -\left(1+\frac{y}{R}\right)^{-1} z\left(\frac{\mathrm{d}\theta_s}{\mathrm{d}s}-\frac{\theta_y}{R}\right), \\
\gamma_{sz} &= \left(1+\frac{y}{R}\right)^{-1}\left(\frac{\mathrm{d}w}{\mathrm{d}s}+y\frac{\mathrm{d}\theta_s}{\mathrm{d}s}\right)-\theta_y \,.
\end{aligned} \tag{46}$$

3.8 Equilibrium; second case

The virtual work of internal forces

$$\delta w^I = \int_V \left(\sigma_s \delta\varepsilon_s + \tau_{sy}\delta\gamma_{sy} + \tau_{sz}\delta\gamma_{sz}\right)\mathrm{d}V \tag{47}$$

becomes finally

$$\delta w^I = -\int_s \left[M_s\left(\frac{\mathrm{d}\delta\theta_s}{\mathrm{d}s}-\frac{\delta\theta_y}{R}\right) - M_y\left(\frac{\mathrm{d}\delta\theta_y}{\mathrm{d}s}+\frac{\delta\theta_s}{R}\right) + Q_z\left(\frac{\mathrm{d}\delta w}{\mathrm{d}s}-\delta\theta_y\right)\right]\mathrm{d}s \tag{48}$$

where the stress resultants are

$$M_s = \int_A \left(y\tau_{sz} - z\tau_{sy}\right)\mathrm{d}A, \quad M_y = \int_A \sigma_s z\,\mathrm{d}A, \quad Q_z = \int_A \tau_{sz}\,\mathrm{d}A. \tag{49}$$

The external virtual work from the transverse load P at the beam tip is

$$\delta W^e = P\,\delta w\big|_{s=l} \tag{50}$$

The virtual work equation gives after the necessary integration by parts manipulations the field equations

$$\frac{\mathrm{d}M_s}{\mathrm{d}s}+\frac{M_y}{R}=0, \quad \frac{\mathrm{d}M_y}{\mathrm{d}s}-\frac{M_s}{R}-Q_z=0, \quad \frac{\mathrm{d}Q_z}{\mathrm{d}s}=0 \tag{51}$$

and the traction boundary conditions

$$M_s = 0, \quad M_y = 0, \quad Q_z = P \tag{52}$$

at $s = l$.

4. CONCLUSIONS

The present paper shows some simple examples to demonstrate the use of the method of local Cartesian frame by emphasizing the role of the kinematics to take into account the loading and the geometry of the structure considered.

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EFFECT OF THE TEACHING ACTIVITY EVALUATION IN THE ENGINEERING EDUCATION QUALITY

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EXTENDED ABSTRACT

The main objective of this paper is to prove the positive effect that teaching activity evaluation of university professors has on the quality of engineering education. This conclusion can be obtained after an analysis of six years of experience in the Escuela de Ingenieros de Caminos at the Technical University of Madrid.

Professor´s evaluation in Spain was introduced in 1983 with the University Reform Law (Ley de Reforma Universitaria, LRU), focusing separately on the teaching and research activities of the professor. However, while the research activity evaluation was delegated to a national commission (Comisión Nacional Evaluadora de la Actividad Investigadora, CNEAI) according to a general procedure, the teaching activity evaluation was delegated to each University by their own rules. Unfortunately, most of the Spanish universities gave no enough relevance to teaching evaluation and, of course, there was no standard procedure to perform this evaluation. In most cases, the teaching evaluation was traditionally conducted by students' unions. The usual procedure was a paper form given to students who were attending lectures on a given day near the end of the term. The results had all type of errors: arithmetic, confusion among subjects and among professors, lost data, etc. Finally, dissemination of evaluation results was forbidden and limited to the professor himself and, eventually, to the Director of his Department.

In 2005, the Escuela de Ingenieros de Caminos (School of Civil Engineers) developed a new on-line system for teaching activity evaluation. This system was immediately accepted by the students and their participation has been growing since then. Faculty were, with few exceptions, collaborative, interested and satisfied with the procedure. The evaluation results were exposed publicly (of course, within the limits of the Spanish Data Protection Law). The system has been carried out from the academic years 2005-2006 to 2009-2010.

By analysing the results of the evaluation in these years, it can be concluded that there has been a general improvement of the quality of teaching, and that one of the main reasons for that has been the public dissemination of results, since professors are more prone to make an effort to improve their own results, and consequently the quality of their teaching. This effect is most evident in younger and non-staff professors. The reasons are twofold; firstly they improve as they get the feedback of their teaching activity and can compare it with the results obtained by their colleagues and, secondly, they improve due to the necessity to get good qualifications to become permanent university employees.

KEYWORDS

Teaching activity evaluation, Professor evaluation, Teaching survey

1. INTRODUCTION: EVALUATION OF TEACHING IN SPAIN

University professor evaluation was introduced in 1983 by law. But it did not begin until 1989, when the Royal Decree 1086/1989 on professors economical retributions was enacted, proceeding to evaluate teaching and research activities of professors. A year later, the University Council delegated the evaluation of teaching to each university and the evaluation of research to a national commission (Comisión Nacional Evaluadora de la Actividad Investigadora, CNEAI).

Since then, the evaluation of teaching activity has been done in different ways by each university, through few and poorly regulated procedures, designed to give, without many qualms, the five-year terms retribution to professors, even if they had no effective teaching performance. However the evaluation of research activity centered in the CNEAI has been very selective, developing a regulated procedure with very comprehensive and specific rules, as well as clear criteria (discussed and criticized, but effective).

Therefore, after more than 20 years of professor's evaluation, the result has been what it was expected. The evaluation of teaching is not reliable or relevant for promotion of professors, but only to get additional remuneration. Meanwhile, the evaluation of research activity, as well as additional remuneration, is the only way for professors to access and to promote inside the university [3]. In a few years the damage that this procedure has caused to Spanish universities will be visible, although in some disciplines where technology-oriented vocational professors are required, the effects are already evident [9].

To correct this situation, the National Agency for the Evaluation of Quality and Accreditation (ANECA) introduced in 2007 the DOCENTIA program, to establish a consistent and verified procedure for the evaluation of teaching activity [5, 6]. The DOCENTIA program is a first step, but is far from being an effective evaluation procedure [8] and it still focuses on facilitating the provision of five-year terms, but generating more paperwork in the process. But the procedure is not useful to recognize the worth of professors who are engaged in teaching activities in a satisfactory manner, and to identify those who are not, with the consequences that can result in both situations.

To bridge this regulatory gap, the School of Ingenieros de Caminos of the Technical University of Madrid (UPM) introduced a very innovative system for teaching evaluation in 2005-06 [7]. After five years, this paper examines the results and verifies the positive impact that the procedure has had on teaching. Compared to the present Spanish university system, which greatly underestimates the teaching activity, we believe that the procedure implemented in the School has increased the interest and respect for this activity.

2. EVALUATION MODEL OF THE TEACHING ACTIVITY IMPLEMENTED IN THE CIVIL ENGINEERING SCHOOL OF UPM

Teaching evaluation in the School of Ingenieros de Caminos, as well as in most university schools, has traditionally been conducted by student unions, with their own means and at their own expense. The usual procedure was to fill out a paper questionnaire among students attending school on a given day. The processing of the results was painstaking and slow, lasting from 9 to 12 months. The results had all type or errors: arithmetical, confusion of subjects and professors, lack of evaluation of some subjects and professors, etc. Besides, it was usual that some academic years surveys were not carried out at all. The results, when available, were delivered only to the professor concerned and his Department Director.

During the academic year of 2005-06, the new School management team considered that proper evaluations could not rely on the goodwill of the students and their limited means. A new teaching evaluation system was developed by the School head-professor [1, 2]. No reference has been found that a similar procedure implemented in any other university, Spanish or foreign [4]. The system was immediately accepted by the students. Their participation has been growing since then, as shown in Table 1 (the slight decrease in 2008-09 was due to the fact that surveys had a shorter time limit, and in 2009-10 was due to the implantation of DOCENTIA in the middle of the surveying period). Professors are, with minor exceptions, interested and satisfied with the new procedure.

Table 1: Evolution of subjects and professors survey

Academic year	Number of evaluated professors							Number of evaluated subjects	Number of surveys			Dissemination
	1st year	2nd year	3rd year	4th year	5th year	6th year	Total		On professors	On subjects	Total	
New System: on line evaluation												
2009-10	31	27	39	35	68	66	266	68	2.513	1.034	3.547	Yes
2008-09	34	29	40	37	62	69	271	64	3.126	1.237	4.363	Yes
2007-08	32	32	35	36	67	71	273	68	3.449	1.352	4.801	Yes
2006-07	41	24	36	31	60	63	256	68	2.263	1.022	3.285	Yes
2005-06	28	30	28	30	51	62	235	68	908	535	1.443	Yes
Former traditional System: paper and pencil in the class room												
2004-05	7	13	36	38	29	59	182	48	No data			No
2003-04	10	26	22	26	56	58	198	59	No data			No
2002-03	No professor evaluation was conducted											
2001-02	No professor evaluation was conducted											
2000-01	9	15	0	16	28	38	106	35	No data			No

Note: The number of students ranges between 1.800 and 2.000. The number of professors ranges between 255 and 270. The curriculum in the Civil Engineering School has six years of studies with 79 different subjects, most of them compulsory for the student, plus the final Project.

The procedure had other effects not initially foreseen. On the one hand, since the results are now widely known by all professors and students, they have been used (in favor or against) in the renewal and recruitment of professors, and to assign responsibilities for coordinating subjects. On the other hand, it has made possible the delivery of teaching certificates for professors who were involved in accreditation processes, in the absence of an equivalent procedure in the UPM. Finally, the attitudes of professors and students have evolved from a situation of indifference and passivity to an awareness and appreciation for the professor’s role.

In order to describe the procedure, it can be divided into two parts: (1) obtaining information through a web-oriented system for conducting surveys, and (2) the presentation of this information and its dissemination to professors and students.

Students access the system with no other requirement to be registered as users in the virtual area of the school (all students are registered from the moment they begin their studies). The student is presented with the list of subjects in which he is registered. Once selected a subject, the student can fill out the survey of the subject itself and of its professors. When conducting the survey on the subject itself, ten questions are displayed on screen which the student must rate between 0 and 10. When conducting the survey on the professors, the system displays the list of professors of that subject, among whom the student should select those who he wishes to evaluate. The evaluation of professors is also done by rating ten questions between 0 and 10. In addition, on the home page of the system students can freely express their opinions on several educational related issues.

Upon completion of the survey on a subject or a professor, the student cannot modify or re-do it (it is removed from the list of subjects that he can access). However, from that moment on or during subsequent sessions, he can fill in the surveys for the rest of his subjects and their professors. Surveys are anonymously incorporated to a data base, without any reference to the student identity.

The results obtained after processing the surveys are published in late June when the final exams have been completed (about 30 days after the deadline for carrying out the surveys). Data is presented in charts and graphs, simple enough to allow quick comparisons between results, but also with enough detail to analyze particular cases.

Dissemination of results, always within the limits permitted by Spanish data protection laws, breaks the former traditional obscurantism of survey results and is essential for the procedure to be effective. Each professor can compare his results with those of colleagues. Students, who for the first time have access to the results of professor evaluations, may use the results to choose their elective subjects.

3. ANALYSIS OF RESULTS

In this five years there have been made and processed more than 17,000 surveys on subjects and professors (Table 1). In order to show graphically the results of the surveys in a comprehensible manner, the graph type shown in Figure 1 has been chosen. This graph compares the scores of the first year (2005-06, on the horizontal axis) and the last year (2009-10, on the vertical axis). Each point on this graph represents a subject or a professor and the grades obtained in these two years. All points (subjects or professors) that are located above the diagonal have improved their rating in that period of five years, while those falling below have worsened (the diagonal is considered a strip of width 1.5 points instead of a single line). Furthermore, for faster visual evaluation, the chart area can be divided into six zones shown in Figure 1.

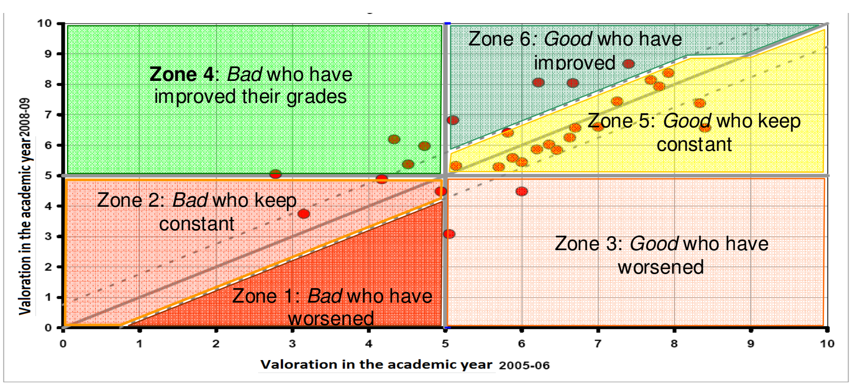

Figure 1: Graph type used to display the results of the surveys.

3.1. Evaluation of subject

The evaluation of each subject is done by the following ten questions:

- A1: You [*the student*] have enough background to follow the course.
- A2: Lectures are useful for learning the subject.
- A3: There is good coordination between the theoretical and practical aspects.
- A4: The course syllabus is appropriate in relation to the available lecture hours.
- A5: The proportion between theory and practice hours is adequate.
- A6: The selected bibliography is correct and easy to find.

- A7: The exam is appropriate to evaluate the learning objectives.
- A8: Your interest for the subject has increased after attending the course.
- A9: You would choose this course if it were optional (or would choose it again).
- A10: General evaluation of the subject.

Students may grade each question from 0 (strongly disagree) up to 10 (strongly agree). However, for questions A4 and A5, also graded from 0 to 10, their optimum value in 5.

Figure 8 (in annex) shows the ratings for each of these ten questions. To clarify the graph, there are only represented the 30 subjects which were evaluated by five or more surveys in each of the five years. When analyzing this figure, almost all questions have more subjects above the diagonal than below it.

Variation of scores from 2005-06 to 2009-10 are shown in Figure 2. Many subjects repeat their rating in all five years, but there are significantly more subjects that end up with better ratings than with worse ones (except for question A2). The evolution is also positive for the main question (A10), where eight subjects improve their score, while four make it worse, although two of these are clearly positive ratings. The remaining 18 subjects maintain their scores (remain in the diagonal band).

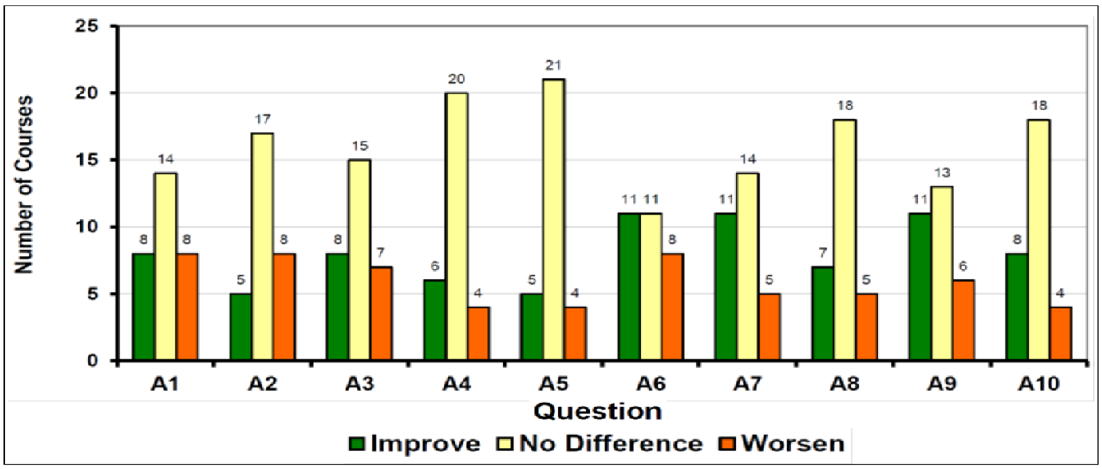

Figure 2: Variation in the rating of subjects from 2005-06 to 2009-10.

Table 2 presents the average ratings for all the questions. Results are higher in 2009-10 than for 2005-06 (for A4 and A5 these differences are negative, because moves away from 5, which is their optimal value). The differences are minimal for questions A1, A2 and A3, but they are significant for A6, A7, A8, A9 and A10. This data supports the conclusion that there has been a general improvement in the subjects during this period.

Table 2: Average rating for questions about the subjects.

Term	Number of subjects evaluated with more than 5 surveys	Average rating for subjects with 5 or more surveys									
		A1	A2	A3	A4 (best if 5)	A5 (best if 5)	A6	A7	A8	A9	A10
2005-06	33	6,2	6,2	5,7	6,3	6,1	5,7	5,5	5,9	5,4	6,0
2006-07	44	6,3	6,1	5,7	6,1	5,9	5,8	5,8	6,1	5,9	6,1
2007-08	48	6,1	6,2	5,6	6,5	6,2	6,1	6,1	6,3	6,1	6,3
2008-09	53	6,5	6,3	5,8	6,4	6,2	6,3	6,3	6,5	6,2	6,4
2009-10	48	6,5	6,4	5,9	6,5	6,3	6,4	6,4	6,5	6,4	6,6

Note: Ratings from 0 (very bad) to 10 (very good), except for questions A4 and A5, where a value of 5 is their best.

3.2. Professor´s evaluation

The evaluation of each professor is done by answering the following ten questions:

- P1: Attends to the scheduled lectures.
- P2: Begins and ends lectures on time.
- P3: Is clear in his explanations.
- P4: Uses properly the educational resources: voice, whiteboard, presentations, ...
- P5: Links the subject with other subjects or with the practice of engineering.
- P6: Motivates students to learn the subject.
- P7: Has, in general, a positive attitude toward the students.
- P8: Is available in his or her office hours.
- P9: You would wish that this professor would teach also other subjects.
- P10: General evaluation of the professor.

As before, students score each question from 0, when they have a very bad opinion about the professor related to that question, up to 10, when their opinion is optimal.

Figure 9 (in annex) shows the ratings for each of the ten questions. There are only represented the 89 professors who have been evaluated by five or more surveys in each of the five academic years. Professors are classified according to their professional category as full professors (Catedráticos de Universidad, CU), associate professors (Titulares de Universidad, TU) and others non-staff professors. Figure 9 shows a general improvement in the ratings since most professors are placed above the diagonal stripe.

Variation of scores from 2005-06 to 2009-10 for each of the ten questions are shown in Figure 3. For questions P4, P6, P8, P9 and P10, there are more professors who improve than those who remain equal or get worse. For questions P1, P2, P3, P5 and P7 most of the professors keep their ratings, although there are more professors who improve than those who worsen.

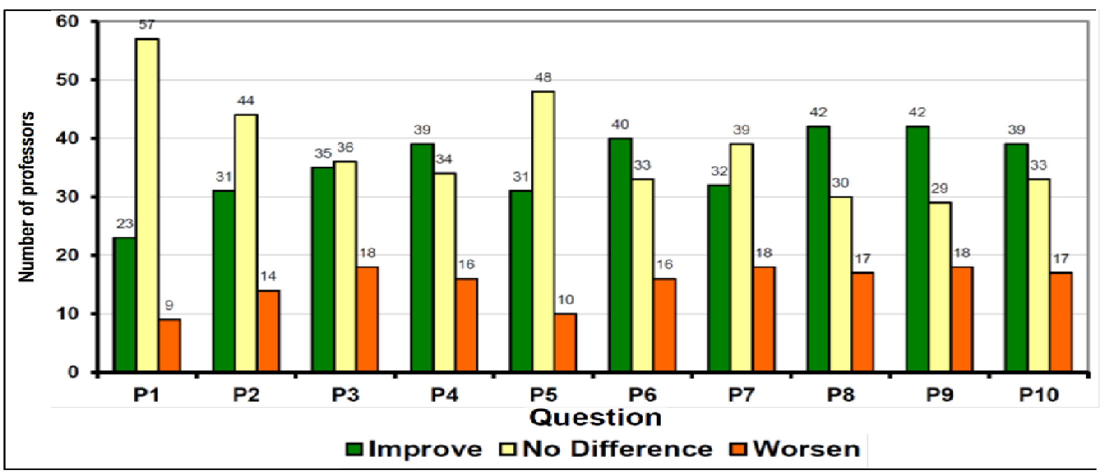

Figure 3: Variation of professor´s ratings from 2005-06 to 2009-10 .

Results of the question P10 can also be analyzed depending on the professional category of professors (CU, TU and others non-staff) and their age (with 58 years or more, between 57 and 47 years, and younger than 46 years). The results are shown in Figures 4 and 5, and in all cases there are more professors who have improved their assessment than professors who have worsened, regardless of professional status and age. However, the proportion of professors who improved is significantly higher for the “others non-staff” category and the younger ones. Equal conclusions can be obtained from Figures 6 and 7, where it seems that the improvement is more related to the age factor than to the professional status.

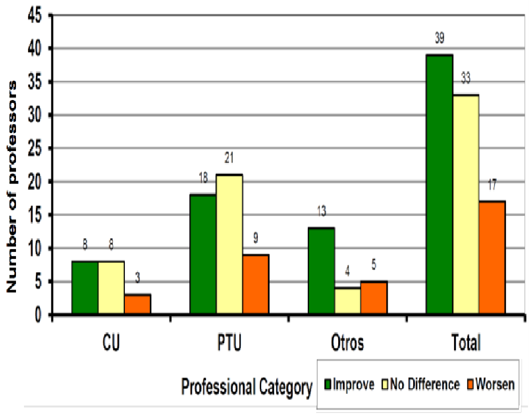

Figure 4: Variation in the assessment of professors depending on their profesional category.

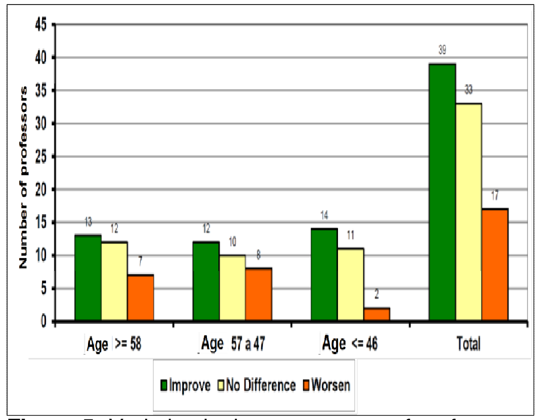

Figure 5: Variation in the assessment of professors depending on their age.

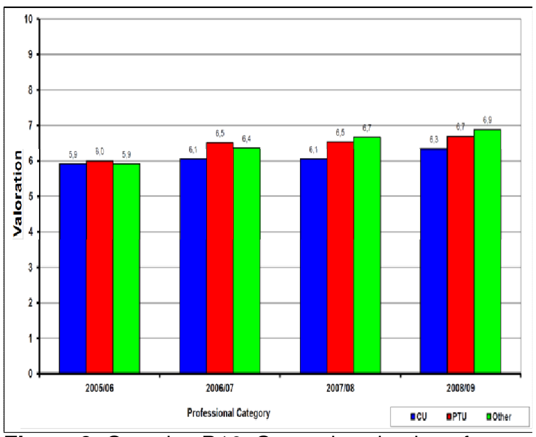

Figure 6: Question P10: General evaluation of professors by his or her professional status.

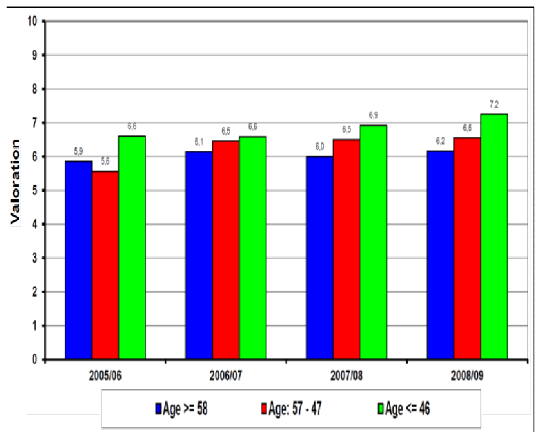

Figure 7: Question P10: General evaluation of professors by his or her age.

Table 3 shows that the average ratings in 2009-10 are significantly higher than in 2005-06. This numerical data supports the conclusion that there has been an improvement in the teaching activity during this period.

Table 3: Average scores for questions on professors.

Year	Number of professors evaluated with more than 5 surveys	Average score for professors evaluated with more than 5 surveys									
		P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**
2005-06	103	8,8	7,3	6,0	6,1	6,2	5,7	6,6	6,1	4,6	**5,9**
2006-07	160	8,9	7,7	6,5	6,5	6,5	6,2	7,1	6,9	5,4	**6,4**
2007-08	185	8,9	7,6	6,6	6,6	6,6	6,2	7,2	6,9	5,6	**6,5**
2008-09	200	9,1	8,0	6,8	6,9	6,8	6,5	7,4	7,3	5,9	**6,7**
2009-10	173	9,2	8,2	6,9	6,9	6,9	6,6	7,6	7,3	5,9	**6,8**

Note: Rating from 0 (worst) to 10 (best).

4. CONCLUSIONS

Four years ago the School of Civil Engineering of the Technical University of Madrid introduced a new procedure for the evaluation of the teaching among its staff of professors. Among its most remarkable elements, student surveys via Internet and the general dissemination of results, stand out particularly. This paper examines the effect that this procedure has had on the quality of teaching.

After analyzing the evolution of scores, there has definitively been an improvement in the quality of teaching, both in mean and individual values. One of the reasons for that improvement has been the public dissemination of results. Now professors know the feedback of their work and can compare with colleagues, or simply are more prone to make an effort when they know that their results will be exposed. This effect is most evident in younger and non-staff professors. This conclusion is obtained from the analysis of more than 17,000 surveys of 68 subjects (out of 79 of the degree) and of 273 professors-subject (out of about 260 professors, some of which teach more than one subject). These numbers are representative enough to validate the conclusions.

Subject quality is evaluated by 10 questions. The results show that the average rating of each of these ten questions has increased in these four years, which allows us to say that there has been an improvement in all aspects of subjects. Teaching activity is also evaluated by other ten questions. The results also show that the average rating of each question has increased, even more than the rating of the subject quality, and that most professors have improved.

Professors have been separated according to their professional status and by age. Results show that professors improve their ratings in all categories and ages, although improvement is more pronounced for non-staff and younger professors. The improvement has more incidences in this group of younger professors, who are probably more motivated to get good qualifications in order to become permanent university employees.

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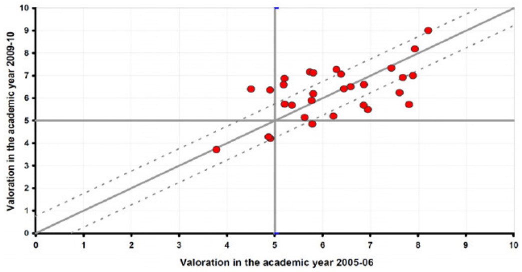
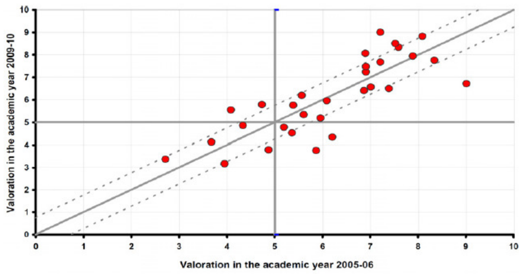
ANNEX

This annex contains Figures 8 and 9 with the detailed results of questionnaires on subjects and professors.



Question A1. You [*the student*] have enough background to follow the course.



Question A2. Lectures are useful for learning the subject.

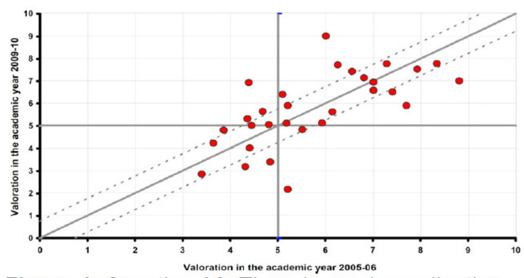
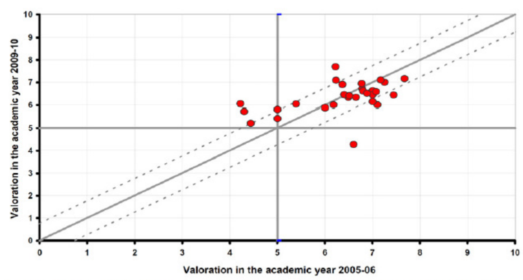
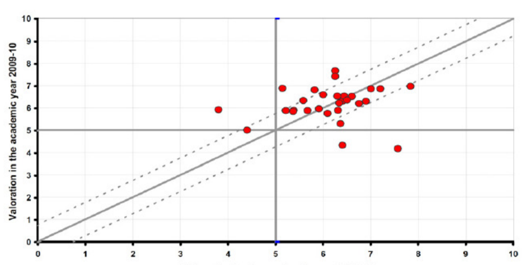


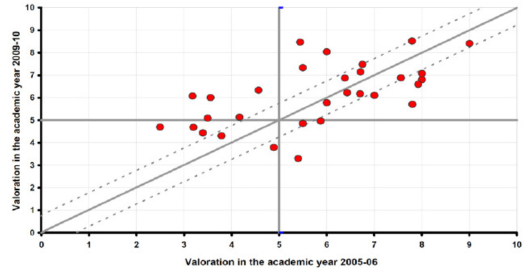
Figure 4: Question A3: There is good coordination between the theoretical and practical aspects.



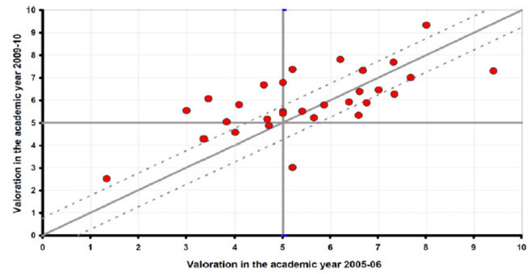
Question A4: The course syllabus is appropriate in relation to the available lecture hours.



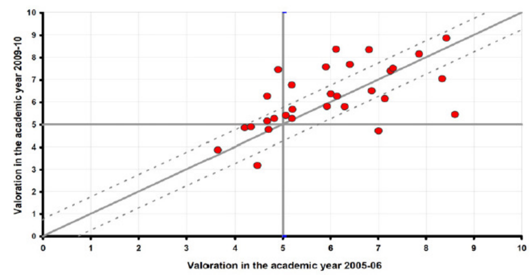
Question A5: The proportion between theory and practice hours is adequate.



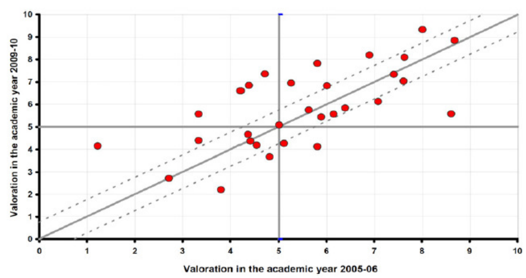
Question A6: The selected bibliography is correct and easy to find.



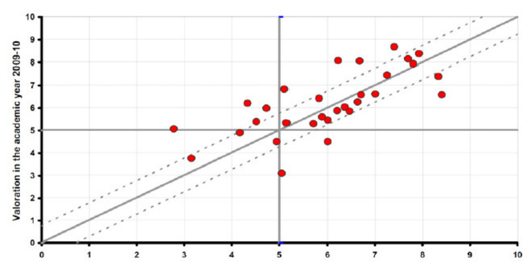
Question A7: The exam is appropriate to evaluate the learning objectives.



Question A8: Your degree of interest in the subject has increased after attending the course.

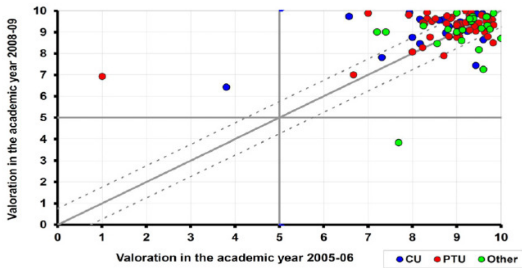


Question A9: You would choose this course if it were optional.

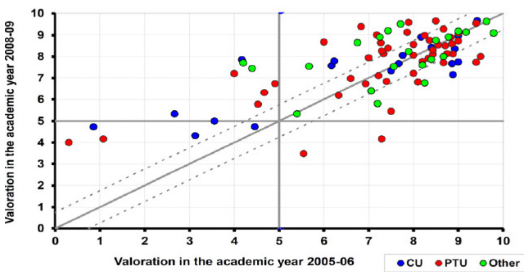


Question A10: General evaluation of the subject.

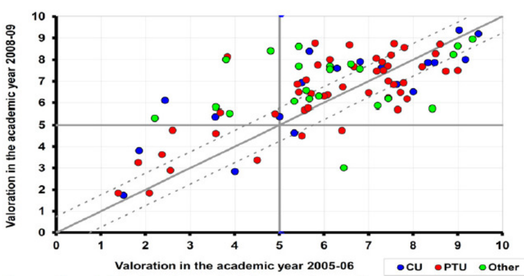
Figure 8: Results of suveys on subjects for every question.



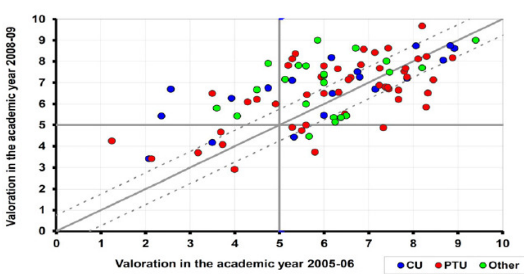
Question P1: Attends to the scheduled lectures



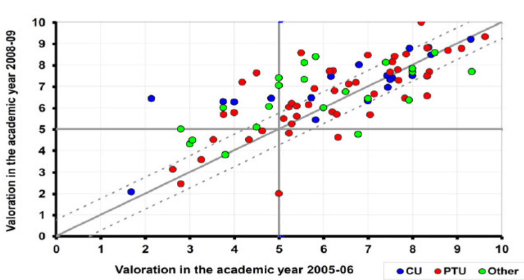
Question P2: Begins and ends lectures on time



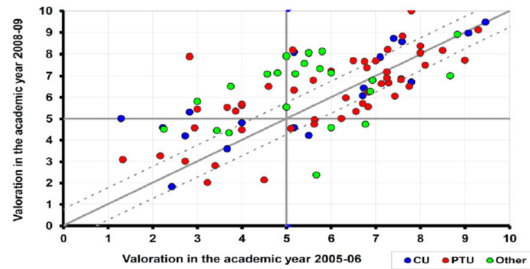
Question P3: Is clear in his explanations.



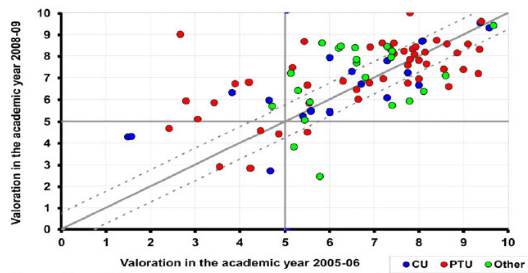
Question P4: Uses properly the educational resources.



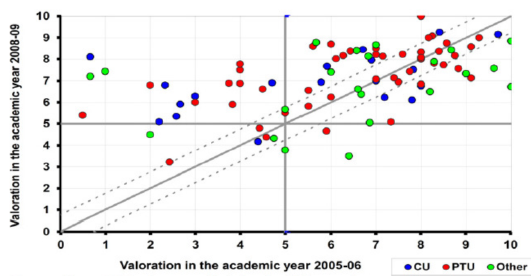
Question P5: Links the subject with other subjects or with the practice of engineering.



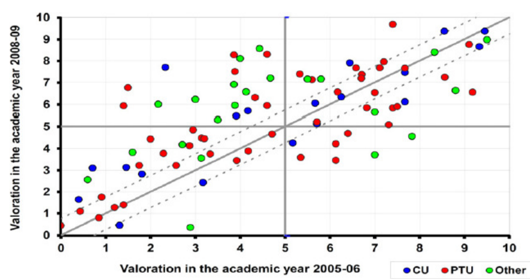
Question P6: Motivates students to learn the subject.



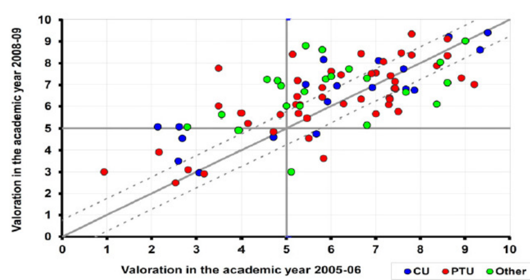
Question P7: Has a positive attitude toward the students.



Question P8: Is available in his or her office hours.



Question P9: You would wish that this teacher would teach also in other subjects.



Question P10: General evaluation of the teacher.

Figure 9: Results of suveys on professors for every question.

QUALITY ASSESSMENT IN ENGINEERING EDUCATION IN SPAIN: TOWARDS A NEW ACCREDITATION AGENCY

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EXTENDED ABSTRACT

Engineering programs have special characteristics within the university systems in many European countries, mainly because the close relationship between their academic programs and university degrees, and their increasingly demanding careers. This has become more important following the adoption of the Bologna Process, in which university education is now organized in two levels, bachelor and master. In addition, the social changes associated with a switch from an industrial to a knowledge economy is also a factor, as in the increasingly role of technology in society.

Quality in higher education is a complex matter and it gets more complicated when education and accreditation systems depend on Governments. In these circumstances, even if the entities responsible for quality assurance try to work independently, their decisions may collide with the interests of the governmental entity responsible for the global education system. Within higher education, the accreditation entities and the regulatory administration may have conflicting perspectives, causing problems for the functioning of the education system. Experience shows that in these cases the entities responsible for the quality of university systems must give valid answers to all the different academic fields involved through general processes and mechanisms in which all the particularities are included. Furthermore, this dependence on Governments prevents the accreditation entities from signing international agreements for multilateral recognition with other prestigious organizations.

Engineering programs in Spain are facing some contradictions despite their reputation, in particular, insufficient academic and professional recognition. Accordingly, some Spanish universities are now seeking ABET accreditation for their engineering programs, which may involve additional costs, internal imbalance, competition between centers and availability of specific study programs. In this paper some thought is given to the possibility of creating an accreditation agency for engineering programs in Spain within the EURO-ACE framework. Its compatibility with the Spanish legislation, its acceptance and possible integration with university and professional systems are analyzed. This is carried out within the European ENAEE network that has not been introduced in Spain yet, maybe due to the particular Spanish structure of the quality and accreditation system with regional agencies.

KEYWORDS

Quality Assessment, Academic and Professional Recognition and Accreditation, Evaluation and Accreditation Agencies

1. INTRODUCTION

Guaranteeing quality in higher education is a matter of great importance, particularly when meeting the international standards of the university systems in the competitive global market. In order to be competitive in this new environment, which can sometimes be unfair in relation to both the access to higher education and suitable use of economic resources, it is necessary to have quality assurance procedures to certify the level and scope of the skills acquired by the students during the training process.

The different scientific, technical, humanistic, social and artistic studies are considered individually as particularities in the university systems, mainly because of the different ties established in each between students training and later activities in their different career fields. Key people and renowned institutions claim that academic skills, knowledge, capacities and abilities, although necessary, are not sufficient to develop the necessary skills that a professional needs in the different work fields. Attitude, in other words, the way individuals approach work and apply their knowledge and skills, is a very important matter that shapes people´s differentiated and particular professional attributes.

All this occurs to a greater or lesser extent in all fields of study and makes it tremendously hard to try to design a single mechanism to guarantee quality. This is a paradox because university systems, national education administration authorities and/or other recognized international organizations tend to set up evaluation and/or accreditation agencies which take into consideration universal objectives. Engineering programs are a good example of this, and many countries have their own national accreditation systems which consider both the academic and the professional aspects of an Engineer's formation. This is very important because accreditation involves academic and, above all, international professional recognition.

In this paper we analyze the situation of the quality systems of engineering programs in some reference countries as a starting point and consider the feasibility of creating a specific accreditation agency for engineering programs in Spain. In addition, we also consider compatibility with the Spanish legislation, its acceptance and possible integration within the university and professional sectors. Furthermore, different organizing formulas to achieve some reasonable results are also analyzed.

2. SOME INTERNATIONAL REFERENCES OF ENGINEERING PROGRAMS ACCREDITATION

There are two clear ways to achieve the status of professional engineer. In countries where the state regulates the programs and is responsible for academic and professional training, the academic degree granted to students is a professional qualification that allows them to work with full responsibility right from the start. In these cases, there are non-governmental engineering associations or institutions, specific in every field of study and professional activity, which control the process through the accreditation of programs and sometimes examinations or professional internship.

The trend throughout the world nowadays is that, whatever the legal academic and professional framework, the accreditation of university study programs must play an important role both to guarantee the quality of the education and to develop professional careers for graduating students. This objective duality explains the boom in accreditation organizations in the world although the consequences in each case depend on their founding principles, structure and organization of the different agencies or committees. In principle, the accreditation organizations should be independent, even if their functional, structural and government models depend directly or indirectly on public organizations adding more operational complexity.

There are two major accreditation systems or entity models. The first deals with the needs arising from civil society and the demands of various social sectors, while the second arise as a result of public policies enforced by law. In this context, the most representative organization of the first model is the *Accreditation Board for Engineering and Technology* (ABET, USA) and of the second is the *Commission des Titres d´Ingénieur* (CTI, France). Both organizations were born and developed at the same time although in different cultural, academic and professional backgrounds.

In USA the programs accreditation was started officially in 1932 by the foundation of the Engineer's Council for Professional Development (ECPD) and the first study programs were accredited in 1936. A few decades later it changed its name to Accreditation Board for Engineering and Technology (ABET, Inc.), which is currently a federation of technical and professional societies that gathered to promote quality in engineering, technology and applied sciences. Although ABET is a private entity, its accreditation activities and quality assurance of engineering studies are widely recognized by the North American official education organizations such as the Council on Higher Education Accreditation (CHEA), and internationally. ABET is currently carrying out the accreditation of engineering programs in hundreds of institutions, mainly in Asia and Latin America, and is a reference for some European systems that are creating accreditation organisms with very similar structure and functioning standards.

France established by law the Commission des Titres d´Ingénieur in 1934, to evaluate and provide accreditation to higher education institutions in Engineering, Informatics, Applied Mathematics and Project Management. It was also responsible for quality control, planning and follow-up activities in higher education. Moreover, French law empowered the CTI to evaluate and analyze engineering studies in Germany, Switzerland, Bulgaria, or Viet-Nam. Other countries such as China, India and Belgium are under the accreditation process. Engineering in France has some peculiarities as is regulated and protected only by a higher education institution accredited by the CTI, which as mentioned before, is an autonomous official commission but financed by the French National Ministry of Education.

Since then, many accreditation institutions and entities have emerged throughout the world, some of them are very important or at least have the same category as the reference institutions mentioned in the previous section. For example, the Quality Assurance Agency (QAA) or the Engineering Council (EC) in the United Kingdom, the Canadian Engineering Accreditation Board (CEAB) in Canada, the Higher Education and Training Awards Council (HETAC) in Ireland, the Japanese Accreditation Board for Engineering Education (JABEE) in Japan, the Accreditation Board for Engineering Education of Korea (ABEEK) in South Korea, the Engineers Australia Accreditation Board in Australia, the Institution of Professional Engineers in New Zealand, the Engineering Council of South Africa (ECSA) in South Africa, la Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) in Brazil, the Consejo de Acreditación para la Enseñanza de la Ingeniería (CACEI) in Mexico or the Agencia Nacional de Evaluación de la Calidad y la Acreditación (ANECA) in Spain. This is a large group of institutions, very similar in many aspects, but also very different in others, which have achieved a diverse reputation within a complex cultural context of academic and/or professional accreditation.

3. GLOBALIZATION, INTERNATIONALIZATION, RECOGNITION AND ACCREDITATION

Globalization is perhaps the economic and social phenomenon that best characterizes modern times. Among many other things, globalization means the internationalization of the activities in all areas. Relentlessly, this fact demands a greater mobility of ideas, people and things. This is not new for engineers, since many claim that engineering has always been a global, transnational and multinational professional career increasingly subjected to international competition. Therefore, engineering programs play an important role in generation and transfer of scientific knowledge to wealth generation. This is essential for the development of the knowledge economy and is the key element in globalization.

As mobility increases, countries need to establish new technology quality mechanisms. Markets take care of the quality of ideas and things and state of the quality of people and employers with their global policies and strategies. In any case, the recognition of people capacities or that of any other economic, professional or social entity is not based on acts of goodwill but in quality objective policies. This is where academic and professional accreditation in education and more particularly, in higher education, play a leading role. It is true that the economy is the dynamic factor of these policies, but it is also true that there are agents leading the economic and social development of their countries who, will finally define or propose the quality and knowledge evaluation mechanisms.

The need to create mechanisms not only to harmonize professional mobility but to help quality assurance in the professional services rendered by engineers abroad, led some countries to set up some agreements and organizations to guarantee the quality of education and engineering professional services. For example, in 1989 the representatives of the accreditation organizations of the engineering programs in Australia, Canada, United States, Ireland, New Zealand and United Kingdom signed the so called Washington Agreement for the professional recognition of the accreditation of the engineering programs. Later eight more countries, China, Taipei, Korea, Hong Kong, Japan, Malaysia, Singapore, South Africa and Turkey joined the list of the promoting countries of the agreement and six more accreditation organizations (Bangladesh, Germany, Russia, Pakistan, Sri Lanka) have applied for membership.

The Washington Agreement (WA) was signed in 1989 for the recognition of the professional engineering qualifications (in Spain these are identified as the long cycle engineering programs). It was complemented some years later, in 2001, with the Sydney Agreement (SA) for the technologists professional qualifications recognition (in Spain this concerns higher professional education) and finally in 2002 the Dublin Agreement (DA) was signed for the recognition of professional technicians (in Spain, this relates to technical engineering) and although all the different agreements were not signed by all the promoting members of the WA, a great number of them did so. An important aspect of all these agreements is that they were signed by the institutions responsible for the accreditation of the engineering programs of the different countries and not by the Governments. This is very important because the legal status of the institutions responsible for the accreditation enables them to establish international agreements with other renowned institutions with similar objectives or to sign multilateral education agreements. Finally, this allows programs, students, and accredited engineering professionals that have been evaluated by these institutions to have a greater international visibility and study programs recognition in the different continents, with a previous accreditation in their countries of origin.

Something similar is happening in Europe with the *European Accredited Engineering Programs* (EUR-ACE, 2006) the objective of which is to complement national accreditations by giving them a more international scope even for agencies from a non-European Higher Education member country. The EUR-ACE seal of quality is promoted by the *European Network for Accreditation of Engineering Education* (ENAEE, 2006) constituted by various economic and social agents from all fields of engineering. The network manages the EUR-ACE seal of quality and accepts the integration under certain conditions. It also manages the seal of quality of general national quality agencies or more specific engineering agencies.

EUROPEAN FEDERATION OF NATIONAL ENGINEERING ASSOCIATIONS	ENGINEERING COUNCIL
COMMISSION DES TITRES D'INGENIEUR	ACCREDITATION AGENCY SPECIALIZED IN ACCREDITING DEGREE PROGRAMS IN ENGINEERING, INFORMATICS, NATURAL SCIENCES AND MATHEMATICS
ENGINEERS IRELAND	ORDEM DOS ENGENHEIROS
CONFERENZA DEI PRESIDI DELLE FACOLTA DI INGEGNERIA ITALIANE	SOCIETE EUROPEENNE POUR LA FORMATION D'INGENIEURS
RUSSIAN ASSOCIATION FOR ENGINEERING EDUCATION	EUROCADRES: CONSEIL DES CADRES EUROPEENS
UNIVERSITA DEGLI STUDI DI FIRENZA	DANISH SOCIETY OF ENGINEERS
BUNDESAMT FÜR BERUFSBILDUNG UND TECHNOLOGIE	ASSOCIATION FOR EVALUATION AND ACCREDITATION OF ENGINEERING PROGRAMS
INTERNATIONAL SOCIETY FOR ENGINEERING EDUCATION	INSTITUTO DE LA INGENIERÍA DE ESPAÑA
ROMANIAN AGENCY FOR QUALITY ASSURANCE IN HIGHER EDUCATION	FINNISH ASSOCIATION OF GRADUATE ENGINEERS

Table1: ENAEE full members

It is interesting to point out that the only institutions participating simultaneously in two of the mentioned initiatives are the Engineering Council of the United Kingdom and the ASIIN (Accreditation Agency Specialized in Accrediting Degree Programs in Engineering, Informatics, Natural Sciences and Mathematics) in Germany. This latter is a relatively new agency founded in 1999 but has developed intensively during the last years. Both agencies have the specific objective of carrying out the accreditation of study programs. Additionally, both institutions, considered as ABET and CTI references, are lined up with each of the alternative options.

4. A PROPOSAL FOR AN ACCREDITATION AGENCY SPECIALIZING IN ENGINEERING PROGRAMS IN SPAIN

Spanish education, professional and accreditation systems are governed by law by the Accreditation National Evaluation Agency (ANECA) and a group of (11) regional agencies established as for the decentralized higher education system transferred to 17 the autonomous communities.

According to the Spanish legislation, only those full members of the *European Association for Quality Assurance in Higher Education (ENQA)* are entitled to accredit university degree programs which are valid in Spain (there are currently 5 agencies: ACSUG, AQU, ACSUCYL, UCUA AND ANECA). In any case, 5 or 12 Spanish agencies are for general purpose and comply with the same or similar evaluation objectives and criteria established by the education authorities responsible for education policies. The same thing happens during the accreditation phase, except for the five accredited agencies by the European ENQA network that play a relevant role in this task.

AGENCIA NACIONAL DE EVALUACIÓN DE LA CALIDAD Y DE LA ACREDITACIÓN (ANECA)
AXENCIA PARA A CALIDADE DO SISTEMA UNIVERSITARIO DE GALICIA (ACSUG)
AGÈNCIA PER A LA QUALITAT DEL SISTEMA UNIVERSITARI DE CATALUNYA (AQU)
AGENCIA PARA LA CALIDAD DEL SISTEMA UNIVERSITARIO DE CASTILLA Y LEÓN (ACSUCYL)
AGÈNCIA DE QUALITAT UNIVERSITÀRIA DE LES ILLES BALEARS (AQUIB)
AGENCIA CANARIA DE EVALUACIÓN DE LA CALIDAD Y ACREDITACIÓN UNIVERSITARIA (ACECAU)
UNIDAD PARA LA CALIDAD DE LAS UNIVERSIDADES ANDALUZAS (UCUA)
AGENCIA DE CALIDAD, ACREDITACIÓN Y PROSPECTIVA DE LAS UNIVERSIDADES DE MADRID (ACAP)
COMISIÓN VALENCIANA DE ACREDITACIÓN Y EVALUACIÓN DE LA CALIDAD EN EL SISTEMA UNIVERSITARIO VALENCIANO (CVAEC)
AGENCIA DE CALIDAD Y PROSPECTIVA UNIVERSITARIA DE ARAGÓN (ACPUA)
AGENCIA DE EVALUACIÓN Y ACREDITACIÓN DE LA CALIDAD DEL SISTEMA UNIVERSITARIO DEL PAÍS VASCO (UNIBASQ)
AGENCIA DE CALIDAD UNIVERSITARIA DE CASTILLA-LA MANCHA (ACUCM)

Table 2: Evaluation and Accreditation Agencies in Spain

This matter will not be discussed further here; however, it cannot be disregarded since the real situation has an influence on any reflection about these matters. In a first approximation, it could be considered and proposed that since there are 5 quality evaluation agencies accredited by the European institutions and that there are 5 big and well defined areas of knowledge in Spain (Legal and Social Sciences, Experimental Sciences, Health Sciences, Art and Humanities, and Engineering and Architecture), each one of these agencies, besides providing general services to their communities or reference education administration, could specialize in the evaluation and accreditation of university degrees in one of the previously mentioned knowledge areas.

Therefore, each regional agency would become a national agency (this is not a contradiction, because the current accredited agencies already have the dual role), and could establish more appropriate agreements at national and international level. Also, and more importantly, it could assess the characteristics of each field of study and its professional consequences. It won´t be particularly difficult for any of the five (5) currently accredited agencies to establish agreements with the Spanish Institute of Engineering (IIE, ENAEE member) nor to adopt the quality methodology and procedures required by the EUR-ACE seal. In any event, all this would demand great efforts and a national agreement, which cannot be anticipated at least in the short term.

It will be then necessary to think about an external solution to the current partial system, as far as the engineering accreditation is concerned. As mentioned before, there are two alternatives:

a) Finding alliances with any of the full members of the Washington Agreement.

b) Becoming part of the ENAEE network through a new agency created specifically for the engineering accreditation in compliance with the EUR-ACE quality seal criteria standards.

In the first case, the members or partners could be the ABET agencies in USA, due to its unquestioned leadership and international reputation, or any of the European promoting agencies of the Washington Agreement such as the Engineering Council in the United Kingdom, the Higher Education and Training Awards Council in Ireland or the Agency Specialized in Accrediting Degree Programs in Engineering, Informatics, Natural Sciences and Mathematics in Germany (this latter after obtaining full membership). This approach would not be hard to follow, and above all, to implement in an independent agency. For example, a franchise or something similar would involve a previous agreement to avoid competition with the services provided by the home institution.

A more comprehensive proposal with more chances of success would be to reproduce in Spain the steps made by the German agency ASIIN. In other words, to create a specific accreditation agency for engineering within the European ENAEE network, in compliance with the rules and procedures established by the EUR-ACE quality seal and request afterwards its integration to the Washington Agreement. Hence, to implement this proposal the new agency should rely on the support and commitment of the Spanish university systems and professionals, including the Spanish Institute of Engineers (IIE), as well as other economic, social agents interested and involved in these matters such as recruitment, businesses and scientific organizations. This would enhance considerably the reputation of Spanish engineering, not only in Europe but, and above all, in the rest of the world.

5. CONCLUSION

The quality evaluation and accreditation system in Spain is very complex, far-reaching and good; however, it cannot provide the appropriate framework for academic and professional recognition internationally. The governmental nature and regulation of the various evaluating agencies and education systems do not allow them to become full members of the international agreements for the academic and professional recognition except for regional agreements.

The integration of the Spanish university system into the European Space of Higher Education is causing engineering problems with some academic activities at undergraduate and graduate levels as well as with engineering degrees recognition. This worries professional engineers and it gets worse when analyzing other group's demands for a greater liberalization of degree programs, which in practice would entail a dramatic change in professional careers and disappearance of the current reservations.

A specific agency for engineering accreditation in Spain would lead to help tackle both these issues, particularly the legal regime that would allow it to become part of the key international agreements without losing its European ties. This would lead to a better international recognition and integration of the various social agents involved in the definition and development of the new economic and productive model and thus professionals that a modern country needs to be competitive in a globalized world.

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THE ROLE OF THE AUDIT PROGRAM IN THE INTERNAL QUALITY ASSURANCE SYSTEMS AS MOTOR OF THE TECHNICAL LEARNING PROCESS ADAPTATION FOR EUROPEAN SPACE FOR HIGHER EDUCATION (ESHE): AN OPPORTUNITY TO RESTART THE SYSTEM

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EXTENDED ABSTRACT

The so-called "Bologna Process" has raised a set of new challenges for the University System that will emerge as essential characteristics of the European University system from now on. This situation will be especially important for the evolution of engineering studies subject to a renovation process that has been increasingly speeding up in the last twenty years. Firstly, new issues have to be included in programs and lectures, secondly some methodological changes are needed to adapt to XXIst Century learning processes and instruments, thirdly the present state of knowledge in the different subjects has to be considered, fourthly the business model has to be redefined by the university, and finally the university products, whether degree or R+D research, have to be reorganized too.

All these processes require a professional staff of managers in the university system that currently does not exist, and a consistent analytical system has to be created in order to conduct the broad and intense decision process needed to adequately pilot this revolutionary change. To guarantee a relative success, a common exigency has been included in the definition of the applied educational policy: the general implementation of an Internal Quality Assurance System (IQAS), as a key instrument for aligning all the efforts involved in the strengthening of the university system.

With this aim, Spanish Public Agency ANECA has developed a set of useful instruments to provide the university with guidelines and procedures for the implementation of a robust framework for the future strategic evolution of the university. Among them, the AUDIT program represents a key issue created to help the Universities and Schools in the process of defining their new strategic adaptation to the European Space for Higher Education (ESHE). This program is an open instrument for each Center to adopt, which initiates a process for qualifying and certifying its quality assurance systems and which represents the highest scale in compromise with official quality exigencies at the present.

The aim of this paper is to analyze the implication of the AUDIT for the strategic evolution of "ETS de Ingenieros de Caminos Canales y Puertos" at the University of Cantabria. The paper is organized as follows. First we start with a review of the Audit Systems procedures and requirements, then we review the specific issues that have emerged through the implementation process, and third we describe the final framework adopted. Conclusions about the value added by the system and the evolutionary paths initiated are then derived.

KEYWORDS

Quality assurance, Integration policy, Evolutionary paths, University management

1. INTRODUCTION

1.1 The ESHE and the University

The European Space for Higher Education launched after Bologna Declaration (1999) represents the starting point for a complex multipurpose process relevant both for the national educational policies across Europe and for the construction of an integrated European University System. This is not the place to discuss the objectives yielding behind this broad reform, but some relevant issues have to be quoted to clarify the general framework we are involved in:

a) The moment has arrived to redefine the role for the educational system at present, new concepts as Life-Long Learning represents are not just a new totem for the didactic paradigm but a new product for the University. To supply this new product a new set of capabilities are required: the ability to migrate to different client, to a different product, (time schedule, learning outcomes, financing details, certificates…). This new paradigm represents a totally new framework that has to be internalized by the university agents. Unfortunately the migration process is to be executed by a previously existent structure and administrative framework that gives very little space for new needs. The implications for this change may be greater than expected according to the present financial and budgetary crisis in European states and hence the university has to adapt to the new situation.

The traditional management system in the university is a combination of several mechanisms: first of all the system is subject of a typical top-down strategies structure where administrative restrictions and budgetary provisions define the conditions for the system to develop its activities. The legal regulations emerging from central state and the budgetary provisions from regional authorities have put a continuous pressure on the university to reduce endogamy, to gain efficiency and to open to social needs. Secondly the bureaucratic and hierarchical internal structures have been fighting to preserve the internal status-quo and hence the system has not showed enough capacity to change and move towards new models. Thirdly the increasing efforts made by Spanish society towards research-funding have attracted researchers and create opportunities to develop new groups and institutions within the university system (and obviously outside of it as competing agents) that require new institutional arrangements. As a result, the polynomial structure of university staff organized around teaching activities, research and industrial interchange, and management and strategies have not yet reached a stable situation. Fourthly the aim of the political agents is to decentralize university agents at a greater scale, making the institution free and responsible to choose self-defined strategies, and compete among them pursuing results. Under this framework political agents keep only the role of regulators of the system. Surprisingly there is very little tradition of debate and spontaneous proposals in the university. The traditional co-optative system for provision of decisive positions in the university, the extremely powerful bureaucratic structures that guarantee a sufficient competence for candidates and a regular profile according with standards, represent a clear limitation for the university to self-lead in the new situation expected under the European Space for Higher education.

A second source of pressure that the university is facing is related with the knowledge itself that has to be handed down to the next generations to guarantee a continuous process of improvement. In this view two relevant issues have to be considered. On the one hand didactic methodologies obviously have to be reconsidered in this XXIst Century, and on the other the menu of contents that have to be studied in teaching activities need to be reviewed as far as the continuous improvement in specialized knowledge needs to find space in the curricula. The methodological issue is especially relevant in this moment when social activities and knowledge sharing have found in the web a new space that has to be assumed by conventional educational system. The traditional strategy of ignoring what emerges outside of the school can no longer deal with new interaction paths. E-learning, B-Learning and M-Learning have been fruitful attempts that at the end may question the traditional educational process. Obviously we are far from arguing that a “new” e-human has born and new e-institutions have to be created, but nevertheless the ultimate function derived from learning activities has revealed to be different: traditional roles as knowledge (read contents) suppliers have lost part of the preeminence and have been assumed by media industry (McGraw-Hill, Pearson…), The training activities (even personalized when needed) can be obtained from different agents in the society as consulting firms in the professional learning industry have showed. The sole area where the university is still leading the match is the area of certificating the competence gained by students along their academic studies, been the extension of this role to the professional career period a question under discussion at the moment.

The second issue in this point related to the extent and timing of contents has to be again under analysis. Along the last 50 years we have assisted to a continuous discussion on the knowledge emerging in curricula, with lack of consensus on the debate. Specialized subjects have found their way to the curricula following the pressures of their promoters' power expansion; but there is also a perception that the level of exigency has dropped in some areas. In any case the debate on the actual needs in contents for a student, the needed instruments to be provided, and distribution of responsibility in this critical point among teachers is still pending. The revolution that the concepts of competencies and learning outcomes aspired to represent, has failed, contents are still the main parameters to define curricula, and in the assessment process competencies are far from playing a relevant role.

A third source of pressure has conditioned the final university framework from outside, the coordination of job and professional framework across Europe is a key issue to guarantee the effective creation of a unified market. Hence the educational system and within it the university system has been called to adapt to a compatible system. But the inertias of the system have stopped this integration process (mainly in technical studies), different cultures have showed different expectations for a degree to cope with. The professional structures and institutions have put strong pressure on the system in order to obtain self-defined objectives and advantages creating a continuous source of entropy that have been received in the university as boundary conditions, often in open contradiction with educational needs and again university institutional objectives have contributed to manipulate the final commitment received. Also a long period of maturing of the process has allowed pervasive arguments to circulate, and perverse rules and proposals to be instilled. The idea that those following the rules strictly as they were originally made will find themselves as naive supporters of a dead revolution is generally accepted.

Although this description may look skeptical or suggest a certain degree of reluctance we have included it in our discussions because this review gives a clear idea of how important the quality assurance system results from now on, and shows the key role to be played.

1.2 The ESHE as a starting Point for the future

All the described phenomena can be understood either as a “lampedusian” strategy to block reforms designed with a conservative scope or, as we believe, this situation is just a complex network of perplex attempts developed by agents that try to adapt to the new situation and is just the first step of an evolutionary process that may drive us to a new state. If we assume this perspective the main issue to be considered is related with learning process across agents facing an uncertain situation. According to evolutionary analysis (Holling, 1973), the situation can be understood as follows: First of all the static situation we initially had, has to be understood as the result of the previous management decisions, taken by relevant active agents according to their boundary conditions. After

this situation was reached a process called “exploitation” started, and along it the different agents involved tried different strategies to reach their objectives, questioning rules, developing new paths, investing in new resources, but as it happens always, this energetic step full of ideas and experiences was followed by a more conservative state “conservation phase” where the winners in this process had already learnt how to obtain the most efficient results and managed to block any kind of innovation that could eventually cause damage to the status quo. One can easily imagine the stakeholders aim to establish control mechanisms and protect the stability of the situation. But the game starts again when some strategic changes are needed, be it by lack of flexibility in the organizations to give space to new agents (generational changes) be it technological adaptation, be it sociological or legal, or whatever the source of obsolescence is, new issues have to be addresses, new agents become protagonist, or new products are needed. Hence the business has to be reformulated but the agents that lead and select the strategies will hardly assume the dynamic attitudes required for this, and eventually prefer a defensive strategy to preserve the situation built with great effort. But as far as the tide have changed the unavoidable pressures that emerge are important enough to restart the process through a “release phase” where a new race start to take advantageous positions, to release old-fashioned controls and refurnish the system with better adapted instruments that will, on their own, reorganize the competitive ranking among agents, redistribute roles and power, and create a new state, reinventing the system. This 4th phase of “reorganization” is essentially the creative destruction process, as Schumpeter defined (Schumpeter 1950), that yields behind all the innovation process, and is the engine of the evolutionary process be it biological or sociological. Obviously, we have to consider two different layers of the problem: on the one hand the university (or the society as a whole) will undoubtedly find an efficient way to cope with the new problem with the available resources, but on the other this optimistic expectancy does not guarantee at all that each organization will find the best path towards success. Hence there is a great dependence in each institution towards the leadership, to be able to imagine and draw the new situation, and incite the institutional arrangements needed, and secondly towards the techno-structure that forms the organizations to identify the problems faced with open mind and flexibility combining robustness and imagination.
Under this scope we can interpret the present situation of the university system as a release state, where new requirements are addressed by the society, new technologies are available to adopt, and new solutions and agents have to be developed in order to deal with these issues.

1.3 The role of the Internal Quality Assurance Systems (IQAS)

As a conclusion from previous items in this paper we can observe three clear ideas. First University has to assume new requirements that have led to the obsolescence of the present model, what was acceptable in the 70´s or the 80´s is no longer valid, be it product (courses, subjects…), instruments (tools, activities…) or results. This does not necessarily mean that we have been doing things the wrong way, but that what was important in our business was not what we thought. Secondly, the financial crisis suffered by European societies will put efficiency in the first level of objectives and a lot of decisions will be taken in the future for this purpose. Thirdly the present organic configuration that has driven the institution until here will not be capable of leading the adaptation to a new state without reinventing the overall system. Fourthly we are facing a new uncertain phase where the conventional mechanisms of control will no longer be the management solution. Fifthly, the role for universities in education is changing from pure content generators and teaching services to tuition and certifying and hence new procedures are needed. And finally we have to assume that the university can supply a broad set of services and activities whose regulations and needed resources need to autonomously emerge from university institutions.

In this scenario a transparent management system as (IQAS) is critical and should be valued as strategic asset in the university. The roles of this institution include giving space to all the contributions, revealing the real situation in the system and guaranteeing a continuous improvement system for a flexible management strategy
Of course the public regulation framework for the universities is defined with a more strict view focusing specifically in the quality of the main business of the institutions that is the regulated education, but as has been previously quoted there are two reason to expect much more from this instruments, first the educational schedule is moving from one single degree to a lifelong learning schema with more diversity involved, and secondly a new idea as this quality culture will hardly limit its impact to a single regulated area.

2. The AUDIT program

According with general objectives of transparence and governance that emerge from ESHE the universities are committed to create an Internal Quality Assurance System (IQAS) that is explicitly defined and openly available.

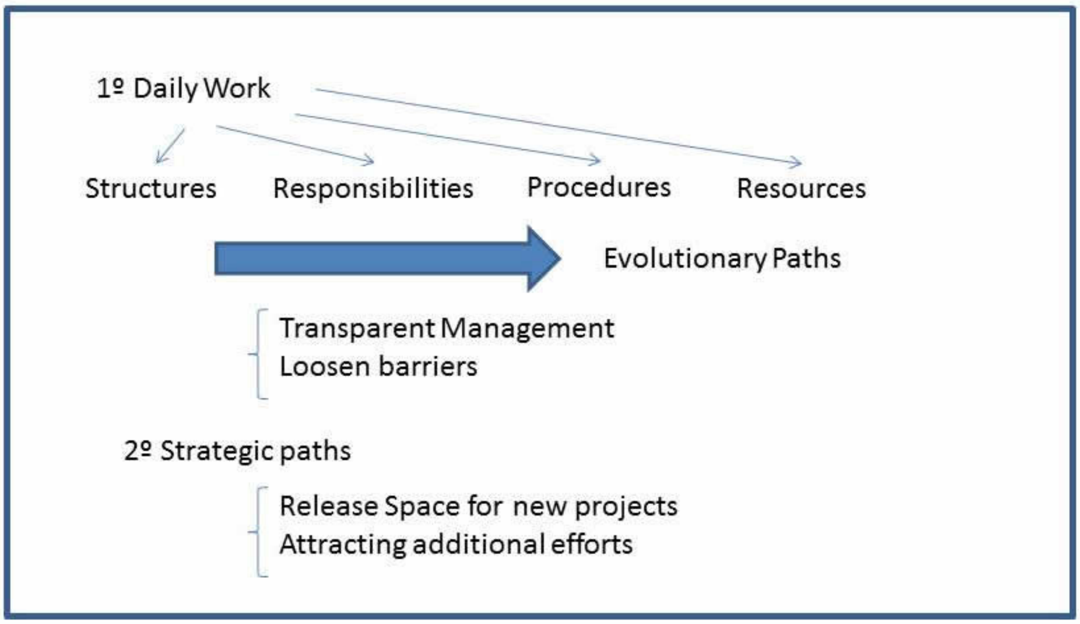

Table 1 General objectives of Quality Assurance System

The aim of the system focuses on two relevant issues: on one hand it affects to the ordinary activities developed on a day by day basis, where transparence is the key factor to work with, and on the other affects strategic management, where consensus and participation are the key factors.
Focusing in the first issue, internal structures, responsibilities distributed, establish procedures and assigned resources should be affected. Transparent and standardized processes have to be adopted so that the evolutionary paths are generally visible and all the affected stakeholders are given the possibility to question and debate and hence have the opportunity to internalize the overall needs and roles to play and develop their own strategies. But as a second result, entry barriers for new projects should be loosen adding flexibility to the system. If this two objectives are successfully reached, the evolutionary paths initiated from now on will increase the efficiency and value add by the agents to the university project, and we will move away from the possibility of collapse.
Focusing on the second issue, the strategic decisions taken at the management levels of the university will also be affected. As the overall objectives and options adopted will be subject to open debate and transparent decisions, the degree of interest, concern and compromise will increase and so the potential of the university will also increase and new efforts and energies can be attracted.

In order to reach these objectives, the debate has to focus in three issues to be solved: (ANECA 2010)

1st The aims and expectations of the different stakeholders have to be explicitly expressed and disseminated, a clear transaction has to emerge between individuals and groups with needs and objectives on one hand and the overall strategies collectively (and transparently) defined. Quality assurance does not guarantee a "best solution" for the business case under analysis, but the transparent definition of objectives that consistently represents the collective decision.

2nd The definition of the role played by the quality assurance system: the long and short term objectives, instruments and resources will define what QA represents for each organization so that no agent or stakeholder takes decisions and develops strategies without robust information on evidence and knowledge on the existent collective problems.

3rd The QA criterion have to be defined in order to send a message to all the involved agents on how all the emergent management issues have to be processed. The continuous revision of rules and procedures is essentially a continuous sequence of management decisions produced not as executive decisions but as normative, but in both cases what we expect from managers are decisions.

2.1 The stakeholders and their relevant issues

The first step to introduce is the definition of the involved and legitimate stakeholders to be considered as participants and involved in the management of the university:

- Students

There is an obvious reason to consider the students as part of the educational system. As clients they have the ability to select among studies on a transparent basis that guarantees an informed decision process. But there is also the issue derived from their role as students in the university where the incentives created for them to improve and develop their competencies should be first of all transparent, secondly adequate to the objectives and thirdly accessible for them to be obtain in a realistic approach (but without losing their incentive capacity). And finally there is the final issue of the success obtained in the transition to the labor world according to their expectation. All this issues have to be taken into account when the management of the system is considered.

- Teachers

This category is the obvious agent to include as far as teachers play a central role in the system. In contact with all the stakeholders and directly involved in the process, the management problem in education is directly related with teachers. The processes that we have to consider includes, first of all the selection and recruiting system for teachers as a static process, where the conditions are transparent and public, and as an intergenerational process, where future needs in different areas are publicly solved. Secondly promotion plans have to be transparent and equitable, given opportunities to all the teachers to be promoted and to develop a successful career according to their attained results and goals. Thirdly the teacher's involvement in a successful curricula definition requires their open contribution in a debate where the evidence on the results and the available alternatives are discussed. Fourthly the definition of each subject contents and objectives cannot be established without collecting the teacher's contribution, actually the process has traditionally been done through the debate among teachers but transparency and openness is a critical goal for this issue. Fifthly, the activity program, within and across the different subjects, configure the overall exigency both to the staff and the students and again is the result of a general experience where teachers are a principal agent to take into account. And finally the contribution of teachers to the feed-back process is again critical for the success of the system.

- Educational staff

The teaching process has evolved in the last century from a situation where all the responsibility was committed to the teachers alone, to a modern situation where the technical support from educational staff, that provide pedagogical advice and assessment, technological staff responsible for the implementation, exploitation, updating and maintenance of web infrastructure, (a new teaching instrument that is critically changing the educational process through wikies, forums, social networks…), and finally job and career advisers and counselors that have a new view of the situation that might enrich the collected evidences of the functioning of the system.

- Administrative staff

The administrative staff has reached a relevant role in the university system. Starting from an initial point, where pure auxiliary duties where their area, it has move to a modern framework where the rigorous treatment of the accreditation process, and the collection and treatment of evidences derived from the educational activities that represent a critical issue for the system, are their main contribution to the educational process. The educational activity is far from a pure teaching activity that happens in the classroom in a limited time schedule, and finishes not only with a competence acquisition, but with a degree award.

- Management staff

A new relevant source for the quality system to develop its function is the presence of a new category of agents formed by the management staff, typically formed by qualified teachers that move their career from pure teaching activities to a new job as managers, they need be suitable for this new role. Their contribution to the quality of the system is again multiple. First of all they play the role of promoters of innovation and adaptation measures and hence they are responsible for the functioning of the system. And secondly they provide the system with the global view of the organization. They deal with rankings strategic decisions, options selected, representation into the society, global motivation…. They have a prominent set of evidence to supply to the system and their voice has to be heard.

- Job Employers

Until this point we have been focusing on internal agents involved in university, even in the student´s case we were interested in their role as members of the community and clients more than external stakeholders that may produce a feed back for the system. But if we want an adequate university product definition there is an obvious need to consider the final receptor of our product, represented by those who recruit our graduated students put price to their abilities, integrate them in the real world, and contribute to develop their careers. Their views on the set of degrees offered, the orientation given to the studies, the adequacy of the competence level acquired by the students cannot be adequately defined without paying attention to employer´s views. Hence a robust system to collect their feed-back is needed. No quality or excellence can be reached without this. The strategic movements needed to adapt globally the university degrees can hardly be produced through an internal debate without their advice.

- Graduated students.

A qualified stakeholder to be considered is the graduated student. This agent, as long term related stakeholders has a rich critical and balanced view of the experience collected in the global interchange with their educational community, and the final contrast with job experience is obviously observed by him. The evidence collected on their long term satisfaction will balance the short term views from students and moderate bias from job employers.

- Public supervisors

As external agents, public supervisors have a new different view of the situation in the university, their role as intermediate agents between public policies and objectives on one hand and management agents in the society on the other, give them the possibility to assist to the management and strategic processes, making a critical contribution through the exigency of this quality assurance policy to be pursued. But from a more specific point of view, public supervisors are responsible for the certification of the degrees and hence represent the final guarantee for the stake-holders of the adequate functioning of the system.

- Society in General

There is an obvious contradiction between the strict definition of stake-holders and specific contributions and the introduction of a global stakeholder as society. Nevertheless we cannot avoid the fact that at a higher macro level issues as financial contributions to the university, overall assessment of adequacy is executed by families, media, politicians, voters… a complex amalgam of agents that produce the final valuation of the university, and whose verdict can hardly be ignored. The evidence collection in this issue is a highly sensitive matter that we cannot solve directly but that somehow has to be taken into account.

Stake-Holders	Processes
Students	Selection and admissions Studying process Labor and professional career
Teachers	Selection and contracting Promotion Plans Curricula definition Subject definition Time-schedule Feed back
Educational Staff	Curricula definition Subject definition Time-schedule Feed back Labor and professional career
Administrative staff	Feed back Certification Degree awards
Management staff	General Strategy Staff Motivation General Policy adequacy Representation
Job employers	Definition of offered degrees Training profile Quality of training Job adequacy for graduates.
Graduated students	Definition of offered degrees Training profile Quality of training Job adequacy for graduates
Public supervisors	General Strategy Staff Motivation General Policy adequacy Representation Degree Certification
Society	Funding policy Social Support Values and cultural exigencies

Table 2. Stakeholder and contributions to an IQAS

2.2 The Quality Assurance criteria

In order to define a "correct" policy a set of criterions have to be defined on the following relevant issues:

- Quality policy and objectives

We can consider this issue to be adequately treated if two conditions are guaranteed, first of all transparency in the objectives and procedure is critical. Everybody must have a free and operative access to information during the process of implementation of the system and on the results collected through evidences. It has to be noted that this criterion, although looks evident and somehow naive, is one of the most important source of problems for the implementation of the quality system. Evidence collected on the actual sources of information, the actual level of knowledge, and the actual use made to the rules and procedures should demonstrate the actual state of this issue in the assessed institution. As a result the quality culture will be evident.

- Design of the training offered by the center

The criterion in this issue creates the exigency of providing a flexible mechanism capable of generating robust degrees recognized by the market, and successfully adopted by the students. This issue has two different layers to be considered, first the internal mechanism have to show their ability to identify, diagnose the problems and finally react to them in a continuous improvement process. But in a second layer the system should show the capacity to adapt to unexpected needs and problems and show the ability to migrate to new configurations when needed.

- Teaching and learning activities

Under this issue the criterion defines the exigency for the center to have an adequate procedure to firstly control the actual process under development, so that evidence can be collected on the actual execution of the projected curricula, and secondly on the evaluation of obtained results providing evidence that the instrument adopted has been successful and efficient. This goes further than just checking the agenda and reviewing the assessment but requires a more profound attitude open to rich and fruitful revision of the learning process, in the broad sense of the concept, covering from the formal activities (lectures) to the internship activities developed outside of the university.

- Academic and support staff

Evidence should be collected that the staff involved in academic duties, be it teachers or support staff is first recruited with open standards that facilitates the competitive access to the job, following recruiting policies that guarantee the best candidates to be selected and further on that the promotion and payment systems helps a continuous improvement process to be adopted.

- Available resources

Evidence should be collected that show the adequacy of the resource providing system to detect the actual needs, to provide the sufficient resources, and to assign them with transparent and efficient criterions. Obviously this idea has to be moderated with the funding policy of the educational system and the university, but from the evolutionary point of view developed in the first part of this paper, it becomes again a critical issue to guarantee that funds are allocated according to global needs and not the individual agent´s needs.

- Learning Outcomes

As previously established control of activities is not enough to guarantee a proper behavior for the university, the final results of each activity be it lecturing, practical issues, external internship, selection of subjects…, have to be assessed according with their contribution to the students competence and hence the evaluated institution should demonstrate its ability to capture this evidence, to analyze it, to obtain conclusions and apply improvement measures.

- Transparence policy

Under this criterion, evidence has to be collected that the institutions are ready to elaborate transparent indicators and make them visible to the stakeholders that have to take decisions based on them. Once again this is more than pure statistical data diffusion, but to identify relevant, pertinent and opportune indicators, to circulate them on a transparent basis and to avoid external agents to create inaccurate judgments on the institutions.

3. CONCLUSIONS

In this paper we have introduce three separate ideas. First of all we have made an analysis of the present situation on the university in order to verify its capacity to cope to with the challenges created by the Bologna Process. Secondly we have reviewed the situation from an evolutionary point of view, showing the role played by the agent´s implication in the management and strategic policy of the university. This two initial analysis have showed the evidence of critical role to be played by Quality Assurance System to lead this process. And thirdly we have review how the Audit program is ready to contribute to the strategic evolution of the University.

More specifically we can conclude that:

- We are initiating a new phase of evolution of the university where management and strategy issues will be critical. This does not mean that educational activities are going to lose importance in the university but that their contribution to the learning outcomes of the system have to be explicitly showed and justified.
- The business model for the university is giving increasing preeminence to the certification of awards and degrees, and hence the IQAS is evolving to be a strategic policy for the university.
- The stakeholders involved, the process they have to work in and the criterions to approve and validate the institutional frameworks are emerging issues in the definition of a university institution.

The AUDIT project has been introduced in the Spanish university as an instrument to provide clear guidelines to guarantee that all the institutions adopt the new philosophy and responsibly adopt their future strategies. For this process to be successful three layers are critical:

- Stakeholders contributions have to be openly assumed and freely discussed
- Clear criterions have to be applied in decisions and guarantees have to be offered that the final products offered respond to the actual needs.
- Transparence on the dissemination of results is needed to produce successful results.

The consequences of the inclusion of new quality assurance system will not be seen in the immediate management procedures that will increase their bureaucratic load, but in the future evolution of the university system that will improve its flexibility.

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GERMAN STUDY PROGRAM ACCREDITATION AT DEAD END?

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EXTENDED ABSTRACT

The Bologna Process, with its comprehensive change in study structures all over Europe, was the starting point for a detailed quality assessment in which accreditation as an external quality assurance method plays a major role. Under the guise of safeguarding the quality, year by year German universities spend enormous sums of money for quality assurance, especially for the accreditation of the universities' bachelor and master programs. Universities feel impelled to develop curricula for study programs based on the guidelines of the accreditation agencies to get a successful accreditation. But is the system of accreditation really necessary and helpful to improve the quality of study programs at universities? And furthermore, is it in conformity with the German Law?

The paper offers a closer look at the development of accreditation as a quality assurance system. Furthermore, the accreditation system in Germany is described by using the example of the accreditation of civil engineering programs. In the fourth part, the legal basis of accreditation under German law is analyzed. Among other things the violation of basic rights by the accreditation processes, especially the university professors' Freedom of Free Teaching, enshrined in the Freedom of Sciences, is discussed.

The conclusion of these analyses is that the German system of accreditation is not reasonable. Furthermore, in the authors' opinion, it has no legal basis under the German Law in force and does not meet the requirements of Article 5.3 sentence 1 Basic Law of the Federal Republic of Germany, in which the Freedom of Sciences is fixed. This would mean that there is no legitimate obligation under German law to bring the universities' bachelor and master programs under the accreditation process at this point in time. Due to a constitutional complaint of a German university, the German Federal Constitutional Court is currently involved with the question of whether the system of accreditation is in conformity with the German Constitutional Law or not. The importance of the decision is obvious: if the Court decides that accreditation is unconstitutional, it allows German universities to be much more independent in developing curricula for civil engineering programs without conforming to the guidelines given by the accreditation agencies. This would be important in relation to European competition for the best students. Thus, the result of the decision may have an influence on the European idea of common standards and procedures for accreditation.

KEYWORDS

Bologna Process, Accreditation, Freedom of Teaching, Civil Engineering Programs

1. INTRODUCTION

The Bologna Process was the beginning of a comprehensive change within the higher education systems in most of the European countries. The starting point for this development was the Bologna Declaration in 1999, whose objectives were permeability, higher transparency and acceptance of university degrees across Europe. Year by year accreditation of bachelor's and master's programs at German universities commits a virtually inconceivable amount of human and financial resources creating a plethora of jobs and spending tens of thousands of Euros. Of course, universities will only be able to survive in a globalized educational market if teaching and research quality are on a high level. But fees for a single bachelor's or master's program accreditation in Germany can be between 10.000 to 15.000 Euros. For the accreditation of all courses of study, costs of a total of 400.000 to 500.000 Euros may incur for larger universities which must be paid from the universities' budgets. And this money is much-needed by universities for the improvement of teaching and equipment. So the question is if the accreditation is in conformity with the German Law. The paper will offer a look at the development of the accreditation system and its implementation in Europe. Furthermore, the accreditation system in Germany will be introduced and the legal basis under German Law is discussed. The aim of this paper is to show that the current accreditation practice in Germany is neither necessary nor reasonable and has no legal basis under the German constitutional right.

2. ACCREDITATION AS A QUALITY ASSURANCE SYSTEM

2.1 The origin of accreditation as a quality assurance system in Europe

Accreditation (derived from the Latin verb *accredere* meaning to give credibility) as a quality assurance system was developed in USA. In the United States, higher education institutions and their study programs are not under state regulation and supervision. This is why universities seek certification of the high quality of their education by private non-profit accreditation agencies. It is important to know that in the hotly contested US-American education market quality is decisive. However, accreditation is no must-have for the US-American Universities, but can be a winning argument in the competition for paying students.

The starting point for accreditation done in Germany was the reorganization of the European Higher Education Area based on the Bologna Process. When the Bologna Process was started in the 1990s, the ministers of education of 29 European countries committed themselves to save and improve the quality of university education. The targets of the European Bologna Process included quality assurance for higher education by accrediting the courses of study. The idea behind this is to guarantee that degrees are mutually equivalent so that programs of study offered by universities meet standards in terms of quality.

2.2 Types of accreditation

There are two different types of accreditation. On the one hand the program accreditation and on the other hand the system accreditation. Program accreditation means the individual check of each single course of study offered by a university including curriculum, qualification of lecturers, teaching equipment, relevance for the labor market, gender mainstreaming and so on. The universities must submit a detailed and comprehensive report for every program. It takes a lot of time of preparation and wastes plenty of material. In Germany, program accreditation of one course of study costs between 10.000 and 15.000 Euros. For a cluster procedure, which means the accreditation of two or more courses of study at the same time and at the same accreditation agency, universities may get a package price. On the other hand, system accreditation does not examine each course of study offered by a university. Rather, the agency examines the quality management of the university. Currently, the program accreditation is dominating, because system accreditation is much more complex and much more work for the universities. But more and more criticism is expressed that the accreditation system is absurd, expensive and only intends only to keep the university staff busy instead of making a contribution to the improvement of the teaching quality.

3. THE GERMAN ACCREDITATION SYSTEM

To realize the aims of the Bologna Process in Germany, bachelor and master courses were introduced permanently at almost all universities in 2002. As a consequence, already 82 % of the former courses of study at German universities have been replaced by bachelor's and master's courses. Currently, 2.482 bachelor's courses and 1.462 master's courses are offered by universities of applied sciences as well as 3.366 bachelor's courses and 3.824 master's courses by universities in Germany [Standing Conference of the Rectors of all German Universities 2011]. It is planned to bring all programs under the accreditation process. However, it is important to know that the German higher education system differs fundamentally from the US-American system, where accreditation was developed. In Germany, universities are still under state regulation and supervision.

3.1 The structure of the German accreditation system

It should be pointed out that universities in Germany are accredited by private agencies which in turn are accredited by the Accreditation Council of the Foundation for the Accreditation of Study Programs in Germany [German Accreditation Council 2011]. The accreditation agencies operate as non-profit organizations which are financed through membership fees as well as through higher education institutions for accreditation services provided. The agencies are contracted by the accreditation council which – as the central decision-making body of the foundation – defines the basic requirements of the process. The Accreditation Council has its legal basis in the Act for Establishment of a Foundation for the Accreditation of Study Courses in Germany, which is state law of the German federal state of Nordrhein-Westfalen. Currently, 10 agencies are registered. Some of them specialize in certain fields, for example in the accreditation of engineering programs or social and health care sciences. The accreditation agencies have the mission to organize the quality assurance system for study programs and teaching by accrediting study programs. In this connection they check whether the course of study satisfies the requirements set up by the Resolutions of the Standing Conference of the Ministers of Education and Cultural Affairs of the Federal States in Germany [Standing Conference of the Ministers of Education and Cultural Affairs of the Federal States in Germany 2010] and Standing Conference of the Rectors of all German Universities [Standing Conference of the Rectors of all German Universities 2007]. Such requirements can be specific combinations of subjects in specific curricula, physical equipment and personal resources, internationalization and the graduates' preparation for the labor market. By so-called standards, the program that is applying for accreditation will be compared with a presumed ideal program. The agencies argue that standards are important to create transparency, to define points of intersection and to ascertain compliance with legal regulations [ACQUIN 2009].

Using a degree program's declared objective as a starting point, the accreditation agencies examine the coherence and consistency of the concept, the coherence of implementation as well as the competence and capacity of the degree program. That means applying universities have to write a self-evaluation report freely on the basis of the accreditation guidelines, which is intended to clarify the quality profile of the degree program and the strengths and weaknesses of the individual elements. Thus, the following questions must be asked:

- Have valid degree program objectives been defined?
- Is the degree program as a whole, together with the individual degree course modules, a suitable means to reach the objectives of the degree program?
- Is a consistent implementation of the degree program concept assured?
- Are the target definitions, the course concept that is built upon them, and the degree to which it is implemented checked?
- Does iteration take place in order to eliminate errors and assure optimization at all process stages? [ACQUIN 2009]

The higher education institution is asked to describe to what extent these aspects of the guidelines were considered in building up the curriculum, in accordance with the different institutional circumstances, intentions and possibilities. Alternatively, they are asked to justify why the degree program diverges in substance from the given advices.

3.2 Process of German accreditation

The accreditation process consists of several stages and is based on the peer review principle. When a higher education institution submits an application for a study program accreditation to an agency they have chosen, the relevant agency deploys an evaluation group (peer group) whose composition must be a reflection not just of the special focus of the study program but also of its specific profile. Thus, each peer group includes representatives of universities, such as professors and students, and representatives of the profession. The evaluation of the study program is carried out in accordance with the given Criteria for the Accreditation of Study Programs by the Accreditation Council and, as a rule, includes an on-site inspection of the higher education institution by the peers. After sending the self-evaluation report to the agency, the audit will take place at the university. While meeting, peers and representatives of the university discuss the program. In some cases, peers also want to have a look at some bachelor's or master's theses. Also students can be interviewed and laboratories can be visited.

On the basis of the assessment report drawn up by the peer group and in accordance with the decision regulations provided by the Accreditation Council, the responsible Accreditation Commission decides either to grant accreditation for the relevant study program, to grant accreditation under certain conditions, to abandon the process or to reject accreditation. If a study program has successfully undergone the accreditation process, it is awarded accreditation for a limited period (usually 5 years), with or without conditions, and carries the Quality Seal of the Foundation for the duration of this period. In some federal states of Germany, accreditation is a precondition for state approval.

3.3 Accreditation of the Civil Engineering Bachelor's/Master's Program at HTWK Leipzig

The specifications of the private accreditation agencies concerning the curricula are not only problematic in a constitutional sense. Unfortunately, instead of learning from other higher education systems, the accreditation system has been adopted without any critical reflection. The requirements in terms of "soft skills" (meaning social competence, foreign languages, interdisciplinary subjects and knowledge of business management) cause problems to any six- or seven-semester's bachelor curriculum that has already been compressed down from an eight- or ten-semester's German "Diplom" curriculum. Beyond this, times for practical training courses and studying abroad have to be radically reduced to guarantee that the course content can be taught in the prescribed time. In spite of all this, universities must guarantee the graduates' employability. In 2007, the Department of Civil Engineering and Architecture at the Leipzig University of Applied Sciences (HTWK Leipzig) had to bring the civil engineering bachelor's and master's program under accreditation. One department employee spent nearly one year in preparing all necessary documents and information starting with human resources and teaching equipment to program objectives and course concepts. During the accreditation process, the department had to give reasons for the course contents and even change the name of a master`s specialization. The decision to grant accreditation without conditions was made in 2009, two years later. Moreover, the agency advised the Department of Civil Engineering and Architecture to inform the peers about all major changes in study structure, study content or resources. In that case, the agency has to examine the program again, of course with additional fees.

4. ACCREDITATION AND GERMAN LAW

It has to be said that accreditation in Germany is constitutionally controversial. A reason for that is the comprehensive examination of the study programs based on detailed specifications of private accreditation organizations and other requirements without the effect of a parliament's act. The problem is that the detailed examination increasingly interferes with the Freedom of Sciences, seen as unity of research and teaching, protected by the German Constitution. Due to a constitutional complaint of a German university, currently, the German Federal Constitutional Court is involved with the question whether the system of accreditation is in conformity with the German Constitutional Law or not [Administrative Court Arnsberg 2010]. The court has to decide if the accreditation with its current methods infringes the constitutionally guaranteed Professor's Freedom of Free Teaching.

4.1 Freedom of Sciences

In Article 5.3 sentence 1 of Basic Law of the Federal Republic of Germany as well as in the constitutional law of the federal states of Germany, the Freedom of Sciences is fixed as the most important basic right of universities and scientists in Germany. The Freedom of Sciences originates from the Middle Ages and was guaranteed in the universities' charters [Rüegg 2004]. Everyone operating scientifically is assured of the Freedom of Teaching and the Freedom of Research without governmental control and influence. Every scientific activity is protected, provided it is considered as a serious and methodical attempt of finding the truth [German Federal Constitutional Court 1978]. The Freedom of Teaching allows the lecturers to define the content and method of their courses, especially the topic, form (lectures, seminars, practical and non-practical exercises), structure and duration [Fehling 2004]. Any exertion of influence on the method or content of the courses violates the individual basic right of the lecturer. This basic right was meant to avoid any governmental influence, for example the decision about relevant or non-relevant research or teaching. Also, universities as institutions are protected by Article 5.3 sentence 1 of Basic Law of the Federal Republic of Germany, which guarantees the autonomy of universities in academic terms of teaching and research.

This constitutionally guaranteed liberty is enforceable and can only be confined by other basic rights, for example the right to live as expressed in Article 2.2 of Basic Law of the Federal Republic of Germany. Such a confine needs to be authorized by an act of parliament. Binding provisions or guidelines by accreditation agencies, the Standing Conference of the Ministers of Education and Cultural Affairs of the Federal States in Germany and the Standing Conference of the Rectors of all German Universities, as described in paragraph 3, are no acts of parliament and thus do not meet the requirements [Quapp 2011].

4.2 Infringement of the Freedom of Sciences

During the process of accreditation, the agencies do not only control the program's concept, but also the educational equipment, such as lecture rooms and labs, as well as human resources. Additionally, the program's relevance for the labor market, self-development support for students, stimulation of student's interest in interdisciplinary fields and gender mainstreaming are checked. The examination of these aspects as well as the assessment of a lecturer's competence and didactic concept violates the Freedom of Teaching. But the most significant infringement is the obligation to modularize the bachelor's and master's programs. That means the curricula have to be structured in modules according to the guidelines of the Bologna Declaration. Modularization means the combination of lectures and seminars with similar program contents in thematic units. Each module will be completed by one or more examination. Modules must have 4 to 10 ECTS (Credit Points in the European Credit Transfer and Accumulation System). One Credit Point corresponds to 30 student's work hours. That means in fact that the lecturer has no longer the possibility to decide about the duration of courses. Moreover, the accreditation agencies give advice concerning the curriculum's content. So, the guidelines of one of the leading accreditation agencies for engineering programs, mathematics, informatics and sciences requires 10% of the curriculum to be interdisciplinary courses and 15% to 20% to be subject-specific basics. At worst, universities will be recommended re-naming modules or whole programs.

As described before, the Freedom of Teaching can be delimited by other basic rights, such as the student's occupational freedom enshrined in Article 12.1 of Basic Law of the Federal Republic of Germany. However, that article only allows the student's free choice of courses of study and university. It does not give the students the right to demand special course contents or modularization. Also, Article 23 of Basic Law of the Federal Republic of Germany, which contains a national objective to encourage a Unified Europe, is only an abstract declaration of intent. That's why it cannot be a legitimation for violating basic rights.

Even if it is argued that the Freedom of Teaching is delimited by another basic right, there is no act of parliament which authorizes a confinement of the Freedom of Teaching. The Act for Establishment of a Foundation for the Accreditation of Study Courses in Germany was set up by state law of one federal state and that is why it cannot have any kind of effect for the other 15 German federal states. Also, the Federal States University Acts cannot be a legal basis for delimiting the Freedom of Teaching, because in most of the university acts of the Federal States the system of accreditation is only mentioned and not described in detail. In other university acts, accreditation is not mentioned at all. Further, the Criteria for the Accreditation of Study Programs by the Accreditation Council, the requirements set up by the Resolutions of the Standing Conference of the Ministers of Education and Cultural Affairs of the Federal States in Germany and the Standing Conference of the Rectors of all German Universities are not binding because they are no acts of parliament. That means that there is no obligation for universities to bring their course of study under accreditation at all.

In recent years there have always been governmental attempts to undermine the Freedom of Sciences. But it is an alarming development that non-governmental agencies and organizations try the same without any legal basis. The Freedom of Sciences can be called an endangered basic right by now [Quapp, 2010].

Due to the accreditation guidelines and requirements, interdisciplinary courses, social competences, management training and a fixed semester's work load had to be implemented in the curricula with the consequence that the time for subject-specific contents and practical training had to be reduced. The German Accreditation Council, which accredits in turn the accreditation agencies, granted two big agencies the accreditation seal only under the condition that they respect the professors' Freedom of Teaching and their decisions about course content. So now the agencies have to clarify that their requirements for curricula are not binding for the universities. Further, there shall be no need for universities to give reasons if they do not meet the curricula standards set by the agencies. But this sanction against the agencies must be interpreted against the background of the expected Constitutional Court's decision. Thus, the Accreditation Council tries to hold on the system of accreditation as a quality assurance method.

5. CONCLUSION

The paper concludes that accreditation is not a suitable mean to assure the quality of study programs. Program accreditation infringes the basic rights of the lecturers at universities, especially the Freedom of Teaching, and thus has no legal basis under the German law.

Even though there is an interest in harmonizing European higher education by means of accreditation, it will not improve academic mobility. Accreditation will only cause the loss of national uniqueness in higher education and a downgrading of Germany's quality level in this sphere. Now, some years after the replacement of the former "Diplom" program by the bachelor/master programs and the implementation of the accreditation system, Industry complains about the loss of the graduates' qualification. But this problem cannot be solved by means of program accreditation.

The German universities' resistance against the system of program accreditation becomes stronger. This is also a result of the latest announcement of accreditation agencies to reject accreditation certificates to programs which grant students, according to their choice, either a Bachelor's/Master's degree or a "Diplom" degree. So the German Association of University Professors and Lecturers claims the end of the "accreditation nonsense" and the implementation of a modern and self-governed quality management system at universities [German Association of University Professors and Lecturers 2011]. In Germany, which has one of the most highly-valued higher education systems, it is mortifying to have no confidence in the professors' and lecturers' teaching quality. A university's reputation guarantees the high quality of the study courses it offers. It is better to use the financial and human resources to improve the quality and not to finance private non-profit organizations such as the accreditation agencies. One of the German top managers once said: "Quality must be produced; it cannot be reached by quality assurance".

The importance of the Constitutional Court's decision is obvious: if the court decides that accreditation is unconstitutional, this would allow German universities to be much more independent in developing curricula for civil engineering programs without following the guidelines given by the accreditation agencies. That will make it much more difficult to implement a unified European accreditation system. Thus, the result of the decision may have a huge influence on the European idea of common standards and procedures for accreditation. If the accreditation guidelines violate the lecturers' basic right to create study programs in Germany, the improvement of comparability of study courses will be pretty difficult or even impossible. Quite recently, representatives of European national accreditation agencies met in Split/Croatia to establish the society for "Central and

Eastern European Network of Quality Assurance Agencies in Higher Education e.V.". Their aim is to support the development of a unified European Higher Education Area. It also demonstrates once again the attempts to harmonize higher education at the national and European level. If the German Federal Constitutional Court decides that accreditation with its current practices is not in conformity with German law, it will influence the ambitious efforts to harmonize the courses of study at European universities by means of accreditation. Then, unified European quality assessment will only be a toothless tiger. Without binding guidelines universities will decide on their own about the curricula. Maybe in other European countries the legal development will be the same. As a result, harmonization by binding accreditation requirements will be no longer a mean to create a unified European Higher Education Area. European universities should rather try to reduce the administrative barriers for foreign students and to implement the European idea at higher education institutions. But it cannot be reached under duress. It has to come from the universities' ambition to improve academic mobility. Until then, permeability, higher transparency and acceptance of university degrees across Europe will remain a great dream.

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GREEK UNIVERSITIES AT A CROSS-ROAD: HOW CAN THEIR DECLINE BE REVERSED

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EXTENDED ABSTRACT

It has been widely admitted by everyone who has some knowledge about the Greek Universities that in the past few decades the quality of their output is in a continuous decline, no matter which index is used to measure such output. This observation is shared both by faculty and students alike, as well as by large sectors of the Greek society. In this paper we present a very brief review of the basic changes that were introduced in the Universities back in 1983, when the old system, a copy of the German Chair based system, was changed by a law written with the American University system in mind. The main changes introduced by that law included the abolishment of “Chairs”, the introduction of the Departmental Divisions, the four grades of faculty members, the large representation of students in the electoral bodies for elections of the University officials (rectors, vice rectors, deans, Department Heads, Division and laboratory Heads) and the large percentage of students in the Department General Assembly, which governs the Department

Subsequently, the problems of today attributed to this law or to misapplication of the law or to other factors related to Greek society in general are presented and discussed, starting with the two main causes from which these problems originate: one political and the other associated with the university itself. The political or better partisan factor entered into university affairs through politically controlled student unions which designate the very high numbers of student representatives, not only to the electoral bodies for university officers but also to the administrative bodies, e.g. the Senate and the Departmental General assemblies. Consequences of this are: (a) Not to elect the best people in the various university posts, (b) The Committee responsible for temporarily “lifting the asylon” and for asking the police to intervene in case that criminal acts are committed in the University, is never formed since the student unions refrain from designating the student member to the Committee, (c) Blocking of important decisions like, e.g., establishing lists of prerequisites, abolishing the “automatic“ student enrollment in any term without some minimum requirements etc. The second cause is associated with a non negligible number of university professors who favor the existing state of affairs and indirectly support or at least do not react when any minority decides to take over a university building or the whole university and close it, usually to protest about something. The same group strongly reacts not only to the creation of private universities in Greece but also to any proposal that would help exiting from the present crisis.

To reverse the decline it is proposed that a new law should include the following provisions:

1. The fundamental right of students to attend classes without any obstacle and of the professor to teach and do his research must be protected and secured by penalizing the taking over of university buildings by anyone. Persons violating this right, including University officers who do not carry out their duty to use ALL the provisions of the Law to secure this right, should be held accountable. This implies drastic reform of the existing “asylon” provisions.

2. Drastic reduction of the student representation in the electoral as well as the administrative bodies of the university.

3. Departments in which course prerequisites are not introduced should not be allowed to give degrees.

4. Establish firm requirements for a student to register in each Semester (e.g. minimum and maximum number of courses he is permitted to register for).

5. Establish rational procedures for course exams and conditions under which a student should not be allowed to continue his studies.

6. Establishment of new procedures for election of University officers (Rector and Vice Rectors) and Department Heads.

7. Grant greater authority to the Rector, Vice Rectors and to Department Heads for a number of academic matters, including disciplinary action in cases of violations of the Law or the University rules and code of ethics by students and faculty.

8. Restriction of the Senate role to strategic planning and to major issues only, by transferring administrative matters and pertinent decisions to the Rector and Vice Rectors. Do the same for the Department General Assemblies and delegate more authority to the Department Chairman and the Division Heads.

9. The Ministry of Education should grant greater autonomy to the Universities, reduce the bureaucracy and keep for itself only the role of oversight, for making sure that there are no violations of the Law by anyone.

10. Re-examination and possible revision of the criteria and procedures for election, promotion and granting of tenure to faculty members, giving as much emphasis to teaching as to research and publications. Establishment of periodic evaluation of all faculty members at every level.

Finally we conclude by outlining how the required changes can be implemented in a way that they will not be short lived, as it has often happened with similar attempts in the past.

KEYWORDS

University, Chair, Decline, Student participation, Administration, Rector, Department, Taking over by students, Accountability, Law revision, Required changes

1. BRIEF HISTORICAL REVIEW

The Greek university system until 1982 was quite similar to the German system operating with the "Chair" as the basic unit of each Department. The Chair holder Professor had almost absolute power over everything associated with the "Chair", such as budget, activities, office spaces, laboratories, equipment, and, of course, over all personnel working in the "Chair", administrative, technical and scientific. This had few advantages and many more disadvantages, the two most important of which were the following: (a) If a problematic professor managed to be elected to the "Chair", then the consequences on the quality of education in the area covered by the Chair would last for decades, i.e. for the period till he retired. It was practically impossible to get rid of a "bad" professor. It is noted that since the election to a Chair was done by an electoral body consisting of all the Chair holders of the university, quite often this turned out to be a process controlled by favoritism and family connections rather than meritocracy. As a result, not only some excellent or even top people were left out of the university, in many cases totally worthless individuals were elected because their father, uncle or other relative had a Chair. (b) Since the Chair holder had tenure till his retirement and no incentives, whatsoever, to publish and thus follow the developments in his field, many of the old professors were teaching what they themselves were taught as students and any progress in their respective fields would not be filtered into the educational programs until the Chair holder professor retired and a younger, more informed individual was elected.

All this changed in 1982 when the new socialist government of Andreas Papandreou passed Law 1268/82 that abolished the Chair system and introduced a new framework for university education, modeled after the US system, but with few important differences. These differences had to do with the way University authorities i.e. Rector and Vice Rectors, Deans and Department Heads were elected, the unusually high percentage of student participation in electoral as well as governing bodies (like Senate or Department General Assembly), the nearly total absence of accountability at all levels, etc. Their consequences will be discussed below but here we will note that a number of deficiencies in that Law were the result of interventions by young university assistants with academic ambitions, who were placed in key governmental positions as very active members of the ruling socialist party. It is also worth noting that the "Chair" system was abolished by an earlier law in 1978, passed by a government of K. Karamanlis, but due to many reactions at that time the Law was never actually applied as Law of the land.

2. MAJOR CURRENT PROBLEMS

There is no doubt that the Chair abolishing Law of 1982, introduced some good changes such as the "opening" of the university to younger scientists, the introduction of incentives to do research and to publish and thus stay abreast of recent developments in one's field and the modernization, to a certain extent, of educational programs. However, it also created conditions of operation that led to many unacceptable practices and to a continuous decline of all higher education in Greece. An idea about some of the ill happenings in Greek universities and their causes is given in an article posted on a Greek site on the internet, where, in free English translation, we said:

"Has anyone wondered why in our country, plenty of totally irrational things happen, while the obvious actions and response become points of endless discussions and controversy?? What else other than incredible and totally irrational would one characterize the repetition over the last thirty years, of vandalism, arson and thefts of university property, under the eyes of the police, which however, will not enter into a university campus, unless invited by a University Committee that has never been formed? This unique provision in the Greek Law, known in Greece as University "Asylon" (a status granted to ancient Greek Temples , where any chased man, criminal or not, could seek protection from his pursuers who would be violating a sacred Law if they were to capture him in the Temple). Has anyone wondered why in our universities we sometimes witness raw violence, such as the violent expulsion of Professors from their offices or classrooms, the taking over of university buildings by small groups of protesting students for days and even the “locking” of the whole Senate in their meeting halls, till they reverse a decision that some student groups did not like?? Is there any other university in the world in which as a consequence of the abnormally high student representation in the Department General Assembly, course prerequisites have never been established, leading to the automatic student enrollment from one semester to the next, without any requirement for successful completion of any single course from all the courses in any of the preceding years?. Among the many bad consequences of this practice is the extension of the time taken to get a university degree by perhaps 30%-50%, over and above the normal period, since the students who complete the number of semesters required for a degree, are allowed to participate in subsequent exams, as many times as it takes to pass any given course, without any time limitation. So it is not unusual to see students of 5-year engineering programs to get a degree in 7, 8, or even 10 and more years. Is there any other country in the world, in which university officials have been publicly complaining for vandalisms and destructions caused by partying students in university halls, although they are the ones who gave permission for such use, in spite of warnings by many that this was going to happen? Is there any other country in the world in which a historical university building has been put on fire twice by rioting mobs, and whose rector, who had decided not to call the police so that the “asylon” would not be “violated”, was rewarded by a his reelection to the same position ? All these are signs and indications of a deep, long running crisis, in which Greek Universities were gradually pushed after 1982. They also explain the very low ranking of all Greek universities in various international evaluations.”

Nearly all university officials, past and present, claim that the basic problem of the Greek universities is the lack of autonomy from the Ministry of Education. In our opinion this is only an excuse since most of the above described phenomena of decadence, could have been prevented if the officials were willing to face the challenge of applying the Law and not hesitate to “collide” with the small minorities of student extremists, who often get instructions from “centers” outside the university. Of course, no one denies that Greek Universities are burdened by the same terrible bureaucracy that plagues the Greek State. But this could never be an excuse or alibi for inaction and tolerance of criminal acts taking place in the universities.

In our opinion the decline of the Greek Universities is due to two basic causes: one political and the other associated with the university itself. The political factor is due to the partisan policies that entered into university affairs through politically controlled student unions that designate the high numbers of student representatives, not only to the electoral bodies for university officers but also to the administrative bodies, e.g. the Senate and the Departmental General assemblies. The main consequences of this are: (a) Not to elect the best people in the various university posts, (b) The Committee responsible for temporarily “lifting the asylon” and asking the police to intervene in case that criminal acts are committed in the University, is never formed since the student unions refrain from designating the student member to the Committee, (c) Blocking of important decisions like, e.g., establishing lists of prerequisites, abolishing the “automatic“ student enrollment in any term without some minimum requirements etc. The second cause is associated with a non negligible number of university professors who favor the existing state of university affairs and indirectly support or at least do not react when any minority decides to take over a university building or the whole university and close it, usually to protest about something. The same group strongly reacts not only to the creation of private universities in Greece but also to any proposal that would help exiting from the present crisis.

3. REQUIRED REFORMS

The main points of the required reform to the existing legislative framework under which Greek Universities operate are known to everyone and there is complete agreement on these by everyone with experience from foreign universities and with a sincere desire to stop the current decline. They have been presented in the past and publicly discussed. Here we will only list them without many comments.

1.The fundamental right of students to attend classes without any obstacle and of the professor to teach and do his research must be protected and secured by penalizing the taking over of university buildings by anyone. Persons violating this right, including University officers who do not carry out their duty to use ALL the provisions of the Law to secure this right, should be held accountable. This implies drastic reform of the existing "asylon" provisions.

2. Drastic reduction of the student representation in the electoral as well as the administrative bodies of the university (e.g. from the 40% of the number of faculty members it is today to 5%).

3. Do not allow Departments to operate without establishing course prerequisites,

4. Establish firm requirements for a student to register in each Semester (e.g. minimum and maximum number of courses he is permitted to register for)

5. A course must be examined at the end of the semester it is taught and once more in the following September. If the student fails in September, he must register again for the course in the next Semester. In case he fails again in both periods, the student will be allowed to register once more for the course but he would have to pay tuition fees for the course. If he fails again in both periods, his enrollment is discontinued. The same will happen if he exceeds by 40% the regular time required for obtaining his/her degree.

6. Establishment of new procedures for election of University officers (Rector and Vice Rectors) and Department Heads.

7. Grant greater authority to the Rector, Vice Rectors and to Department Heads for a number of academic matters, including disciplinary action in cases of violations of the Law or the University rules and code of ethics by students and faculty.

8. Restriction of the Senate role to strategic planning and to major issues only, by transferring administrative matters and pertinent decisions to the Rector and Vice Rectors. Do the same for the Department General Assemblies and delegate more authority to the Department Chairman and the Division Heads.

9. The Ministry of Education should grant greater autonomy to the Universities, reduce the bureaucracy and keep for itself only the role of oversight, for making sure that there are no violations of the Law by anyone.

10. Re-examination and possible revision of the criteria and procedures for election, promotion and granting of tenure for faculty members, giving as much emphasis to teaching as to research and publications. Establishment of periodic evaluation of all faculty members in every level.

11. Course notes and example problems for each course should be available to the students posted on the internet

Details in implementing the above recommendations must of course be worked out, taking into consideration available experience from Greece and abroad.

4. HOW TO PROCEED

Having read the above problems plaguing the Greek Universities, the question comes naturally: "Why has this situation lasted so long? Why this long sought reform has not been implemented earlier?" The answer to this must be sought into the Greek political system and the populist conditions that prevailed in the country since the time the current Law has applied i.e. since 1982. In our opinion the main reasons are: (a) Populist policies greatly affected by vocal student minorities who were reacting strongly to any efforts of raising educational standards. (b) Reactions for reform by the university establishment described earlier. (c) Partisan reactions and disagreements to whatever the government by the ruling party would recommend. (d) Lack of continuity in the Greek set of Laws and rules under which the country operates. This is a general illness of the Greek state of affairs and is witnessed not only when the opposition gets the majority and forms a new government and then tends to replace many of the Laws voted by the previous parliamentary majority, but also when a reshuffling of the same Government occurs and a new Minister takes over. This sad sequence of events has been witnessed over and over during the past thirty years and the result is not only what we have just described above for the Greek Universities but also the near bankruptcy condition in which the whole country is nowadays.

We feel that if we would like to see a successful educational reform an agreement must be reached at the highest political level, i.e. between the Prime Minister and the chiefs of all parties represented in parliament. **The agreement must NOT be about what should be reformed but rather on how to draft the reform in all its details.** We feel that the government should try forming a high level Committee whose members should meet very high academic standards that the government will set. This committee does not need to have many members: a number between 7 and 12 could be sufficient. The government should ask each party in parliament to propose a number of members to this committee in proportion to its parliamentary power, with the non negotiable requirement that each of the proposed members meets the high academic standards set by the government. Then all parties must agree (a) that they will accept whatever that Committee will recommend and will vote it into Law and (b) that this Law will not be changed soon, except for possible minor improvements as a result of gained experience after it is applied. If this procedure could be followed, the risk will be minimized that when a new party gets to form a government it will try to change the Law. Another advantage of this procedure is the following: There is a belief among many that ideological differences between right and left wing parties, e.g. between Christian democrats and socialists, are such that the two sides would be unable to agree on the same educational framework because the different philosophies would permeate into the educational system. We do believe that no matter what ideological differences the members of the above suggested Committee may have, their high academic credentials and experience not only from Greek but from some of the best foreign universities, would be a guarantee that they will sincerely suggest what they believe is the best reform. It will certainly be much easier for them to reach a consensus on topics, on which different viewpoints will be presented, than between politicians of different parties who not only lack the required knowledge and experience but also feel as opponents in different teams.

At the time this is submitted, a new Law has been voted by the Greek parliament with the support of the two major political parties. It brings drastic reforms to the existing legal framework governing higher Education in Greece but has generated great reaction in the academic community. Most of the reaction comes (a) from the usual small groups of radical students who have always supported old fashioned leftist ideas and populist positions (b) from the rectors and vice rectors of All Universities, who are afraid that under the new Law, they would have little or no chance of ascending in the top positions they hold today, and (c) by the faculty members mentioned earlier, who react to any changes of the status quo for a number of reasons, e.g. the fact that under the current system there is essentially no accountability for the way they fulfill their obligations, no performance evaluation, especially for the tenured faculty, and the loss of some other “privileges” that we will not discuss here. Irrespective of the fact that the new law includes some of what we have suggested above, it too suffers from the problem that it was drafted by a Committee for which the opposition and the other parties had no saying, although the major party in the opposition finally voted for it after some last minute changes it demanded to be made. The reaction to the Law still remains high, with some University administrations threatening not to apply it, based on the opinion of some legal advisers that some provisions of this law violate our Constitution. Unfortunately Greeks must still learn how to solve major problems of National importance by consensus and without creating major turmoil.

ON HIGHER CIVIL ENGINEERING EDUCATION IN RUSSIA: A CASE OF A MASTER'S DEGREE ON STRUCTURE RELIABILITY & SAFETY

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EXTENDED ABSTRACT

Transition to the tiered system of education in Russia poses a workload problem for teachers, as it is associated with an increase in the number of master's programs related to the modern problems in construction. One of such problems is the safety and reliability of design of buildings in emergency situations, either man-made or natural. These problems are particularly relevant, considering the recent devastating earthquakes, tsunamis, numerous acts of terrorism, fires and other emergency situations. Moscow State University of Civil Engineering has developed a master's degree program on the subject of the "Reliability and safety of building constructions", aimed at training of experts in the analysis, in computational and experimental modeling, as well as in the development of building codes and standards for design and construction in special circumstances.

The developed master's program meets Federal State educational standard of Master in the field of "Construction", approved by the Ministry of Education and Science of the Russian Federation. The structure of the standard stipulates a percentage of about 30% of compulsory subjects (18 - 20 credits) for all master's programs in this field. The remainder, i.e. about 70% (40 - 42 credits), of the program consists of special courses reflecting the content of training for each individual program. Finally, 60 credits are allocated for research work and state certification. This masters program is described in Section 1 of this article.

In preparation for Masters, 8 of 10 special disciplines are required, while 2 of 4 subjects are optional. Optional disciplines permit students to advance their knowledge in topics such as general mechanics as well as numerical and experimental methods for mechanics of deformable solids. In Sections 2 to 9, the article gives a summary of the following eight disciplines of the aforementioned master's program "Reliability and safety of building constructions", as they are taught in this particular program:

- reliability and safety of technical systems, man-made risk;
- theory of reliability of structures;
- theory of seismic stability of structures;
- fire and explosion safety of structures;
- loads and effects on buildings and structures;
- design codes in civil engineering;
- multifactor structural analysis;
- structural survey and research.

KEYWORDS

Civil engineering education, Reliability, Man-made risk, Construction codes, Testing facilities, Earthquake resistance

1. INTRODUCTION

Transition to the tiered system of education in Russia poses a workload problem for teachers, as it is associated with an increase in the number of master's programs related to the modern problems in construction. One of such problem is the safety and reliability of design of buildings in emergency situations, either man-made or natural. These problems are particularly relevant, considering the recent devastating earthquakes, tsunamis, numerous acts of terrorism, fires and other emergency situations. Moscow State University of Civil Engineering has developed a master's degree program on the subject of the "Reliability and safety of building constructions", aimed at training of experts in the analysis, in computational and experimental modeling, as well as in the development of building codes and standards for design and construction in special circumstances.

Table 1 presents the contents of the program for master's degree in the subject of "The reliability and safety of building constructions".

Table 1: Program content

№	Name of subjects	Labor input (Credits)
M.1.	**General scientific cycle**	**30**
1	Philosophical problems of science and technology	2
2	Methodology of scientific research	2
3	Mathematical modeling	3
4	Special sections of higher mathematics	3
5	Reliability and safety of technical systems, man-made risk	4
6	Theory of reliability of structures	4
7	Theory of seismic stability of structures	4
8	Fire and explosion safety of structures	4
	Optional disciplines	
9.1	Sustainability and dynamics of structures	4
9.2	Plasticity and creep theory	
M.2.	**Professional cycle**	**30**
10	Foundations of pedagogy and adult learning	2
11	Business language	2
12	Information technology in construction	2
13	Methods for solving scientific and technical problems in structures	4
14	Loads and effects on buildings and structures	4
15	Design codes in civil engineering	4
16	Multifactor structural analysis	4
17	Structural survey and research	4
	Optional disciplines	
18.1	Computer-Aided analysis in mechanics	4
18.2	Experimental structural mechanics	
M.3	**Practice and research**	**57**
	Research work and practice	19.5
	Master's thesis	37.5
M.4	**Final state certification**	**3**
	Total workload	**120**

2. RELIABILITY AND SAFETY OF TECHNICAL SYSTEMS, MAN-MADE RISK

The reality is that technospheric (technosphere - the environment altered by people) human development leads to a deterioration of the environment. Man began to destroy the Earth before developing the ideas of cherishing and protecting it. The recent gradual greening of economic activity, aimed at reducing anthropogenic impact on the environment, is a source of optimism. An important role in this process can be played by education in general and education on "life safety" in particular. In our opinion, it is necessary to form a new specialized scientific field of knowledge, called "Health and Safety in Technosphere". In essence, this is a new form of technology, technology of risk management, which considers and solves a wide range of related issues (technical, environmental, socio-economic, informational, political, etc.). This approach allows us to identify "weaknesses" in the existing or emerging technospheric systems, in order to further optimize safety measures and reduce the likelihood of natural and man-made emergencies.

The discipline "Reliability and safety of technical systems and man-made risk" explores reliability of technical systems and safety as an integral part of technological security. Definitions of the basic terms in reliability of technical systems are provided and the basic dangers of technical systems are identified, thus proving the urgency of the problem of safety from the point of view of its social and economic importance. Substantive provisions of the theory of reliability of technical systems and man-made risk are considered. The basic methods of increase of reliability and examples of use of the theory of reliability for an estimation of safety of human-machine systems are formulated. The methodology of the analysis and estimation of man-made risk is considered. The basic qualitative and quantitative methods of an estimation of risk, methodology of an estimation of reliability, safety and risk with use of logical and graphical analysis methods, criteria of comprehensible risk, principles of management of risk are stated, and examples of use of the concept of risk in engineering practice are considered.

3. THEORY OF RELIABILITY OF STRUCTURES

So far, almost no attention has been paid to the issue of appropriate duration of maintenance of buildings. The pyramids were built for eternity. The same can be said about medieval cathedrals, and probably about the palaces of the Renaissance. In contrast, operation of aircrafts is limited in time - about 30 thousand flight hours or approximately 10 years. By 1920, it became apparent that most of the buildings have a finite lifetime. It was clear that sanitation facilities, which were excellent in 1870, became bearly satisfactory by 1920. Sometimes it was easier to tear down the building and build a new one than to improve the technical equipment of the old building. Consequently, industrial buildings, office buildings and apartment houses have a limited service life and the existence of structural foundations of a building, which outlasted its purpose, loses its meaning.

As a rule, the practical life of the building, depending on the expected changes in the area it serves, can be from 50 up to 100 years. Only some monumental buildings can be designed for longer existence.

One very important factor of enhancing the reliability and durability of constructions is to improve the methodology of calculation of building constructions on the limit states. Probability theory and mathematical statistics are theories of mass phenomena, which describe the possibility of recurrence of a random event in similar conditions. Application of methods of mathematical statistics in the study of design and construction failures meets difficulties in the respect that repeatability of the separate reasons that caused failures, takes place in some cases (for example, crash damage from the cold brittleness of steel, the loss of stability of constructions, etc.). However, uniformity of conditions of failure repetition, as a rule, is absent.

Failures are individual and are caused by a combination of different reasons. The onset of an emergency condition should not be considered as a homogeneous mass event. Tests for durability of a material and checks of the size of the applied load can be repeated many times, and in certain cases — working conditions of construction as well, such as crane load and its impact on the crane structure. In general, the working conditions of construction can't be considered as mass events. It is also impossible to consider an advance in the construction of the limit state as mass event.

4. THEORY OF SEISMIC STABILITY OF STRUCTURES

The development of theory of seismic stability of constructions has become increasingly important in the last decade. Various phenomena can lead to earthquake-like events, such as activity of volcanoes, explosions, hulling of arches over karst areas etc. From the engineering point of view, the greatest interest represent earthquakes of a tectonic origin, i.e. associated with the accumulation of stress over large areas of the earth's crust.

Assessment of seismic resistance of buildings, taking into account the spatial fluctuations, is associated with significant design challenges due to the complex dynamic processes occurring in the building, which depend on numerous factors. To solve this problem, you must have a correct idea of the actual mechanical properties of the support structure and take into account the spatial work of buildings under static and dynamic loads and have enough information about the seismic influence impact.

Application of seismic protection is one of the promising trends in earthquake engineering. This trend has resulted in a number of constructive suggestions, some of which haven't passed the necessary theoretical and experimental verification. The theoretical justification of an active seismic protection of a building is currently an important area of research.

The analysis of consequences of strong earthquakes shows that fluctuations of both separate structure elements, and buildings as a whole occur simultaneously in several directions, i.e. these movements are spatial and non-stationary. Ground movement during an earthquake is also a complex multi-dimensional random process and therefore there is a problem of accounting for the spatial nature of the seismic influence.

The seismic stability theory or **the seismic stability analysis** is the earthquake engineering tool that breaks this complex subject into a number of subsections for the best understanding of the behavior of buildings and constructions under seismic loading.

The seismic stability theory is based on principles of dynamics of constructions and antiseismic design. Within the present decade, the *response spectra* method has been the most common method of **seismic stability analysis,** which is being developed at present.

However, *response spectra* are only good for systems with one degree of freedom. Using the step of integration of real or synthetic accelerograms is more effective method for systems with many degrees of freedom and with significant non-linearity in the transition process of kinematic excitation.

5. FIRE AND EXPLOSION SAFETY OF STRUCTURES

The construction setup design should provide arrangements for labor, fire and explosion safety during the construction and reconstruction of existing enterprises, as well as measures providing stability of structures saved.

When determining conformity of frame constructions with fire and explosion safety, the following shall be established:

- fire resistance limits and limits of fire spread to walls, partitions, floors, coatings, elevator shafts, as well as for doors and gates;
- foundations or foundation beams with fireproof walls in frameless buildings;
- fire protection of walls separating the outer walls of combustible or hardly flammable materials and going beyond the plane of the exterior walls, ledges and overhangs roofs at 30 cm;
- fire protection of walls separating the outer walls of profiled metal sheets or asbestos-cement panels with heat insulation from hardly flammable or combustible material or with glazed and not going beyond the outer plane of the wall;
- separation of the outer walls of profiled or asbestos-cement sheets with synthetic insulation from hardly flammable or combustible materials, as well as tape glazing fire walls;
- the amount of the total openings in fire barriers;
- sealing of gaps between MEP systems and fire barriers;
- diaphragms in air gaps between walls and facing of non-combustible materials, as well as in air gaps in wooden coatings and floorings;
- presence of (tambour-gateways, exterior removable frame constructions, their space requirements to the fire code standards, as well as fire resistance and fire spread limits for constructions of tambour-gateways.

6. LOADS AND EFFECTS ON BUILDINGS AND STRUCTURES

The only source of data about loading conditions is the design standards, which don’t give any explanation, but seem reasonable because of frequent use. However, the regulations of different countries often provide enough guidance on the different selection of loads and while working on foreign orders, when these instructions have to be performed, a lot of new issues arise, which are related to the fact that the "usual” domestic rates don’t align with overseas. And the fact of differences between domestic and foreign approach provokes desire to correct "their erroneous point of view", though very convincing arguments may be the basis for this discrepancy.

However, there are scientific monographs devoted to particular kinds of loads, for example wind, but most of them are designed more for the reader-researcher than for the practicing designer. In addition, such books often require specialized knowledge that is missing from the experts with the usual training in civil engineering. Fairly typical is representation of the problem of loads and influences in reference books. Appeared to be a popular handbook of theoretical designer, released in 1960 under the editorship of professor. A.A. Umansky, the section *"Standards of loads and sizes"* disappeared from the second edition of this handbook, published in 1973.

Dynamic loads were luckier, they were adequately presented in three volumes of a handbook, edited by B.G. Korenev and I.M., Rabinovich and A.F, Smirnov. A recent excellent study guide by V.N. Gordeev, *"Loads and influences on buildings and constructions"* was published in Moscow in 2007.

The proposed discipline will be the first attempt of a comprehensive coverage of the issue of loads and influences taken into account when designing buildings and constructions. Principal views of loads and influences are described, including emergency and special load type. For each of the considered loads the description of its physical origin is resulted, and the basic information on characteristic parameters of these loads are supplied. Data from domestic and foreign standard documents are provided and compared.

The purpose of this discipline is to acquaint the future civil engineer (designer) with the properties, methods, definitions and characteristics of interaction with the design loads and influences of various types.

7. DESIGN CODES IN CIVIL ENGINEERING

The proposed discipline is expected to consider the methodology of creating and writing design standards and their application in the design and construction of buildings and constructions. It will also contain a section describing the current state of norm-setting in different countries.

8. MULTIFACTOR STRUCTURAL ANALYSIS

Elastic calculation methods are applied in most cases when calculating the buildings and constructions on operating load. Special effects, including seismic and emergency (such as explosion, impact, etc.) usually cause tension in structures close to the limit, lead to large deformations and displacements, failure of separate elements. Therefore, the calculation must be based on physical, geometric and structural nonlinearities. It should also be noted that almost all the special effects are dynamic. In order to adequately reflect the work of the structures in the calculation of the special effects nonlinear dynamical calculation methods should be applied. First of all it concerns main buildings and facilities constructions: high-rise and wide-span.

9. STRUCTURAL SURVEY AND RESEARCH

The development of this discipline in Russia is very promising, because currently there are practically no specialists able to completely carry out examination and test individual elements of the buildings - slabs, floors, foundations, columns, crossbars.

A survey of building designs of buildings is usually made to find out their bearing ability by identification and testing calculations of designs.

A survey of construction of buildings is necessary under the following circumstances:

- it is planned to increase the load on the floor when the functional purpose of the premises is changed, or the characteristics of the equipment and production modernization are planned;
- it is planned to move partitions (premise re-planning);
- growth of deformations is detected (increase in a deflection of overlapping plates, cracks in wall panels, etc.) and there is no information about bearing ability of structures (it is also unknown under what loading the structure was designed);
- time has come to replace structures (rotten wooden floors in structures of historic building);
- if there is an increase of a building deformation (generally, this means crack formation in the walls), which indicates problems with the foundations;

- if building foundation lifetime is depleted (and foundation reinforcement is scheduled);
- if there are regular roof leaks, wall depressurization, wall blotting or wall freezing;
- if a survey of building engineering network is required in connection with their malfunction.

Technical survey of buildings and constructions is the process of determining (control) technical state of operated building or structure and its components.

Technical survey of buildings and constructions may include:

- instrumental acceptance survey of completed building or capitally repaired structures , as well as reconstructed buildings or constructions; instrumental survey of technical condition of buildings and engineering equipment for maintenance of buildings or constructions;
- technical survey of residential buildings for a planned overhaul, modernization or reconstruction;
- technical survey of buildings and constructions with structural damage and accidents during the operation.

The technical survey of buildings include:

- objectives definition;
- receiving of baseline data from the customer;
- general technical survey of buildings;
- detailed technical survey of buildings;
- preparation of technical conclusion.

The monitoring of correct work or normal functioning of engineering structure or its elements require knowledge of the actual technical state of a building. It always contains a diagnosis of structures. The aim of the full-scale surveys is to obtain reliable data on the technical state of building constructions and engineering systems and identify the reasons behind this situation. The materials from a survey of technical condition of the building help to conclude the conditions of further operation of building elements, the activities to ensure their reliability and durability or replacement.

The need for technical survey of buildings and structures occurs if there is:

- defect or structure damage (e.g., due to stress, corrosion, temperature or other influences, including non-uniform foundation subsidence), which can reduce the strength, deformation characteristics of structures and degrade total operational condition of the building;
- increased operating load or influence on the structure by remodeling, modernizing and increasing the number of building stores;
- reconstruction of buildings, even without increase in load;
- lack of project design and as-built documentation;
- change in building and structure functionality;
- resuming of the interrupted construction in the absence of preservation or after three years after the termination of construction with preservation;
- need to monitor and evaluate the technical state of buildings, located near the newly built structures;
- need to assess the technical state of building structures which were exposed to fire, natural disasters of natural origin or man-made accidents, etc.

REFERENCES

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