Proceedings of the 1st Joint Conference of EUCEET and AECEF
Thessaloniki, Greece, November 12th, 2021

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"THE ROLE OF EDUCATION FOR CIVIL ENGINEERS IN THE IMPLEMENTATION OF THE SDGs"

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INTRODUCTION

In 2015, the United Nations adopted the 2030 Agenda for Sustainable Development – "a plan for people, planet and prosperity", which includes 17 Sustainable Development Goals (SDGs) that service as a roadmap for the national and international policies that should be implemented to achieve a better and more sustainable future for all. Society, Economy and Environment are recognized as the three pillars for sustainable development. After several attempts to identify and agree upon a global policy for a sustainable future, it is time for implementation. It is time now for global Engineers to get involved in order to bring results in the direction of the implementation of the SDGs.

The two European Civil Engineering associations, the European Civil Engineering Education and Training Association (EUCEET) and the Association of European Civil Engineering Faculties (AECEF), joined their forces to investigate the very important issue of "The role of education for Civil Engineers in the implementation of the SDGs". The topics of the conference are related, but not limited, to the following SDGs:

- SDG4 - Quality education
- SDG6 - Clean water and sanitation
- SDG7 - Affordable and clean energy
- SDG8 – Decent work and economic growth
- SDG9 – Industry, innovation and infrastructure
- SDG11 – Sustainable cities and communities
- SDG13 – Climate action
- SDG14 – Life below water
- SDG15 – Life on land

CONTENT

Presentations

Papers

"The role of education for Civil Engineers in the implementation of the SDGs"
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NEW CALCULATION METHODS IN CIVIL ENGINEERING – IMPLICATIONS ON ENVIRONMENT

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Key words: Calculation methods; Results analysis; Project solutions vs environmental repercussions.

ABSTRACT

Paper presents new analysis and calculation processes that gradually came to replace the traditional ones used until almost end of the eighties of the twentieth century. Its use, nowadays widespread, came to gradually replace traditional calculation processes. This transformation may bring consequences to the adequate interpretation of design solutions related with sustainability and environment.

Experiences are analysed in the development of studies and projects in the areas of structures, hydraulics, roads and geotechnics presenting the evolution of different solutions, drawing attention to positive aspects (calculation time and inherent costs), while pointing out fewer interesting aspects inherent fundamentally to the ability to analyse the results obtained by younger civil engineering professionals.

1. INTRODUCTION

In this presentation the author refers to some aspects related to the use of calculation and analysis software used nowadays, focusing mainly on the importance of a careful analysis of the results obtained in order to avoid errors of analysis with repercussions and consequences in environmental and landscape terms.

Naturally, with the exposed in this presentation, we try to avoid the consideration of less correct results by young colleagues.

It was not considered important to carry out an exhaustive referencing of the programmes used.

It was considered important to exemplify with some of the more widespread programmes (and in which the Author has some experience) the correct procedure of analysis of the results obtained.

2. HYDROLOGICAL STUDIES – BUREAUX'S INDOOR PROGRAMS

Sometimes there is a temptation, in view of the existence of more complete series of flows, to consider them instead of shorter series, which are perhaps more appropriate for the quantification of the ecological flow value, which can be evaluated from below.
This is a procedure that may escape a young hydrologist who is more concerned with fitting the calculation programme with a larger number of data and making it 'run' with a view to determining the average annual daily flow and the flood wave, the latter having direct repercussions on the design of the flood spillway.

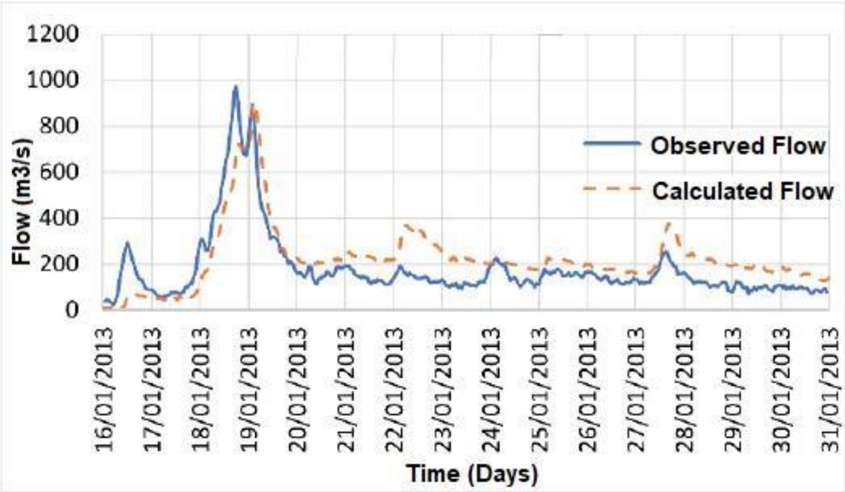

Fig. 1: Observed flow vs Calculated flow

3. FLOOD WAVE STUDIES – "DAMBRK" PROGRAMME – "HEC-RAS" PROGRAMME

The development of flood wave studies using specific calculation programmes (such as DAMBRK or even HECRAS) must always be accompanied by a critical analysis of the territory located downstream of the retaining reservoir.
This critical analysis is essential to be done ''a priori'' so that the singularities of the downstream valley and its occupation are taken into account in the analysis of the results obtained with the calculation programme, in order to avoid an erroneous propagation of the flood wave.
The topography of the site is also very important for a correct interpretation of the flood map.
Another important aspect is the definition (consideration) of the type of breach that depends on the material in which the dam is built: Concrete, Reinforced Concrete, Earth Embankment and Rockfill Embankment.
These are the main questions that may escape a young engineering professional, naturally gifted with a "critical sense" that is only enriched with years of experience in studies of this type.
The conclusions to be drawn can (and have) very important consequences in environmental terms in the Downstream valley area.

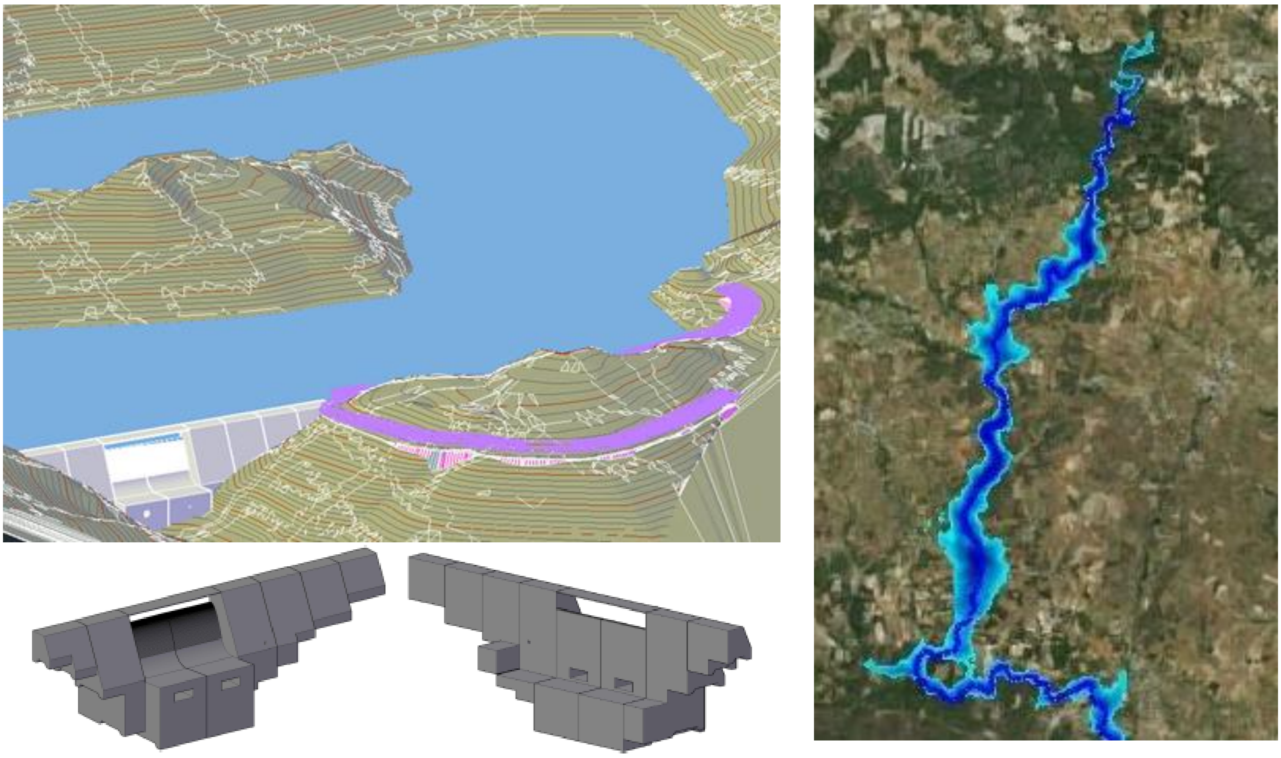

Fig. 2: Calvelhe Dam – Flood Wave Model

4. STUDIES OF NETWORKS (SUPPLY AND IRRIGATION) – INDOOR PROGRAMME OF THE STUDY BUREAUX. "HYTRAN" PROGRAMME

The existing commercial programmes and those of the Study Bureaux indoor programmes applicable to these Projects are very efficient and fast.

Special care and critical sense on the part of users is fundamental for the correct pursuit of the objectives to be achieved, particularly regarding the data input.

It is common to work with the piezometric coordinates $(z + \frac{p}{\gamma})$ of the nodes of the networks or meshes defined.

Professionals with less experience should take special care in the prior analysis of topographic surveys (auxiliary works) in order to fix correctly the position and reference of the axes of the pipes to be designed (z values).

When designing networks and meshes, the load and energy lines are considered in terms of piezometric data $(z + \frac{p}{\gamma})$ and not in terms of altimetric data (z-values), resulting the values established for the piezometric heights $(\frac{p}{\gamma})$, which should comply with the minimum values required, on the assumption that the values of the kinetic heights are negligible in view of the low velocity values to be considered in the pipelines. If such velocity values are achieved, the energy considerations must take into account the correct total energy:

$$E = z + \frac{p}{\gamma} + \frac{U^2}{2g} \quad (1)$$

The young designer should therefore be aware of all this problematic and not take the results obtained lightly, running the risk, if he does not analyse them critically, of being misled, with consequences starting with the dimensions of the trenches which will have environmental consequences.

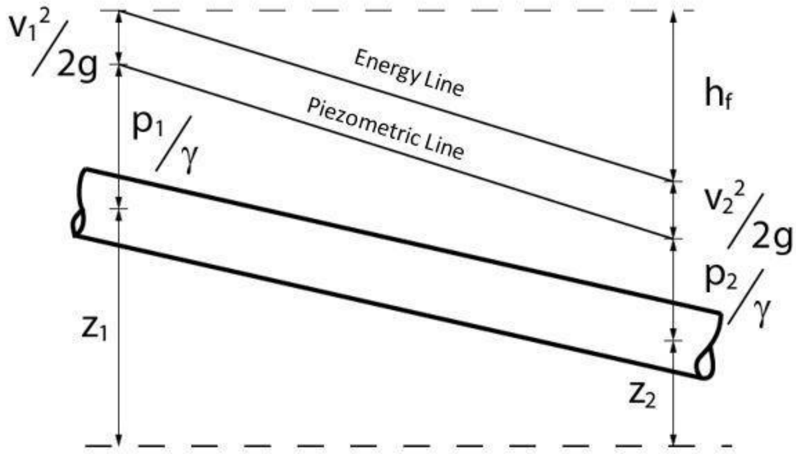

Fig. 3: Energy line – Piezometric line

5. STUDY OF ROADS – CIVIL 3D PROGRAMME. EARTH MOVEMENT. EXCAVATION STUDIES

Often the results obtained with the use of this programme are not properly analysed by young designers who are more concerned with obtaining results quickly, especially with regard to the quantification of earth movement (volumes of excavation and landfills).

In fact, prior to using the programme, a careful analysis of the topographic surveys used must be carried out in order to obtain and somehow understand (foresee) the excavation and landfill areas.

The geotechnical component (the knowledge of the geomechanical characteristics of the massifs to be considered) is also of great importance in these projects. Young designers should take into account geotechnical aspects that will have important repercussions on the proposed support scheme and consequently repercussions in environmental and landscape terms.

In this way it will be easier to carry out the analysis and criticize of the results obtained rather than simply accepting them, which could have negative repercussions in environmental terms.

When it comes to analysing the excavations themselves, regardless of whether it is a Roadway project, the above-mentioned considerations seem equally adjusted and applicable.

Fig. 4: Dargão Stadium Tunnel / Catapereiro Dam – excavations

6. STUDIES OF CURRENT AND SPECIAL STRUCTURES – "ROBOT STRUCTURAL ANALYSIS PROFESSIONAL" PROGRAMME– "VIFEM" PROGRAMME

The traditional structural calculation processes based on Structural Mechanics analysis methods allowed to enhance along its development a better knowledge of the structural functioning by the designer.

However, they were very slow processes which gradually progressed to the final solution of the structural design.

The appearance of commercial programs such as the "Robot Structural Analysis Professional" or even the "indoor" development of structural analysis programs in the engineering bureaux themselves (as the VIFEM program) has enormously reduced the calculation time itself.

The most important and interesting phase corresponds to the design of the calculation model itself. It is not about the input of the data itself and the limit conditions of the structural functioning. Such task however deserves a special care by the designer, particularly in what concerns to Special Structures.
Regarding the results obtained, the respective analysis should always be very careful, so that the dimensioning of the different components of the structure is correct and appropriate to the conditions of global behaviour of the structure.
However, such a careful analysis may often not be done with the necessary depth by young (and therefore less experienced) professionals.
Another aspect that I would like to point out concerns the possible mistakes (errors) in the data input itself, which being a very repetitive and tiring task, may generate wrong results that may not be detected by less experienced young technicians, who are more concerned about minimize their analysis time in order to obtain the final results, which may not be the best ones.


Fig. 5: Belo Jardim (Azores) Thermal Power Plant / Industrial Building (Famalicão) - structures

7. CONCLUSIONS

The main conclusion of the considerations presented is to enable the young civil Engineers to analyse properly the results obtained when operating with the new analysis and calculation processes

IMPROVING QUALITY AND QUALITY ASSURANCE OF ENGINEERING STUDY PROGRAMMES

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Key words: Quality, Qualification Frameworks, Competences, Learning Outcomes, Civil Engineers.

ABSTRACT

Paper addresses the relationship between quality assurance in education and in Civil Engineering in particular and UNSDGs. It presents an overview of methods and practices used to ensure quality in terms of policies, of legislation and of institutional regulations. The question of addressing shifts in teaching methods to focus on students learning is presented and discussed. The engineering programs outcomes are analysed and a presentation is made of indicators of performance for graduates at bachelor and master levels. Based on the analysis of existing professional engineering frameworks some evidences of identified needs for education and training about sustainability are presented and discussed. Coupled with those needs the teaching, learning and assessment modes are linked with sustainability requirements for Civil Engineers.

1. QUALITY AND QUALITY ASSURANCE

The issue of the quality education is certainly an issue on the agenda in Europe and, more generally, in the world. Presenting only three examples to illustrate the relevance of quality in education.

In her ‘Political Guidelines’ [1], Commission President von der Leyen committed to making the European Education Area a reality by 2025. Education is the foundation for personal fulfilment, employability, active and responsible citizenship and the right to quality, together with inclusive education, training and lifelong learning, it is proclaimed in the European Pillar of Social Rights as its first principle. The Union is resetting its growth strategy, based on sustainability, with green and digital transitions as its transformative drivers. Education is at the heart of the European way of life, strengthening social market economy and democracy with freedom, diversity, human rights and social justice.

In the document ‘Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions on achieving the European Education Area by 2025’ of the European Commission [2], the Commission proposes to consolidate ongoing efforts and further develop the European Education Area along six dimensions. The first one regards quality education.

The ‘2030 Agenda for Sustainable Development’ [3] adopted by United Nations establishes ensuring inclusive and equitable quality education, together with and promoting lifelong learning opportunities for all, as one of the 17 Sustainable Development Goals.

In the ISO 9000:2015 norm [4] quality is defined as the “degree to which a set of inherent characteristics of an object fulfils requirements”.

In the context of education programmes, coherently with the ISO definition of quality, for ‘education programme quality’ one should intend the grade (level) of achievement of the educational objectives established coherently. These will comply with the needs and expectations of all those who are interested in the educational service provided, that is the ‘interested parties’ or stakeholders. Therefore, quality of an education programmes depends not only on the achievement of the established educational objectives, but also on the value of the established educational objectives, measured by their consistency with the stakeholders’ needs and expectation.

Quality of training has always been a goal of engineering programmes in general and of those in Civil Engineering in particular. This is fully justified by the role played by Civil Engineering in society. Civil Engineering provides the majority of the infrastructure and significant parts of the public and private facilities that are used in our day-to- day lives. It is the area of engineering that most affects and transforms the physical world and is the backbone of modern living related with, buildings, urban planning, environment and materials, running and clean water, transportation infrastructures. Additionally, most Civil Engineering projects are unique and have a long design life in contrast with the short lifetime/obsolescence of many manufactured products of other engineering fields.

Quality Assurance (QA) is a more recent concept, a consequence of the not yet completed Bologna process. Coherently with the definition of QA established in the ISO 9000:2015 norm [4], for ‘education QA’ one should intend the whole of the activities (processes) for the management of the educational service aimed at achieving the established educational objectives and then at ‘ensuring trust’ in meeting the quality requirements.

Programme QA is essential for the comparability of study programmes, the first objective of the Bologna process in order to establishing the European Area of Higher Education.

In order to establish the European area of higher education and to promote the European system of higher education world-wide – goals of the Bologna process – the ‘Bologna Declaration’ of 19 June 1999 [5] identified six objectives, the first of which is “the adoption of a system of easily readable and comparable degrees”, and in order to be comparable, programmes must have:

- comparable duration, or comparable students’ workloads measured in ECTS credits,
- comparable programme learning outcomes (PLOs), consistent with the PLOs shared at international level, and, last but not least,
- must assure their quality or assure that every effort is made in order to achieve the established PLOs.

Today the definition of suitable academic strategies in order to promote programme quality can rely on the standards and guidelines for internal QA of higher education established in the document Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG 2015) [6]. This document fulfilled another of the objectives of the Bologna process:

"the promotion of European co-operation in quality assurance with a view to developing comparable criteria and methodologies".

The document was prepared by the European Association for Quality Assurance in Higher Education (ENQA) [7] in co-operation with the European Students' Union (ESU) [8], the European Association of Institutions in Higher Education (EURASHE) [9] and the European University Association (EUA) [10]. It was adopted by the Ministers of Higher Education of 45 countries in the meeting in Bergen (Norway) on 19-20 May 2005 and was revised in the meeting in Yerevan (Armenia) on 14-15 May 2015. It has found a generalised acceptance in the European context.

It is important to note that the purpose of these standards and guidelines is to provide a source of assistance and guidance to HEIs in developing their own QA system, as well as to contribute to a common frame of reference, which can be used by institutions. It is not the intention that these standards and guidelines should dictate practice or be interpreted as prescriptive or unchangeable.

Quality Assurance covers all processes for the programme management: from design to delivery, from result monitoring to improvement actions. Among these, the main processes that – in the opinion of the authors – are at the basis of the programme quality regard:

- Design of student-centred study programmes and the definition of PLOs,
- Adoption and implementation of student-centred teaching, learning and assessment approaches,

which, frequently, have not yet achieved a satisfactory implementation at European level.

2. STUDENT-CENTRED PROGRAMMES

The objective of the comparability of the PLOs had (or should have had) as a consequence the necessity of a new approach for designing programmes after the Bologna declaration. The 'pre-Bologna' programmes can be considered as 'input-based' or 'staff-centred'. Such programmes assumed that the proper object of study is what the individual professor thinks the student should learn in his/her course unit. The emphasis was placed on the individual interests of academic staff.

On the contrary, the aim of a student-centred programme is to make students as competent as is feasible in a given timeframe for their future role in society. In these programmes the focus is no more on what a student has been taught, but on what a student has learned and is able to do, that is on competence development and the achievement of intended learning outcomes of the learning process.

Consequently, programmes leading to a bachelor or master degree are no longer to be described and planned solely according to their content, but mainly according to the competences to be developed and obtained by graduates and the programme learning outcomes to be achieved by students at the completion of the educational process.

It should be underlined that competences and learning outcomes are not the same thing.

According to the definition adopted is the European Qualifications Framework for lifelong learning (EQF for LLL) [11], "Competence means the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development”. Learning outcomes are statements of what a learner is expected to know, understand and be able to demonstrate after completion of a learning experience. Consequently, competence can be defined as the ability to use learning outcomes in work or study situations.

It is a fact, however, that at present, Higher Education institutions are still undergoing a transformation process. The traditional approach is slowly giving way to an ‘output-based’, ‘student-centred’ approach, which takes the student as the centre of the teaching and learning process. As Robert Wagenaar, one of the creators of the Tuning project [12], wrote in the Application of the ‘CALOHEE - Measuring and Comparing Achievements of Learning Outcomes in Higher Education in Europe’ project [13]: “ …, we have to conclude that the actual implementation of the competences and LOs based approach at degree programme level, and its underpinning with suitable Teaching, Learning and Assessment (TLA) strategies and methodologies, has had limited success so far in the wider European context.

It is in fact accepted that the modernization process of HE-programmes in Europe and therefore the actual establishment of a single EHEA - notwithstanding the shared architecture -, has made limited progress, after a very promising first phase of six years of developmental activities. Although the architecture seems to be in place in most countries, the actual implementation process and the realization of the expected benefits, have been far from smooth and complete. Rather, in many contexts, actual change in learning teaching and assessment methods and philosophy has met resistance, ...”

3. PROGRAMME LEARNING DESCRIPTORS

To establish PLOs shared at international level is a condition for the comparability of study programmes and for the realization of the Bologna process goal. There is a common understanding throughout the world of what an engineer is supposed to know and be able to do, which probably differentiates engineering from many other disciplines.

Very known frameworks of engineering PLOs, some specific for Civil Engineering, are:

- Tuning-AHELO framework [14];
- EUCEET framework [15];
- EUR-ACE framework [16];
- International Engineering Alliance (IEA) framework [17];
- ABET framework [18];
- Conceiving, Designing, Implementing, Operating (CDIO) Initiative framework [19];
- National Society of Professional Engineers framework [20];
- American Society of Civil Engineering (ASCE) framework [21].

As a matter of fact, the PLOs defined in these frameworks are more ‘descriptors’ of learning outcomes than ‘learning outcomes’. In fact, they do not correspond to the requirements that should be fulfilled by ‘learning outcomes’ according to the current literature.

At the European level, the EUR-ACE programme outcomes (POs) were re-defined by the European Network for Accreditation of Engineering Education (ENAEE) in the document EUR-ACE Framework Standards and Guidelines (EAFSG) [16] and were approved by the Administrative Council of the European Network for the Accreditation of Engineering Education (ENAEE) on March 2016. These POs are the basis for a European mutual recognition agreement, currently developed under the framework of ENAEE. EUR-ACE programme outcomes (POs) and corresponding accreditation criteria have been integrated into national learning outcomes and accreditation requirements of fifteen countries signatories of the Bologna process: Finland, France, Germany, Ireland, Italy, Kazakhstan, Poland, Portugal, Romania, Russia, Slovakia, Spain, Switzerland, Turkey and UK.

A revision and an updating of the EUR-ACE POs was made in the context of the CALOHEE project [13]. The revision is based on an interesting merge of the two European overarching qualification frameworks: the European Qualification Framework for lifelong learning (EQF) [11], which identifies three dimensions ('Knowledge', 'Skills' and 'Competence', where competence is described in terms of responsibility and autonomy), and the Framework for Qualification of the European Higher Education Area (QFHEA) [22], that identifies five dimensions ('Knowledge and Understanding', 'Applying Knowledge and Understanding', 'Making Judgements', 'Communications Skills', 'Learning Skills'). The revision assumes the EQF as the reference framework and asks to provide evidence, for each of the LO of the SQF dimensions, associated to the QF framework, the 'content' in knowledge, in skills and in autonomy and responsibilities.

As in the EUR-ACE POs, the main difference between the descriptors at Master and Bachelor level regards the typology of problems / products, processes and systems / issues / activities that can be solved / designed / investigated / conducted.

At Bachelor level the engineering problems / products, processes and systems / issues / activities that can be solved / designed / investigated / conducted are problems / etc. in the field of study defined as 'complex', where complex means problems / etc. that cannot be solved / etc. without:

- knowledge and understanding of mathematics, sciences and engineering disciplines underlying engineering specialisation, and/or
- knowledge and understanding that support solving of engineering problems, designing of engineering products, processes and systems, investigation of engineering issues, conducting engineering activities and/or
- knowledge and understanding of engineering practice.

At Master level the engineering problems / products, processes and systems / issues / activities that can be solved / designed / investigated / conducted are complex problems / etc. in the field of study that may be new or unfamiliar, involve considerations from outside the field of study, incompletely defined and /or conflicting issues and non-technical constraints, and require original/innovative thinking.

These definitions are consistent with the statements of the EQF at levels 6 and 7 and with the statements of the QF for the first and second cycle of the Bologna system.

It seems to be important to note that the definition of complexity here adopted differs from the definition adopted in the context of the International Engineering Alliance [17], for which complex problems and complex activities correspond to problems and activities that in the European system can be dealt with only at Master level.

The revised learning outcome descriptors are shown in Annex 1.

3.1. Contextualization of Programme Learning Descriptors

The definition of PLOs requires the contextualization of the proposed learning outcome descriptors.

Literature is rich of suggestions for the formulation of PLOs.

A common requirement is that PLOs are S.M.A.R.T.:

- Specific: they should adequately reflect the context, level, scope and content of the programme;
- Measurable: they should be properly detailed in order to favour the understanding of the depth and extent of expected learning and objectively assessable in terms of what the student has actually achieved at the end of the programme;
- Achievable: consistent with the institutional context and the available resources;
- Relevant: only the learning outcomes necessary to fulfil the programme educational objectives should be established at programme level;
- Time-bound: plannable and achievable within the specified workload.

A set of valid and synthetic guidelines are those provided by the ECTS Users' Guide 2015 [23]:

"A widely accepted way of formulating learning outcomes is based on three essential elements:

1. Use an active verb to express what students are expected to know and be able to do (e.g. graduates can 'describe', 'implement', 'draw conclusions', 'assess', 'plan').

2. Specify what this outcome refers to (object or skill e.g. can explain the 'function of hardware-components', or can present the 'design of a living-room by hand').

3. Specify the way of demonstrating the achievement of learning outcomes (e.g. 'to give an overview of the materials most often used in electro-engineering'; 'to develop a research design by applying up-to-date scientific methods', etc.)".

Regarding the use of active verbs a frequent reference is Bloom's taxonomy revised by Anderson et al. [24].

Contextualization of outcomes' objects, i.e. Civil Engineering problems/products, processes and systems/issues/activities to be solved/designed/investigated/conducted depends on the specialization, and the way of demonstrating the achievement of POs is related with type of outcomes.

Traditionally, Civil Engineering is a professional engineering discipline that deals with the design, construction, and maintenance of the physical and naturally built environment, including works like buildings, bridges, canals, dams and roads. There are several specializations, like construction, hydraulics, structures, etc. Several other specializations were created within Civil Engineering and have gained independent status like Mining and Mechanical.

It is a fact, however, that the labour market has acquired in recent years extreme dynamism and variability, due to the need to respond effectively to the challenges posed by social, productive, environmental and, ultimately, increasingly complex and interconnected health care. Furthermore, Civil Engineering work has an inherently high degree of complexity, where non-engineering issues dealing with social, political, economic and environmental concerns, as ethical issues, have become far more important than previously, with the emerging of new fields of activity such as Urban and Environmental Planning, Strategic Environmental

Assessment, Economic Evaluation of Projects and so on. Also, sustainability calls for Civil Engineers to be leaders.

The 2030 Agenda for Sustainable Development [3] establishes several goals that require or may require specific skills of Civil Engineering for their achievement. A list of these goals and associated targets is given in Annex 2.

In this context, typical Civil Engineering problems/products, processes and systems/issues/activities graduates in Civil Engineering should be able to solve/design/investigate/conduct are:

- Civil & Industrial Buildings; Bridges; Reinforced Concrete Dams; Metallic Structures; Brick and Timber Constructions;
- Roads; Railways; Airports; Ports; Interconnecting infrastructures; Cableways;
- Hydraulic Constructions; Water Supply and Sewage Systems; Works for Hydraulic Protection of the Territory; Waste Disposals and Sanitation Works;
- Foundations; Retaining Structures; Earthworks; Underground Works; Artificial and Natural Slopes;
- Information Technologies in Civil Engineering.

4. STUDENT-CENTRED TEACHING, LEARNING AND ASSESSMENT

The development of meaningful and measurable PLOs for engineering programmes is critical to the systematic improvement of the educational experience for engineering students, but it is not sufficient. PLOs must be taught and learned and the level of their achievement assessed. The adoption of appropriate teaching and learning methods or modes and of accurate assessment tools is equally critical.

Although the use of the LOs approach seems to have been implemented widely in the engineering domain, this does not imply that applied teaching, learning and assessment strategies are appropriate to this approach, especially to promote the fulfilment of the autonomy and responsibility requirements necessary for the carrying out of the role of Civil Engineers in the society.

Indeed, particularly in the last decade, there is increasing recognition of the difficulties faced by engineering schools around the world in order to be able to meet the needs of a rapidly changing society and posing global challenges such as digital transformation, environmental and economic sustainability, new globalisation, protection and protection of health [25]. In the context of these challenges, the role of engineering must be to imagine, implementing and managing the technical infrastructure for sustainable change and therefore the training and qualification of engineers of the future plays a central role in building the knowledge society [26].

The centrality of the role of the engineer in this process of change has required a reflection on the possible disparity between the need that the society expresses in relation to a modern figure of engineer who knows how to support and promote the change and the whole of the skills that students develop during their training in engineering schools. In summary, a thorough reflection on training models in the field of engineering was necessary and appropriate. The result of this reflection was the recognition that student-centred programmes based on the development of competencies, measured in LOs, require other methodologies and strategies than more traditional, staff-centred degree programmes.

Indeed, as acknowledged in the EUA's report 'Student-centred learning: approaches to quality assurance' [27], today "there is a widely accepted paradigm shift from teaching to learning. … This approach, which is commonly referred to as 'student-centred learning', stipulates that education provision and all its aspects are defined by the intended learning outcomes and most suitable learning process, instead of the student's learning being determined by the education provided. Recent evidence [28] and European Commission/EACEA/Eurydice, 2018 [29] attests that there is widespread will across European higher education to focus more on the student learning experience and to back this up with the necessary changes in policy and practice".

The central function of student-centred learning for the development of high-quality education is also highlighted by standard '1.3 Student-centred learning, teaching and assessment' in the ESG 2015 [6]. Accordingly, "Institutions should ensure that the programmes are delivered in a way that encourages students to take an active role in creating the learning process, and that the assessment of students reflects this approach". The introduction of this standard was one of the major novelties of the to reflect the changing higher education landscape.

4.1. Teaching & Learning

The Guidelines associated to Standard 1.3 of the ESG 2015 explain why the standard is important and describe how might be implemented.

Some of them promote the flexibility of the teaching and learning process:

- "respects and attends to the diversity of students and their needs, enabling flexible learning paths";
- "considers and uses different modes of delivery, where appropriate";
- "flexibly uses a variety of pedagogical methods";
- "regularly evaluates and adjusts the modes of delivery and pedagogical methods".

Others stimulate students' engagement in the teaching and learning process:

- "encourages a sense of autonomy in the learner, while ensuring adequate guidance and support from the teacher";
- "promotes mutual respect within the learner-teacher relationship".

Students should be considered partners of the teacher in the teaching process and actors, not passive subjects, in the learning process. Therefore, it is a clear evidence that a wide variety of educational tools need to be used to achieve the desired LOs.

An investigation of the teaching and learning activities through which the LOs could be achieved by students who are attending a Civil Engineering degree programme at their institution was carried out in the context of the CALOHEE project [13].

Below is the list of the identified methods:

- Lectures;
- Seminars;
- Tutorials;
- Flipped classroom;
- Blended learning;
- Exercise courses / Practical classes;

- Oral assignments;
- Written assignments;
- Investigation assignments;
- Laboratory assignment;
- Numerical modelling assignment;
- Problem-based learning;
- Design-based learning;
- Work-based practice (internship/traineeship);
- Fieldwork;
- Role play;
- Peer reviewing;
- Individual supervision.

Among these, Design-Based Learning (DBL), as well as Problem-based learning, appears as a very interesting collaborative approach to successfully teach and learn (and asses) key learning outcomes in engineering. DBL is conceived as 'an educational model in which a major part of the curriculum and study programme is aimed at learning to design in engineering'. In DBL, not only are the resulting products important, also the underlying process is highly relevant. DBL explicitly involves a form of university education giving academic skills a prominent position. These would include strategic thinking regarding activities, critical analysis of design tasks, broad interpretation of design requirements, incorporation of contemporary scientific views, etc.

DBL could be characterised particularly as integrative, multidisciplinary, practice-oriented, creative, cooperative (teamwork), competence-oriented (skills), activating, fostering responsibility, synthesising, and leading to professionalization. In DBL, once the design task is set, the teacher transfers all authority to (a group of) students. The students' tasks are open-ended and students become actively involved in defining design questions in their own language and working out solutions together instead of reproducing material presented by the teacher or the textbook. It is believed that students are truly thinking critically when they formulate their own constructs and solutions. By making use of DBL, students are stimulated to develop higher level thinking skills, gain a positive attitude toward the subject matter, practice modelling societal and work-related roles, and generate more and better design questions and solutions. DBL is assumed to increase knowledge retention, develop students' general problem-solving skills, improve integration of basic science concepts into real-life problems, stimulate the development of self-directed learning skills, and strengthen intrinsic motivation».

Independently from the educational activity involved, an 'active learning' approach should always be pursued. Students need an intellectually stimulating, inductive, and co-operative leadership environment in order to be more engaged in the learning experience. To this regard, active, collaborative learning approach appears particularly effective.

Finally, the role of innovative educational technologies can play a part in the effectiveness of the learning and enhancing the transmission of knowledge. It thus becomes strategic also a continuous motivation of teachers towards new approaches and tools.

By the way, it must also be said that many engineering faculty members enter the education environment with little or no understanding of desired LOs or how to design and execute a learning experience for such outcomes to be achieved. Institutions should create a supportive environment for education innovation and consider strengthening faculty development programmes so faculty members may be more familiar with desired LOs and therefore carry out their duties more effectively.

4.2. Assessment

As for teaching and learning, also for the assessment of the LOs' achievement there is a variety of methods that can be used.

There have been initiatives to find proper assessment methods for the different types of LOs. An interesting classification of them, based on the Bloom's taxonomy revised by Anderson et al. [24], was the one proposed by the ALOE Model [30] for the Alignment of Learning Outcomes and Assessment, specifically developed for engineering programmes, which identifies the assessment methods listed below:

1. Multiple Choice Questions (MCQ): Remember, Understand, Apply, Analyse, Evaluate and Create.
2. Essays: Speculative essay, Quote to discuss, Assertion, Write on, Describe/Explain, Discuss, Compare, Evaluate and Problem.
3. Problem solving: Routines, Diagnosis, Strategy, Interpretation and Generation.
4. Practical work: Demonstration, Exercise, Structured enquiry, Open-ended enquiry and Project
5. Short-answer questions: Select crucial evidence, Explain methods, procedures and relationships, Present arguments, Describe limitations of data, Formulate valid conclusions, Identify assumptions, Formulate hypothesis and Formulate action plans.
6. Reflective Practice Assignments: Concrete experience, Reflective observation, Abstract conceptualization and Active experimentation.

The assessment is mostly by written or oral end-of-semester examination, often supplemented by mid-term examinations, homework exercises, and where relevant project assignments and programming assignments. If end-of-semester examinations are the sole assessment there is of course less feedback, and therefore less opportunity to learn through assessment, available to the students. It has been noted that shortcomings in students' understanding of what is required of them often only becomes apparent at the time of assessment.

Final year projects and second cycle dissertations have feedback built in as part of the supervision process. Some students perform better in this situation than in the traditional examination format. They also afford the opportunity to assess the acquisition of the generic and subject-specific competences for each cycle.

LOs, especially when mapped to specific educational experiences, can also be used by students to assess their own progress. A valuable tool in this regard is e-portfolios, which may be used by both students and their teachers to assess knowledge, skills and attitudes in engineering. In addition to the standard, summative teacher-course evaluations, face-to-face interactions between students and 'trusted' advisors can be used to obtain more detailed information regarding the 'success' of the education experiences.

Independently by the assessment method and process, Guidelines associated to Standard 1.3 of the ESG 2015 clearly specify what should be the objective of students' learning assessment:

- "the assessment allows students to demonstrate the extent to which the intended PLOs have been achieved"

and state that:

- "the criteria for and method of assessment as well as criteria for marking are published in advance".

Assessment methods include the whole range of tests that are used to evaluate the student's progress and ascertain the achievement of the learning outcomes of a course unit or module, whereas assessment criteria are descriptions of what the student is expected to do, in order to demonstrate that a learning outcome has been achieved.

In order to be appropriate, the assessment methods and criteria chosen for an educational component have to be consistent with the learning outcomes that have been defined for it and with the learning activities that have taken place.

5. CONCLUSIONS

Creating and implementing a learning outcome approach is not easy. Given governments' authority over educational issues, much depends on local conditions and cultural settings. Local and national autonomy influence how learning outcomes might be best introduced in practice with the appropriate mix of top-down and bottom-up measures. Learning outcomes are often viewed as a threat that will streamline education and limit academic freedom. The concept of learning outcomes within the field of engineering, on the other hand, has proven to be well-established and has been welcomed by most stakeholders.

Engineers have an easier task than other disciplines, as in Europe and throughout the world there is a great degree of consensus concerning what an engineer is supposed to know and be able to do. It is opinion of the author that the systems of learning outcomes for the engineering domain and then for the Civil Engineering subject domain, should start from the EUR-ACE programme outcomes. These combine EQF for LLL and QF-EHEA approaches and are consistent with the most influential learning outcomes frameworks in the engineering field and can be a useful reference for the definition of engineering LOs at national level in the European countries and in other areas of the world.

Adoption of active teaching and learning approaches and of problem-based/design-based teaching and learning methods have to be taken into account as essential in order to promote the fulfilment of the autonomy and responsibility requirements necessary for the carrying out of the role of civil engineers in the society.

At the same time, the adoption of methods of assessment of the student leaning able to assess the level of achievement of the learning outcomes – issue still object of debate at international level – is considered essential in order to assure the quality of education.

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Annex 1 - Programme Learning Descriptors for Engineering Degree Programmes

Programme Learning Descriptors for Engineering Bachelor Degree Programmes

Learning Areas	Programme Learning Descriptors		
	Content in Knowledge and Understanding	**Content in Skills**	**Content in Autonomy and Responsibility**
1. Knowledge and Understanding	Demonstrate knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying Civil Engineering specialisation at a level necessary to achieve the other programme outcomes.	Apply knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying Civil Engineering specialisation to solve / design / investigate / conduct complex Civil Engineering problems / products, processes and systems / issues / activities.	Identify knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying Civil Engineering specialisation necessary to solve / design / investigate / conduct complex Civil Engineering problems / products, processes and systems / issues / activities.
2. Analysis and Problem Solving	Demonstrate knowledge and understanding of the processes and established methods of analysis / solution of engineering issues (products, processes, systems, situations) / engineering problems in the Civil Engineering subject area and of their limitations.	Analyse / solve complex engineering issues (products, processes, systems, situations) / engineering problems in Civil Engineering subject area by applying appropriate and relevant established methods of analysis / solution.	Identify appropriate and relevant established methods of analysis / solution of complex Civil Engineering issues (products, processes, systems, situations) / engineering problems.
3. Design	Demonstrate knowledge and understanding of the process and established methods of design in Civil Engineering subject area and of their limitations.	Design complex Civil Engineering products (devices, artefacts, etc.), processes and systems by applying appropriate and relevant established design methods.	Identify appropriate and relevant established design methods of complex Civil Engineering products (devices, artefacts, etc.), processes and systems.
4. Investigations	Demonstrate knowledge and understanding of codes of practice and safety regulations and of investigation methods (consultation of sources of information, simulations, experimental methods) in	Consult and apply codes of practice and safety regulations and conduct investigations (consultation of sources of information, simulations, experimental methods) in Civil Engineering subject	Identify appropriate and relevant investigation approaches (among codes of practice and safety regulations, consultation of sources of information, simulations, experimental methods) in

	Civil Engineering subject area and of their limitations.	area in order to meet specified needs and report the investigation results.	Civil Engineering subject area and analyse, explain and interpret the investigation results with respect to the needs to be met.
5. Practice	Demonstrate practical knowledge and understanding of materials, equipment and tools, processes and technologies in Civil Engineering subject area and of their limitations.	Conduct complex engineering activities in Civil Engineering subject area, using and applying practical knowledge and understanding of materials, equipment and tools, processes and technologies.	Identify practical knowledge and understanding of materials, equipment and tools, processes and technologies necessary to conduct complex engineering activities in Civil Engineering subject area.
6. Decision Making	Demonstrate awareness of the key aspects of professional, ethical and social responsibilities linked to management of Civil Engineering activities, decision making and judgment formulation.	Manage work contexts in Civil Engineering subject area, take decisions and formulate judgments.	Identify appropriate and relevant approaches to manage work contexts in Civil Engineering subject area and reflect on professional, ethical and social responsibilities in taking decisions and formulating judgments.
7. Team-working	Demonstrate knowledge and understanding of functioning methods of teams that may be composed of different disciplines and levels.	Function effectively in national and international contexts as member of teams that may be composed of different disciplines and levels contributing to meet deliverable, schedule and budget requirements.	Identify appropriate functioning methods and relevant management strategies of teams that may be composed of different disciplines and levels and elements of successful teamwork.
8. Communication	Demonstrate knowledge and understanding of established communication methods and tools and of their limitations.	Communicate effectively, clearly and unambiguously information, describe activities and communicate their exits/results to engineers or wider audiences in national and international contexts, using appropriate established communication methods and tools.	Identify appropriate and relevant established communication methods and tools.
9. Lifelong Learning	Demonstrate knowledge and understanding of the learning methods	Engage in independent lifelong learning and follow developments in	Identify appropriate learning methods in independent lifelong

	necessary to follow developments in science and technology in Civil Engineering subject area.	science and technology in Civil Engineering subject area autonomously.	learning to follow developments in science and technology in Civil Engineering subject area.

*** Complex engineering problems / products, processes and systems / issues / activities**
Problems / products, processes, systems / issues / activities that cannot be solved / designed / investigated / conducted without:

- knowledge and understanding of mathematics, sciences and engineering disciplines underlying engineering specialisation, and/or
- knowledge and understanding that support solving of engineering problems, designing of engineering products, processes and systems, investigation of engineering issues, conducting of engineering activities and/or
- knowledge and understanding of engineering practice.

Programme Learning Descriptors for Engineering Master Degree Programmes

Learning Areas	Programme Learning Descriptors		
	Content in Knowledge and Understanding	**Content in Skills**	**Content in Autonomy and Responsibility**
1. Knowledge and Understanding	Demonstrate in-depth knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying Civil Engineering specialisation at a level necessary to achieve the other programme outcomes.	Apply knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying Civil Engineering specialisation to solve / design / investigate / conduct very complex Civil Engineering problems / products, processes and systems / issues / activities.	Identify and justify knowledge and understanding of mathematics as well as sciences and engineering disciplines underlying Civil Engineering specialisation necessary to solve / design / investigate / conduct very complex Civil Engineering problems / products, processes and systems / issues / activities.
2. Analysis and Problem Solving	Demonstrate comprehensive knowledge and understanding of the processes and methods of analysis / solution of engineering issues (products, processes, systems, situations) / engineering problems in the Civil Engineering subject area, including new and innovative	Analyse / solve very complex engineering issues (products, processes, systems, situations) / engineering problems in Civil Engineering subject area by applying appropriate and relevant methods of analysis / solution.	Identify and justify appropriate and relevant methods of analysis / solution of very complex Civil Engineering issues (products, processes, systems, situations) / engineering problems from established or new and innovative methods.

	methods, and of their limitations.		
3. Design	Demonstrate comprehensive knowledge and understanding of the process and methods of design in Civil Engineering subject area, including new and original methods, and of their limitations.	Conceive and design very complex Civil Engineering products (devices, artefacts, etc.), processes and systems by applying appropriate and relevant design methods.	Identify and justify appropriate and relevant design methods of very complex Civil Engineering products (devices, artefacts, etc.), processes and systems from established or new and innovative methods.
4. Investigations	Demonstrate comprehensive knowledge and understanding of codes of practice and safety regulations and of investigation methods (consultation of sources of information, simulations, experimental methods) in Civil Engineering subject area, including new and original emerging methods, and of their limitations.	Consult and apply codes of practice and safety regulations and conduct investigations (consultation of sources of information, simulations, experimental methods) in Civil Engineering subject area and within broader or multidisciplinary contexts in order to meet specified needs and report the investigation results.	Identify and justify appropriate and relevant investigation approaches (among codes of practice and safety regulations, consultation of sources of information, simulations, experimental methods) in Civil Engineering subject area and within broader or multidisciplinary contexts, and analyse, explain and critically evaluate the investigation results with respect to the needs to be met.
5. Practice	Demonstrate comprehensive practical knowledge and understanding of materials, equipment and tools, processes and technologies in Civil Engineering subject area and of their limitations.	Implement and conduct complex engineering activities in Civil Engineering subject area and within broader or multidisciplinary contexts, using and applying practical knowledge and understanding of materials, equipment and tools, processes and technologies.	Identify and justify practical knowledge and understanding of materials, equipment and tools, processes and technologies necessary to conduct complex engineering activities in Civil Engineering subject area and within broader or multidisciplinary contexts.
6. Decision Making	Demonstrate critical awareness of the key aspects of professional, ethical and social responsibilities linked to management of work contexts, decision making and judgment formulation in Civil	Manage work contexts in Civil Engineering subject area and within broader or multidisciplinary contexts that may be unpredictable and require new strategic approaches, take	Identify ad justify appropriate and relevant strategic approaches and analyse professional, ethical and social responsibilities linked to the management of work contexts in Civil Engineering subject area

	Engineering subject area.	decisions and formulate judgments.	and within broader or multidisciplinary contexts, taking coherent decisions and formulating coherent judgments.
7. Team-working	Demonstrate knowledge and understanding of functioning methods and management strategies of teams that may be composed of different disciplines and levels and awareness of leadership responsibilities.	Function effectively in national and international contexts as member/leader of teams that may be composed of different disciplines and levels meeting deliverable, schedule and budget requirements.	Identify ad justify appropriate and relevant functioning methods and management strategies of teams that may be composed of different disciplines and levels and elements of successful teamwork.
8. Communication	Demonstrate knowledge and understanding of communication strategies, methods and tools, including new and innovative ones, and of their limitations.	Communicate effectively, clearly and unambiguously information, describe activities and communicate their exits/results – and the knowledge and rationale underpinning these – to specialist and non-specialist audiences in national and international contexts and society at large, using appropriate communication strategies, methods and tools.	Identify and justify appropriate and relevant communication strategies, methods and tools from established or new and innovative ones.
9. Lifelong Learning	Demonstrate knowledge and understanding of the learning methods necessary to follow developments in science and technology and undertake further studies in new and emerging technologies in Civil Engineering subject area and within broader or multidisciplinary contexts.	Engage in independent lifelong learning and follow developments in science and technology and undertake further studies in new and emerging technologies in Civil Engineering subject area and within broader or multidisciplinary contexts autonomously.	Identify and justify appropriate learning strategies and methods in independent lifelong learning to follow developments in science and technology and undertake further studies in new and emerging technologies in Civil Engineering subject area and within broader or multidisciplinary contexts.

* **Very complex engineering problems / products, processes and systems / issues / activities**

Problems / products, processes and systems / issues / activities that cannot be solved / designed / investigated / conducted without:

- knowledge and understanding of mathematics, sciences and engineering disciplines underlying engineering specialisation, and/or
- knowledge and understanding that support solving of engineering problems, designing of engineering products, processes and systems, investigation of engineering issues, conducting engineering activities and/or
- knowledge and understanding of engineering practice,

and that may be unfamiliar or new, involve considerations from outside the field of study, incompletely defined and/or conflicting issues and non-technical constraints, and require original/innovative thinking.

Annex 2 - Goals and associated targets requiring Civil Engineering competences for their achievement

Goal 6. Ensure availability and sustainable management of water and sanitation for all

6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.

6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.

6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.

Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all

7.b By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States and landlocked developing countries, in accordance with their respective programmes of support.

Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

9.1 Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all.

9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities.

9.5 Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending.

9.a Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing States.

9.b Support domestic technology development, research and innovation in developing countries, including by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities.

Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable

11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums.

11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons.

11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries.

Goal 13. Take urgent action to combat climate change and its impacts

13. Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries.

13.2 Integrate climate change measures into national policies, strategies and planning.

Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development

14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans.

Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements.

15.2 By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally.

15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world.

15.4 By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development.

NATURE OF SERINA'S PROJECT RELATED WITH 2016 PORTO DECLARATION AND LINKED TO UNITED NATIONS SDGS

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Key words: SERINA, UNSDG, Fundamental Human Need, Declaration, Porto

ABSTRACT

SERINA (Sustainable Engineering Education, Research in Active Practice) is a global engineering education initiative [1], which stems from the organisation's Porto Declaration in May 2016 [2], being a pledge by members to seek solutions to 21st Century Grand Challenges threatening survival. Launched in Monterey Mexico in May 2018, SERINA is an online portal dedicated to the support and promotion of engineering education and research that best demonstrates or seek to demonstrate active practices of sustainability and engagement within the communities that the initiatives aspire to serve. This paper highlights the origins of SERINA as a research and educational project. It focuses on a number of UNSDG [3] Engineering initiatives and practices and on meeting a set of nine principles of Fundamental Human Needs [4]. These initiatives and practices were initially based on research centred on the signatories of the Porto Declaration. Then SERINA project has highlighted, over the last three years, by creating a archive of engineering focused projects from around the world.

In this paper it is underlined how these sustainable initiatives linked to the UNSDGs also comply with Humanity fundamental needs [5]. SERINA project has been creating a database of education, research and active practices related with engineering education and with continuing professional development that may be useful to those interested in ensuring a hopeful future to all and trying to promote UNSDGs practice within their projects and actions.

1. INTRODUCTION

Building the framework (SERINA) interconnected to the United Nations seventeen Sustainable Development Goals (UNSDGs) and to the nine principles of Fundamental Human Needs (FHN) has been a five-year journey. The seed and catalyser of the SERINA project was underpinned by the 2016 Porto Declaration.

Porto Declaration originated during the 15th World Conference of Continuing Engineering Education of 2016 where signatories assumed the need to take action to keep the unique Earth where we all live. The pledge was seriously assumed by conference participants after several sessions of debate and of consensus about the redaction and about the awareness that engineering education and continuing engineering education can make a substantial difference in the future of the World (Figure 1).

The text of the Porto declaration states:

"-Whereas International Association for Continuing Engineering Education (IACEE) was founded in 1989 to foster a global network of organizations promoting lifelong engineering education.

- Whereas IACEE recognises the scale and complexity of the gap between existing solutions and the needs facing our planet and that the IACEE is uniquely placed to act on this opportunity.

- Whereas IACEE seeks to pivot the organisation to connect individuals, universities, industry, government and NGO organizations to meet the grand challenges facing humanity.
Now therefore in keeping with its dedication to leading lifelong learning, the IACEE will develop global initiatives to address those 21st century challenges threatening the survival of humankind through collaboration, design, creative thinking and engineering.
We the undersigned do hereby declare this at the IACEE 2016 Global Conference in Porto Portugal and pledge our commitment in actioning this call to service."

Fig. 1: Signatories of Porto Declaration, Porto, Portugal, 20 May 2016.

Therefore, SERINA project started with recognizing scale and complexity of the gap existing between current solutions and the needs facing our planet concerning worldwide sustainability and the challenges of climate change. The intent was that SERINA could contribute to act on seeking to pivot itself and other organizations to connect individuals, universities, industry, government and NGOs in meeting the grand challenges facing humanity and our world (Figure 2).

Fig. 2: Engineering responsibility.

2. METHODOLOGY

In keeping with its dedication to engineering education and lifelong learning SERINA has focused on and will continue to focus on engineering education, on continuing professional development, on research and on active practice. Encouraging the adoption of proper engineering practices by active engineers in decision-making functions can contribute to global initiatives addressing the twenty-first century challenges threatening the survival of humankind and of the world inhabitants (Figure 3).

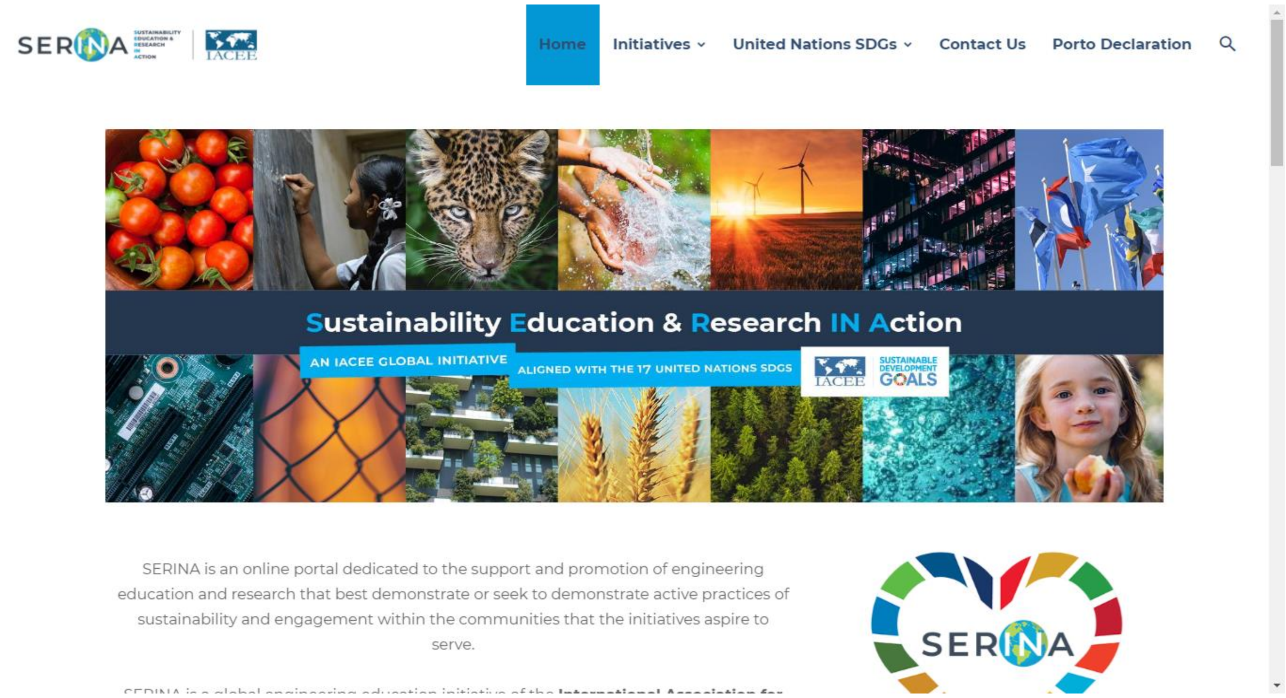

Fig. 3: SERINA website print screen.

SERINA implementation and research has found there is evidence of significant activities in engineering sustainability initiatives taking place around the world, many of which involved the active practice of sustainable engineering and too continuing engineering education. The process followed by SERINA management is composed by the following steps:

1. Access the websites active on continuing engineering education and on engineering education to identify sustainable initiatives.
2. Initiatives are intended for classification in accordance with UNSDGs and with the nine criteria of the Fundamental Human Needs.
3. Choose most relevant sustainability examples and place these on the SERINA website portal.
4. SERINA posts are created weekly from internet searches using relevant keywords.
5. Posts are classified in accordance with the topics of UNSDGs: 1. End Poverty, 2. Zero Hunger, 3. Good Health and Well-Being, 4. Quality Education, 5. Gender Equality, 6. Clean Water and Sanitation, 7. Affordable and Clean Energy, 8. Decent Work and Economic Growth, 9. Industry, Innovation, and Infrastructure, 10. Reduce Inequality, 11. Sustainable Cities and Communities, 12.

Responsible Consumption and Production, 13. Climate Action, 14. Life below Water, 15. Life on Land, 16. Peace, Justice and Strong Institutions and 17. Partnerships for the Goals.
6. The nine criteria of Fundamental Human Needs [4] are also applied in the classification of each post: 1. Subsistence, 2. Protection, 3. Understanding and Meaning, 4. Participation, 5. Identity, 6. Idleness, 7. Creation, 8. Identity and 9. Freedom.
This systematic approach facilitates the information search for website users and promotes interaction with the initiatives. The platform is also available on social media like Facebook and LinkedIn. The collateral benefits of SERINA platform are to provide solutions for sustainability problems, to highlight case studies and examples, to encourage stakeholders, to support engineers and organizations looking for possible tools and techniques and to grow the work done by society while facing this challenge. It is a website which can reach practically all levels of people and organisations throughout the world to empower and inspire others to do the same.

3. RESULTS

Engineering Education (EE) and Continuing Engineering Education (CEE) are crucial in handling the scale and complexity of the gap between existing solutions and the needs facing our planet. Engineers are uniquely placed to act on this opportunity. Lifelong learning has developed and can continue to develop global initiatives to address those twenty-first century challenges threatening the survival of human kind through collaboration, design, creative thinking and engineering. SERINA implementation has shown that it may motivate the engineering community and influence a majority of stakeholders to engage with a framework of global sustainable development.
EE and CEE can influence in the short term the involvement of the engineering community and related sectors to a global commitment in implementing this call to service. This change and improvement can be mostly achieved via education and training of the engineering community around the world, as engineers and related stakeholders have a major influence in the world's development. It is crucial that within a global and international arena that engineers engage in sustainable measures to ensure a future for the world. SERINA and the Porto Declaration can act as beacon and motivation for all and especially for active engineers and for future engineers. The contribution of these initiatives can arise from examples of related activities, the role of online learning in CEE sustainable courses, some guidelines for online sustainable courses and the provision of training and education for a sustainable world.
Engineers in some countries have compulsory periodic CEE and continuing professional development (CPD) to keep their status as engineers [6], [7]. Professional organizations, government agencies, companies, non-governmental organizations and policy makers can transform the competences of active engineers through CPD and CEE to include those related with sustainability. The transformation can be achieved by legislation, by incentives (time or money), by awareness campaigns or by creation of available modules. Engineers are used to attend this type of training given the fact that their profession is evolving constantly (Figure 4).

Fig.4: Continuing Engineering Education session.

A possible incentive to engage active engineers in CPD and in CEE on topics of sustainability can be the recognition of qualifications on sustainability. The title of sustainable engineer maybe awarded to those willing to be trained. The title could bring prestige to the engineer, higher employability and increase in salaries. This CPD and CEE can be formal learning, organized and structured through formal evaluation and assessment in traditional education systems or non-formal learning embedded in planned activities containing important learning elements [8]. The overarching aim of enhancing sustainability competences is to have in place a system to document and to validate the competences that will be easily recognized by companies, professional organizations and society.
Another possible improvement is to have mandatory sustainability education and training for engineering programs. Currently, professional qualification frameworks of engineers already require competences in the area of sustainability [9], [10]. The problem is that many engineering programs from academia do not comply fully with the demands of the professional qualification frameworks and many graduates do not have the necessary sustainability competences in terms of knowledge, skills and attitudes. In this case of transforming the higher education engineering programs it is only viable through the intervention of legislative branches.

4. CONCLUSIONS

SERINA has shown that it is possible to gather examples and case studies valuable for preparation of future graduates and active engineers in the area of sustainability. SERINA maybe replicated by other

stakeholders to become databases of examples and of case studies, of training programs and of initiatives that can bring hope for those concerned with the future. That can bring hope and optimism while developing an active mind set about respect of UNSDG and of FHN enacting its implementation in planning and executing future projects.
Adapting to change is one of the most difficult and complex human challenges to navigate successfully. Yet no person or community has any immunity for change. The dawn of the third decade of the 21st Century has swiftly heralded unimaginable shifts and challenges across the globe without exception. So too, it has revealed signs of tremendous accomplishments, of ingenuity and of adaptability, buoyed by resilient human spirit and by desire to succeed against immense adversity. Against this backdrop, the decade ahead for engineers could hardly be more significant, demanding, and exciting for the best of engineers and of academics as problem solvers.
As engineering students, professionals, educators and administrators, one can look to the enormity of 2030 deadline targets of the UNSDGs with a renewed sense of purpose, urgency and optimism, knowing that the world has demonstrated its ability to adapt at a scale of unprecedented solving measures at the blink of an eye. SERINA is an example of what can be achieved.

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ADAPTABLE DESIGN METHODOLOGY FOR QUALITY DL EDUCATION FOCUSING ON SUSTAINABLE ARCHITECTURE & INTEGRATIVE TECHNOLOGIES

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Key words: Research Methodology, Distance Learning, Sustainable Architecture, Quality Education.

ABSTRACT

While designing and building the infrastructures that support us as a society, meeting also the "social" and "human" spaces' needs (and not only the environmental or the economic) of today without compromising those of tomorrow is one major pillar of sustainability. Although there's a significant progress in research and development for sustainable design practices taught and made in buildings to reduce heating and cooling costs by using less energy, there are limited references for the important part that teaching and integrating "sustainable architecture practices" can play in the field of educating civil engineers.

This research work further discusses the role of the building environment specialists in educating future graduates to apply sustainable design principles and therefore to contribute in the broader field of implementing the Quality Education **S**ustainable **D**evelopment **G**oal (i.e. **SDG**) focusing on the "human" aspect and its' design of spaces quality needs. This research inquiry becomes even more complicated if a master's degree level education, focusing on **S**ustainable **A**rchitecture and **I**ntegrative **T**echnologies (i.e. **SA&IT**) is to be offered online.

The true and accurate information collected during this research, is properly analysed and both the strengths and the weaknesses are judged in terms of well documented internal evidence and external criteria. The Case Study Research Method was strategically followed as the most suited research tactic. It also formed the basis to investigate this empirical inquiry of setting the minimum criteria and the standards for the quality of the educational master's level program, planned to be remotely offered to participants who aim to practice in the built environment field applying sustainable strategies in their designs. The presentation of this investigation's conclusions to the audience of this conference aims for the author to gain valuable feedback and to initiate a generative discussion and a critical conversation on this topic. The answers to the main research question are concluded as follows:

1. This research originates by creating a new pattern that can add academic diversity and specialisation in the market of Higher Education in Europe.
2. It can introduce scientific research practices and technology knowledge to the content of existing educational programs offered.
3. The focus on SA&IT is successful at the development of a holistic approach to fulfilling the SDG goals following a technological, social and site-specific design.
4. The aim should be to integrate many different disciplines and expertise, acknowledging that sustainable practice needs to develop closely through cross-disciplinary collaboration.
5. The cohesion and dedication of a community such as the European Civil Engineering Education and Training Association (EU.C.E.E.T.) and the Association of European Civil Engineering Faculties (A.E.C.E.F.) in our teaching practices is necessary to accomplish this aim.
6. The presence of the membership has the possibility to be advertised and used as an exceptional national and international forum that can support academic, industry and community exchanges on sustainable architecture.

The former six points are indicative of the proposed good practices. The challenges revealed through this research define the framework for further research and development of a prototype program of studies to be offered to professionals who intent to practice particularly in the Mediterranean basin with its unique and characteristic ecosystem regime of mild wet winters and warm and dry summers. These challenges are listed as follows:

1. To develop, refine and clearly articulate a progressive vision for educating Civil Engineers and Built Environment Specialists, making timely, competitive and relatively unique Strategic Plans in the international educational field including the specialised field of SA&IT.
2. To consider how the design focus on SA&IT can add an authentic component to the purpose and activities of the Civil Engineering teaching and learning program pathways.
3. To define the exact academic content in relation to other Master of Science (MSc) and Master of Engineering (MEng) programs offered by Higher Education Universities and Institutions across Europe.
4. To create research-based threads and connections of teaching and learning.

The research study conducted discovers the parameters that dominate the optimum design of teaching and learning basis. It clearly states the purpose, objectives and learning outcomes, as well as the structure and the content of courses that focus on Sustainable Architecture and Integrative Technologies.

The effectiveness of teaching work using the available resources to qualify the higher education graduates is found to be related to the organisation of teaching work, the teaching methodology and personnel and the available resources.

The presented findings initiate the mechanism of further discussion on the role of such quality teaching and learning of the specifics of sustainability particularly designed for graduates specialised in the built environment, in order to draw the necessary conclusions and take further actions. More importantly, the discoveries intent to make recommendations directly related to the purpose and results of this study. Research work and synergies with teaching needed are emphasised. Support of teaching work such as administrative mechanisms, supporting infrastructure and financial resourcing are also mentioned. Special characteristics related to the distance learning delivery of teaching and learning, such as feedback processes, guidance and support, performance monitoring, communication, assessment consistency, teaching materials and electronic sources of information are developed and illustrated for an indicative course. The maximum number of students per class-section, the conduct of written examinations and the number of long distance classes taught by the academic personnel are also stated.

In summary this paper is a critique of the role that the optimum selection among alternative designs of Quality Education regarding Sustainability that will include SA&IT can play in the implementation of SDG's.

1. INTRODUCTION

The general purpose of the study presented in this paper is to extend the inquiry of the role that Quality Education for civil engineers has to play in the implementation of the Sustainable Development Goals (i.e. SDG). The American Society of Civil Engineers in their report for the 2015-2016 Criteria for Accrediting Engineering Programs and specifically for Civil and Similarly named engineering programs, strongly suggest teaching faculty in the programs under evaluation to include principles of sustainability in design [1]. M. Thürer et al. [10] have analysed a total of 247 articles, of which 70 were case reports, from 82 universities. They have concluded that there is a strong political will and commitment towards sustainability and sustainable development which has had an impact on higher education. The importance of it is recognised by research teaching faculty in engineering and among the critical future research questions that emerged from the analysis, was the further exploration of the knowledge and value frameworks of students and teachers. This paper extends the development to include the case of the University of Nicosia, Cyprus Master Program outlining the Sustainable Architecture and Integrative Technologies (i.e SA&IT) orientation.

According to the nature of the architecture and engineering disciplines, the answers to the research inquiries may involve different procedures to follow. The author has been systematically experimenting with the challenges of teaching students both at an undergraduate and graduate level who were educated following either architectural or engineering studies. After many years of teaching, it is now recognised by the author that in order to address properly the education of engineers for careers involving the sustainable development it will require a good understanding of the transformation of not only "what", but more importantly "how" we ought to facilitate the learning towards excellence in the knowledge of different type of learners. In current engineering graduates, critical thinking skills and the ability to collect, evaluate, and utilize information are often not advanced. They also have little or no experience of dealing with uncertainty and ambiguity in problem solving. Too often, engineering curricula place more emphasis on the memorization of facts and well-established procedures than on learning the skills necessary to deal with large, complex problems. As a result, current engineering graduates are entering the market place ill-equipped to deal with the problems society is sure to face to reach the sustainable goals by 2030-2040.

The objective of this contribution is to present a program for graduates and future practitioners in the field of sustainable development of the built environment, who will need to become specialists and competent to face current and emerging demands. The gap identified in recent literature is the need to alternatively offer a unique path for teaching and learning about sustainable goals imposed by the needs of modern societies, following a new student centred, pedagogical model: the Project Based Learning (i.e. PBL). Learner-centred environments are a prerequisite to the redesign of engineering education for sustainability. A more thorough objective analysis is needed.

The investigation undertaken by the author acknowledges the ideas of research teaching faculty at selected universities worldwide, (such as Carnegie Mellon: School of Engineering, Stanford University: Civil and Environmental Engineering, Purdue University: College of Engineering Michigan Technological University Houghton and North Carolina State University in the USA) who address the need for curricular changes that foster sustainable thinking and have been reviewing a number of engineering curricular changes drawing comparisons to medical and other fields. The authors of the research paper on Defining Engineering Thought [5] summarised their analysis of the novel approach to education in general and engineering education in particular that will allow the following: "development of an exciting, learner-centred curriculum that engages and challenges students; development of an integrated curriculum that fosters a mastery of engineering fundamentals within the context of the liberal arts; encouragement of socially responsible and sustainability-centred thinking; development of a socially and personally relevant curriculum to attract and retain women and under-represented minorities; and. encouragement to develop the language of technology and quantitative literacy among non-engineering majors". One of the leading references in engineering curriculum transformation is the Smith College Picker Engineering Program that has dedicated itself to 'redefining engineering education in order to produce engineers that `appreciate and understand the human condition'. [9]. D. Huntzinger et al. [6] concluded in their research that successful integration of sustainability into engineering curricula requires a change in the approach to education. Students need not only the knowledge base to generate effective engineering solutions; they need the intellectual development and awareness to understand the impact of their decisions. Felder et al. [4] in their findings stress the challenges that need to be faced regarding the intellectual development of engineering students. The modern engineer needs to be equipped with the knowledge and skills to manage the uncertainty and ambiguity surrounding the sustainable development and make judgments about the best course of action based on the available evidence. This requires engineers of the 21st century to have creative problem-solving skills and to "evaluate the implications of their solutions beyond their immediate technical context". Wise et al. [11] conducted a four-year longitudinal study of intellectual development in engineering undergraduates. Their results indicate that, without active learning and team-based projects, students fail to progress adequately in terms of intellectual growth.

In turn, they often lack the critical thinking skills, confidence, and creativity needed to successfully evaluate the impact of corporate decisions on the environment and society. The purpose to convey how aspects of behavioural decision science, as well as stakeholder involvement and leadership, inform real-world design decisions can be accomplished using the Case Study Research Methodology This paper follows the guidance of others in the field and contributes to the development of case study research on the Pedagogy and Evaluation of Bridging Sustainable Engineering and Behavioural Science [8]. It aims to encourage more open-access information and participation in the ongoing, intense discussion among faculty debating about the inquiry. In an effort to fill this gap, this paper presents the program coordinated by the author. Sustainable Architecture and Integrative Technologies (DL MSc SA& IT) is an internationally significant Program of Study and this type of program is lacking in the region of south Mediterranean. The intention is to explore the opportunity to engage among Europe in this field; to connect the program with the faculty and prospective students; to increase the visibility of the program and make it more attractive to European students. The inquiry in research that this paper focuses on, refines the planning and learning process, the retrieving of necessary information, the processing of project based learning, the way to develop the creativity skills and shares what subjects needs to be taught and which courses to be outlined for the specialization. Study guides provides a detailed insight of the adopted procedure towards the establishment.

2. METHODOLOGY

Data for this research was influenced by the vision statement and collected for the DL MSc in Sustainable Architecture & Integrative Technologies program of studies. The information was collected from the following sources: -original work of the author and the faculty of Architecture of the University of Nicosia consisting of Course Outlines, Study Guides and Bio Profiles and CV's; -the website of The Cyprus Agency of Quality Assurance and Accreditation in Higher Education (CYQAA), which is the competent Authority responsible for ensuring the quality of higher education in Cyprus and for the support of the processes provided by the relevant Legislation, for the continuous improvement and upgrading of higher education institutions and their programs of study. Specifically, the publications on Standards and Guidelines: Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG) as detailed in [3]; -Answers provided by focus group of Academics and Professionals in the field of Architecture, Civil, Environmental and Mechanical Engineering and in Institutions and Organizations Administration, -Observations of professional evaluation committees internal and external to the University of Nicosia and -Experiments related with the application for evaluation of the DL MSc SA&IT program under investigation and the preparation of the required documentation. The multiple data sources aimed at strengthening the credibility of outcomes enabled different interpretations and meanings to be included in data analysis presented here. The parameters of analysing the collected data are: - Quality Standards and Indicators; -Effectiveness of Teaching Work - Available Resources; - Program of Study and Higher Education Qualifications, - Research Work and Synergies with Teaching and –Distance Learning. The emphasis is on the - Program's purpose and objectives; - Program's Learning Outcomes; - Structure and Content of the Program of Study, -Course Outlines and –Study Guides.

2.1. Quality Standards and Indicators

Quality assurance and accreditation in higher education bodies defined a number of quality standards and indicators that can be grouped in five subjects for master programs. The case study under analysis identifies the following: -Effectiveness of Teaching Work - Available Resources, -Program of Study and Higher Education Qualifications, -Research Work and Synergies with Teaching, -Administration Services, Student Welfare and Support of Teaching Work and Distance Learning Programs [3]. The paper focuses on the work related with the faculty involved and was developed for the evaluation of the MSc DL Sustainable Architecture and Integrative Technologies. It provides a brief summary of all the areas while the program of study, which accounts for 34% of the total, is described in greater detail. As it was observed the standards related with the effectiveness of teaching work accounts for almost one third of the total number indicators and the rest 33% is divided among research, administration and distance learning evaluators, as shown in Fig.1 for Quality Standards and Indicators. The case analysed here has scored as follows: 87 out of 100 indicators are satisfactory, with 2 having received the highest mark, 48 were graded as applicable to a very satisfactory degree, and 37 applicable to a satisfactory degree. There is a 13% space for further improvement and enhancement of the quality of the programme.

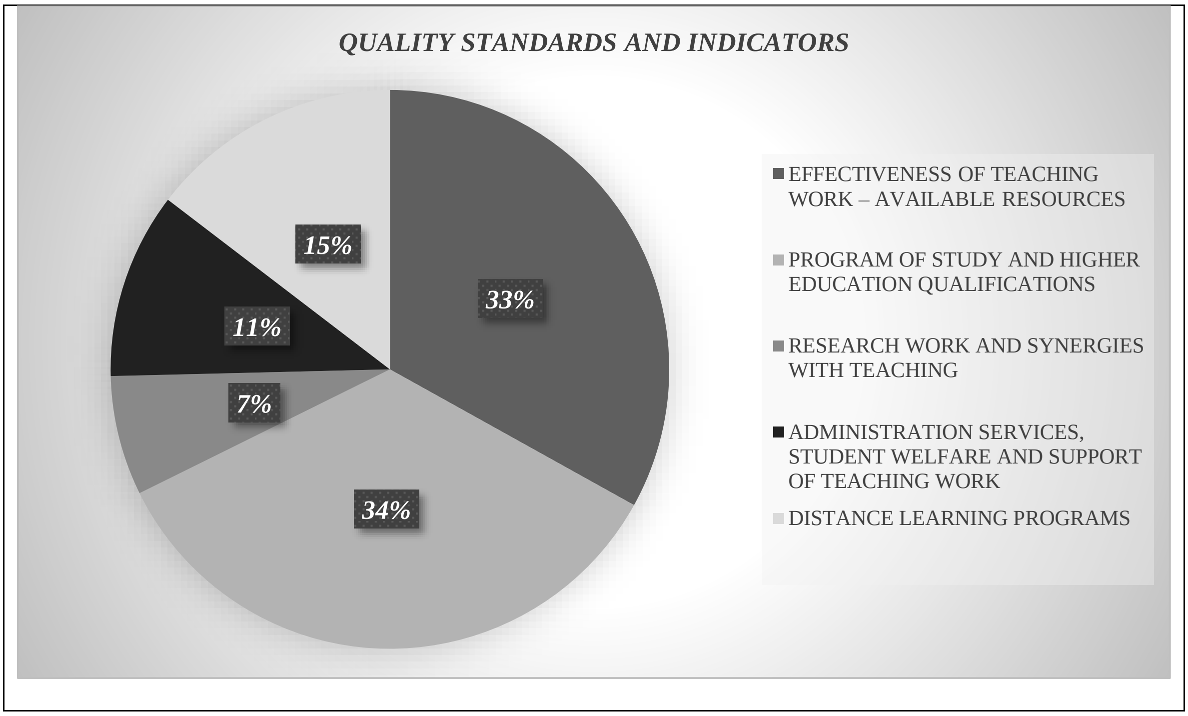

Fig. 1: Quality Standards and Indicators

The following research questions: What are the methods used to measure the competencies: communication, innovation/creativity, lifelong learning and teamwork? Are validity and reliability measured in the studies considered, and if so, which techniques are used? What is the purpose of the measurement used in the study? Which criteria are used to assess these competencies? addressed in [7], initiated critical discussions on the accreditation bodies' selection and allocation of evaluators.

2.2. Effectiveness of Teaching Work - Available Resources

The criteria used to measure the effectiveness in regards to teaching considers the available resources and refers to the following: Organization of teaching work, Teaching and Teaching Personnel. The organization of teaching work assess the student admission requirements, number of students in each class, the educational process (specific academic calendar and its timely publication, the implementation of the program's curricula by people involved, the updates of the teaching material and for the assessments, and the provision of information for improvement), the learning resources (facilities, library, infrastructure, student welfare, academic mentoring), a policy for regular and effective communication and feedback). There are established specific regulations which are adhered to in a consistent manner and allows for constructive teaching and communication according to the current international standards and/or practices. The educational process is organised in such a way that safeguards the quality implementation of the program's purpose and objectives. The learning resources, available to the students, are adequate and modern. For each course, the teaching personnel provide timely and effective feedback to the students. Mechanisms (statutory, control) support students' communication with their mentors and their performance considering a balanced workload and complaint management.

2.3. Program of Study and Higher Education Qualifications

2.3.1. Program's purpose and objectives

The M.Sc. in Sustainable Architecture and Integrative Technologies program aims at producing design or thesis proposals dealing with contemporary challenges, which relate to the sustainable development of the built environment. The main task is to develop work within the sustainable architecture content that will also actively engage the employment of specialized integrative technology approaches. One of the proposed program's purposes is to address the critical assessment of selected design decisions for sustainable architecture concepts. The intention is to develop critical awareness of sustainable proposals developed by professionals in different but related fields, brought together in a unique context. The program is designed with the aim to link sustainability and technology in architecture, and to provide the graduate with the knowledge required to address future environmental challenges and to respond and work confidently in the specialization field. In this respect, the knowledge and understanding for a variety of technologies that could be integrated will be used in new architectural applications for sustainable solutions. The primary objective of this program is to equip prospective graduates with specialized knowledge and practice tools which will enable them to analyse current and emerging demands in the specific field of integrating technologies into sustainable architecture proposals. The further technological focus under the broader umbrella of 'sustainable architecture' is aimed at providing additional qualitative, specific, identifiable and marketable skills and applicable knowledge to the student, that may increase his/her employability prospects. In order to achieve the purpose and the objectives, the program is organized as follows: The first two semesters offer students in depth and directed knowledge/instruction in the advanced principles of sustainable architecture and integrative technologies through a group of introductory and subject specific courses. The third and final semester prompts students to further pursue focused thematic based on individual interests, by undertaking either a thesis or a project along with a supporting elective course. Quality control for the program offered online is assured based on the distance learning guide documentation. The management of the program of study is centrally administered by the university and the facilities offered are considered adequate for its successful operation.

2.3.2. Program's Learning Outcomes

Learning Outcome (LO's) are statements that describe measurable knowledge, skills and competencies that the learner is expected to achieve and can demonstrate as a result of completing learning activities. Teachers use this Bloom's taxonomy to ensure that they are continually striving to develop higher order thinking skills in learners. It is a reference point with regard to creating the learning outcome statements and creating the activities. Bloom's taxonomy is a set of three hierarchical models used to classify educational learning objectives into levels of complexity and specificity. The three lists cover the learning objectives in cognitive, affective and sensory domains [2]. The Teaching Assessments are carefully designed according to the Bloom's Taxonomy; Action Verbs and Actions as shown in Fig.2. The cognitive domain is broken into the six levels of objectives listed in Fig. 3. A significant effort was made to develop new teaching strategies which were inspired by this educational philosophy. The teachers' interpretations are reflected in their writing of the LO's in general for the whole program as follows and they were revised and put in more detail for each course. Upon successful completion of this programme, the students should be able to:

i. Interpret and critically assess the theoretical and applied knowledge in Bioclimatic Architecture and Energy Efficiency and integrative Environmental and Structural systems towards Environmental Building Design to improve the comfort conditions of users (thermal, visual, acoustic comfort, air quality) minimizing energy consumption and align with the European current legislation and policy for energy performance compliance.

ii. Creatively employ the principles of envelope design, energy-efficient and structural systems, energy use and production, alternative energy sources use and thermal comfort, in design proposals for the built environment.

iii. Analyse the quantitative effects of qualitative design decisions via the methodological use of energy and structural analysis through the application of heat transfer and building physics knowledge, using simulation as a tool to interpret performance behaviour of advanced specialised environmental and construction building systems.

iv. Integrate environmental, energy and building systems exploring the advancements in thermal-, passive and active solar energy-, photovoltaic-, thermodynamic-, renewable energy- and kinetic systems' technology into sustainable building designs, through a simultaneously scientific and creative approach.

v. Apply a variety of research methods in chosen topics underpinning the history and evolution of sustainable development and specialised architectural technology

vi. Communicate and defend research and design conclusions clearly to specialist and non-specialist audiences through design projects, research papers and oral presentations, utilizing appropriate graphic, design, written, digital and verbal techniques.

vii. Apply integrative approaches and practices towards the improvement of energy efficiency in the existing built fabric.

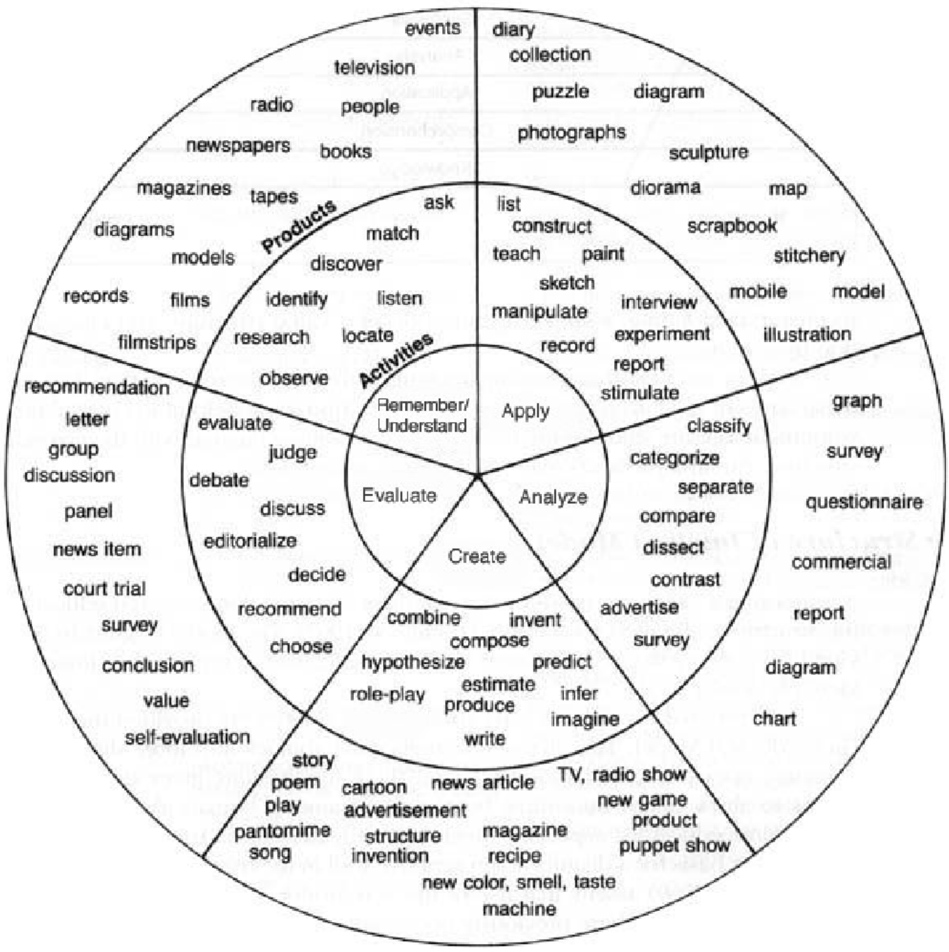

Fig. 2: Blooms Taxonomy; Action Verbs and Activities

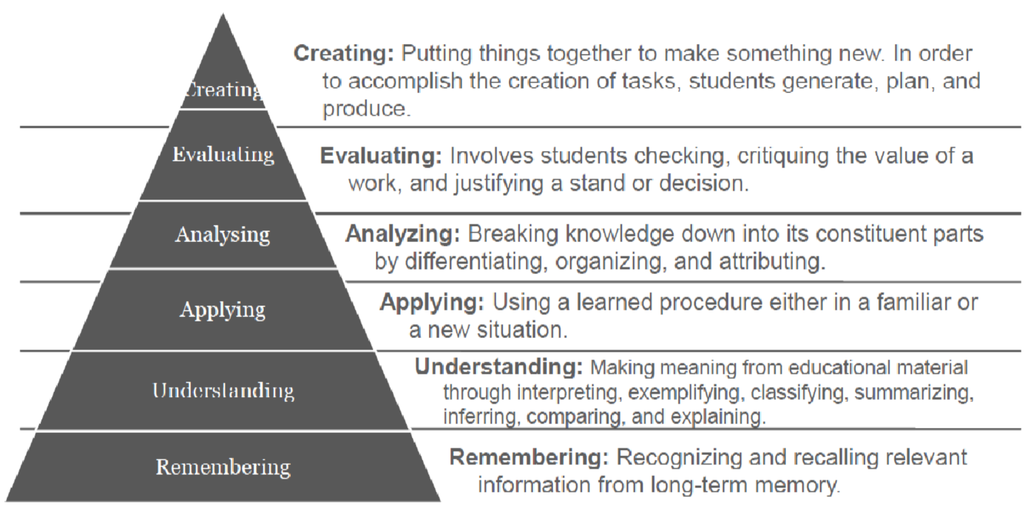

Fig. 3: Bloom's Taxonomy Revised Version

2.3.3. Structure and Content of the Program of Study

The structure of the program of study, indicated in Table 1, and also its components are comparable to other Distance Learning (DL) programmes offered in the US, EU and elsewhere and award the MSc title. A selection of such programmes in Europe refers to : MSc in Environmental Design of Buildings, Cardiff University, UK; MSc in Infrastructure and Sustainable Development, Oxford Brookes University, UK; MSc in Green Architecture, Wismar University WINGS, Germany; MSc in Architectural Technology & Building Performance, Edinburgh Napier University, UK; MSc in Sustainability and Adaptation in the Built Environment, Graduate School of the Environment, UK; Indicatively, we add here one of the conventional face-to-face programmes offering the same title: MSc in Sustainable Architecture Studies, School of Architecture, The University of Sheffield, UK.

Table 1: Structure of the Program of Study

PROGRAM REQUIREMENTS	ECTS
Compulsory courses	60
Postgraduate Assignment	30
Total ECTS	**90**

The presented programme, however, offers distinct educational aspects and unique elements in relation to design quality, sustainability and integrated systems, and geographic location. the degree with which the programme compares positively with corresponding programs operating in Cyprus and abroad in higher education institutions of the same rank is commendable. The interrelation of the individual courses in terms of the learning outcomes, constitute important elements that will assist the attracting of European and/or international students. The horizontal and vertical research based threads develop accumulatively throughout the first two semesters and aim to culminate in a strong, competent, well-informed and consolidated “Research Project”. Fig. 4 illustrates how the courses are structured throughout the three semesters, connected both at a horizontal and vertical level. All courses are compulsory and in the first semester the specialized subject of sustainable architecture, on Bioclimatic Architecture is a corequisite to Environmental Integrated Systems to emphasize the Integrative Technologies aspect, whereas the character of high level of research required is shown with the addition of the Research Methodology course which implies the advanced level. ARCH-590 DL: Research Methodology is taught in the first semester and is compulsory for all students. A larger part of the faculty is assigned to advice students within this module on research methods. From the early stage of studies, and through the research methodology course, the programme contents are interrelated. First semester is a prerequisite to progress to the second semester which unifies what is necessary for a professional academic and practice for the building experts. The architectural intention is combined with both structural and construction efficiency and requires a unified approach. This is achieved with the selection of a structural course (Adaptable Structures: Emerging Technologies), an energy engineering course (Energy Efficiency in Buildings) and because both new and existing buildings need to be addressed, the value of a course specific to the Retrofitting of

Existing Buildings is added. The third semester module, "ARCH-591 DL: Research Project", which is offered either as a thesis or a substantial design project. In order to successfully complete the module students, work on a research project, displaying commitment to methodological rigour, a high degree of scientific and creative achievement, as well as an awareness of context of theories and practices in the chosen field of study. Students will be supported and supervised by faculty with relevant research interests and proven specialised expertise.

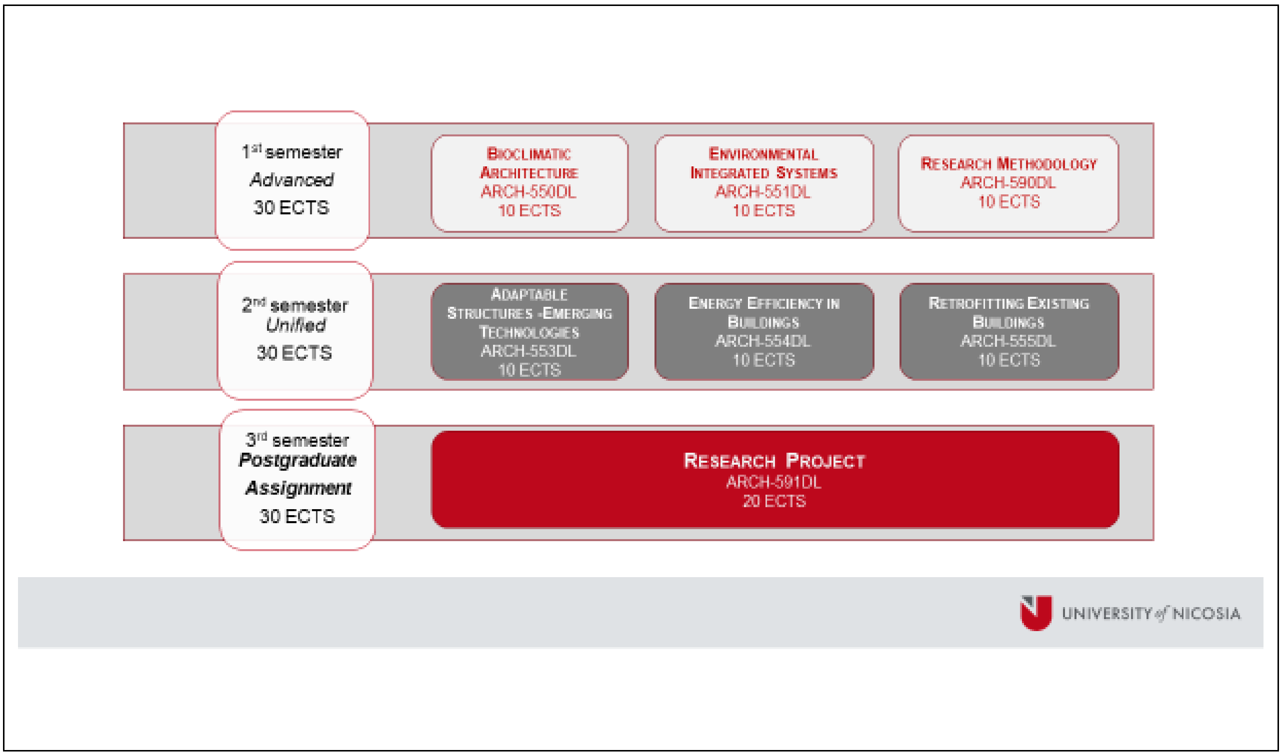

Fig. 4: List of Compulsory Courses

2.3.4. Description of Modules

ARCH-550DL - Advanced Principles of Bioclimatic Architecture -10 ECTS:

The module investigates principles of Bioclimatic Architecture and Environmental Modification. It covers a wide range of topics, from understanding climatic data and human comfort, to basic passive heating/cooling strategies, to more complex autonomous / living systems. The aim is to develop an advanced awareness of how materials, techniques in structure, construction and environmental modification are integrated in the generation and realization of bioclimatic architectural designs. Regional climate, and site-specific microclimates are also examined through literature and practical applications. An overview of the most important issues upon which sustainable planning and design are based, (such as geologic, hydrologic, and ecosystem processes) is also provided. The subject of Building Physics is introduced, especially because the course is targeting different undergraduate backgrounds, within the first two weeks with the aim to better leverage students' basic knowledge.

ARCH-551DL - Advanced Environmental Integrated Systems -10 ECTS:

The module focusing on building technology, provides technical guidance and an up-to-date overview of the latest technology in advanced building systems, to meet the complex challenges of integral planning, requiring the interactions of different but related disciplines. The aim is to reinforce the importance of an all-encompassing consideration of the integral parts of the built environment (such as structure, construction, materiality, systems and servicing, aesthetics and human well-being) as equal, as well as virtually indistinguishable. Within the chapter under “materials” the subject of “heat transfer” is taught (thermal mass, capacity, isolation, etc.) in order to better prepare students to follow the contents of environmental simulations in semester two. The module requires strong design competencies.

ARCH-590DL- Research Methodology-10 ECTS:

The Research Methods module is compulsory for all students; a first year course that prepares students to undertake the research project in year two. The Research Methods module utilizes the research advising by a larger part of the faculty and interrelates the contents of all modules from an early stage. The module aims to accompany the student through all stages of the research. It provides a road map through the challenging process of finding and committing to research methodology. The work builds upon the strength of the faculty members and activities in achieving the required level of scientific and creative achievements in research.

ARCH-553DL - Adaptable Structures; Emerging Technologies -10 ECTS:

Structure is seen as a part of an integrated whole of a building, which evenly supports morphology, construction and energy efficiency. Emerging structural technologies that could be used to better serve the sustainable architectural intention is introduced. Based upon an assessment of the structural behaviour, students will propose a unique form suitable for adaptable structure towards an optimum structural efficiency, construction realization and sustainable (i.e. energy) performance. Structural simulation is explained for the students to qualitatively analyse the quantifiable results from a suitable structural analysis software. Students are not asked to undertake structural analysis. Structural systems related to the application of technology advancements in terms of specialized typologies such as kinetic structures are taught that could be used in advanced design proposals that utilize research results in this architecture technology specialization.

ARCH-554DL - Energy Efficiency in Buildings -10 ECTS:

The module gives an overview of the methodology used to determine the energy efficiency in buildings. It presents the different opportunities and measures for reducing energy use in buildings without sacrificing comfort levels. An overview of how sustainable designs are assessed from a regulatory point of view will be introduced in order for the set out policies to be implemented. Environmental simulations based on the building physics already introduced in semester one are used as a tool for the students to understand the application of computation benefits, through a series of exercises, examples and projects presentations. The Southern Mediterranean area’s localized conditions are specifically considered.

ARCH-555DL - Retrofitting existing buildings – upgrading for energy performance compliance -10 ECTS:

The module aims to introduce retrofitting strategies appropriate to maintain a balance between the need for energy savings and the character of the original building fabric. Integrated retrofit analysis approaches are employed in order to explore and evaluate holistic solutions and practices to improve energy efficiency in existing buildings.

ARCH-591DL- Research Project-30 ECTS:
The third semester focuses on a single concluding Research Project. It is made clear that students should present a single Research Project, as a final piece of work, either delivered as a thesis or design portfolio, underpinned by robust aims, objectives, review of the state of the art and methodology/methods, reinforcing the programme's unique characteristics (i.e. the design quality, innovative design solutions' development and knowledge of regional architecture). In this consolidated Research Project module, students, academic, teaching and administrative personnel of the programme participate in research activities and projects. Each student completes a research project at postgraduate level, which provides evidence of methodological rigour and scientific and creative achievement as well as an awareness of context of theories and practices in the chosen area of study". Student's research projects are supervised by supervisors with appropriate expertise, and the programme takes advantage of a greater pool of supervisors to address this. The module intends to provide students with an opportunity to apply appropriate theoretical concepts to projects, providing an innovative and critical approach. Students should demonstrate problem solving skills through "research by design". Due to the diverse background of students the design brief is flexible enough to suit a variety of problems to be investigated. The module allows students to specialize in a subject of their interest that fits within the ongoing research of the programme. It is an individual research project in which the students demonstrate that they have acquired the relevant competences to plan and realize independent study within a chosen area. The work builds upon the strength of the faculty members and activities in achieving a clear identity and the required level of scientific and creative achievements in research. An indicated Research supervisor, a Project supervisor and a 3rd supervisor chosen in advance are assigned to each student.
Course Descriptions are developed for each course and are agreed with the students during the first day of class. An indicative template is shown in Fig. 5. It includes the information about: -the main objectives of the course, -what is expected upon successful completion of the course for the student, -the content, -the learning activities and teaching methods, -student's obligations, -the type of assessment and its weight parentage to the final grade, -attendance and participation, -general course requirements, -grading scale, -Required and Recommended bibliography, readings, resources, textbooks and any other additional study resources and a thoroughly examined weekly schedule including the demanding sessions, oral presentations, midterms and final exams.
The Intended Learning Outcomes are revised after long discussions in meetings with the faculty teaching, leading and advising. The LO's (Learning Outcomes) were written for every course/module. LO's are carefully decided for each course considering "who" the audience is, what a learner is expected to be able to do that is specific and observable, under which conditions the behaviour is to be completed, including the tools or assistance to be provided and the criterion, the degree of acceptable performance that the learners should exhibit (e.g. time limits, accuracy and quality). In Table 2 the LO's are described for the first semester courses. The legend *1: Remember, Knowledge, 2: Understand, Comprehension, 3: Apply, Application, 4: Analyse, Analysis, 5: Evaluate, Synthesis and 6: Create* is used to make connections with the strategy that was followed having the educational philosophy as a reference. The specific learning outcomes were derived from the taxonomy. More importantly though, it was used to design the learning activities on a variety of cognitive levels. The results are shown in parallel consideration to verify the connections.

UNIVERSITY of NICOSIA

Course Outline

Course Code	Course Title	ECTS Credits
Prerequisites	Department	Semester
Type of Course	Field	Language of Instruction
Level of Course	Lecturer(s)	Year of Study
Mode of Delivery	Work Placement	Corequisites
Course Venue URL:	Course Day and Time scheduled Webex meetings (nine (9) hours for face-to-face meetings) to be announced	Telephone
Office	Email sophocleous.t@unic.ac.cy	Student Consultation Hours Availability through SKYPE

Course Objectives:

The main objectives of the course are to:
1.

Learning Outcomes:

Upon completion of the course, the student is expected to:
1.

Course Content:

1.

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Learning Activities and Teaching Methods:

Self-analysis, self-assessment, individual support and feedback, forums, and chats, Student/tutor interaction (supervision and consultation), Individual instructions

Student Obligations

- Access the course platform at least 4 days per week.

Assessment Type	Weight (Percentage)
Final Exam related to the presentation of the project and portfolio assessment	

Attendance:

Student participation

Course Requirements:

Grading Scale:

Required/ Recommended Textbooks / Readings:

Title	Author(s)	Publisher	Year	ISBN

Weekly Schedule:

Week	Topic	Assigned Readings
1-13		Face-to-Face Tutorial (three (3)) hours. held simultaneously through our teleconferencing system (WebEx - video conferencing facility)

Fig. 5: Course Outline template

In the first two weeks of the delivery of classes information relevant to Bioclimatic Architecture, Environmental Systems and Research Methodology are recognised and the educational material is provided in order to make useful meaning by interpretation. The procedure continues with the use of the gained knowledge and understanding to the use of it where students are asked to apply what they have learnt and produce diagrams, mappings, illustrations and models by summative experiments and reports. Their learning actions are recorded and they are interviewed to stimulate their application potential. The analysis steps follow the progressive learning. Students become active learners and analyse their application proposals. In their Research Methodology for example the compare and examine evidence, and verify the authenticity of information and the sources for their research that they have applied in their proposal based on their knowledge and understanding of a variety of research methods and demonstrating the ways in which choices of methodology are closely linked to broader theoretical and conceptual issues. Moving on to the next step the students are asked to evaluate their peers work and provide feedback. They have to appraise, argue or defend while judging not only their own work but others' as well building on the criticism that was developed during the previous step of analysing their proposals. The final step reached is the action of creation. Students are gradually developing what's allowing them to formulate and write their proposal for a project that has a personal meaning to them and create their final assemble of research methodology for bioclimatic architecture proposals that integrate environmental systems. This allows them to continue to the second semester. The legend under the tables helps to identify the connection between LO's and the educational philosophy. It is important to observe that a systematic rationale of constructing the LO's is followed. Sequence and hierarchy is shown in Tables 2, 3 and 4.

Table 2: Structure of the Program of Study

Semester 1 (Advance)		
ARCH-550DL **Advanced Principles of Bioclimatic Architecture**	**ARCH-551DL** **Advanced Environmental Integrated Systems**	**ARCH-590DL** **Research Methodology**
ECTS 10	ECTS 10	ECTS 10
1. Recognise[1], interpret[2] and apply[3] key concepts of bioclimatic architecture and environmental modification. 2. Demonstrate[3] historic and theoretical references underpinning bioclimatic architecture. 3. Appraise, critique and judge issues of sustainability relating to building performance. 4. Identify[1] and illustrate[2] established passive environmental strategies, systems and their respective characteristics. 5. Examine[4] and analyse[4] published text/ drawings in relation to bioclimatic architecture strategies and tactics. 6. Interpret[2] how materials, techniques in structure, construction and environmental modification are integrated in the	1. Develop[6] an inventory of integrated strategies for indicative built environments. 2. Demonstrate[3] an awareness of historic and contemporary theories surrounding the subject of systems for the built environment. 3. Interpret[2] and critique case studies. 4. Demonstrate[3] an understanding of building technology through the study of sustainable strategies. 5. Identify[1], recognise[1] and integrate[5] systems of construction, and passive and active elements such us HVACs, plumbing and electrical. 6. Demonstrate[3] knowledge of essential building installations and systems. 7. Make judgments through checking and critiquing to develop[6] an advanced and	1. Demonstrate[3] an understanding of a variety of research methods, including survey research, interviewing, participant observation, case studies, comparative analysis, and of the use[3] of documentary/primary sources; 2. Justify[5] a stand or decision concerning their own research and methodology. 3. Demonstrate[3] awareness of the ways in which choices of methodology are closely linked to broader theoretical and conceptual issues. 4. Judge[5] and assess[5] the appropriateness of different methodologies and types of evidence to test alternative hypotheses and to construct various arguments; 5. Describe[2] and classify[2] the qualitative and quantitative approaches to research design 6. Explain[2] ideas or concepts that are related with literature or empirical based research

generation and realisation of bioclimatic architectural design. 7. Explain[2] the complex and diverse relationship between ecology and technology.	highly personalised attitude towards systems integration.	7. Compare[4] and examine[4] evidence, and verify the authenticity of information and the sources. 8. Assess[5] their methodology by making visual representations and by producing images. 9. Apply[3] knowledge and use[3] information provided, in a new situation

The second semester teaching and learning is facilitated by a selection of courses that emphasises the unified character of building design Table 3. The architectural intention that was formulated into an advanced studio design at the end of the first semester, dominates the preliminary design of the structural and mechanical systems to complete the realization in building proposals that could be either new or existing. The Adaptable Structures: Emerging Technologies course has as a main objective to design the structural system of the architectural study which was the outcome of the first semester studies. Students are induced by gaining knowledge to understand the structural requirements that are imposed and controls the design considering adaptable structures solutions. The define and recognise Adaptable Structural Systems, identify their typologies, analyse and develop adequate mechanisms, criticise, (based on their analysis of referenced structural design studies) selected proposals and create their own structural design that is unified with the preliminary formulation of the concept developed during the first semester. Energy Efficiency requirements are also learnt and added to the design solving problems related with in relation to envelope design, energy use and production, energy efficient technological systems, alternative energy sources and indoor/outdoor environmental quality. The Retrofitting existing buildings – upgrading for energy performance compliance course is taught in this semester to fill the increased market demand of today.

Table 3: Structure of the Program of Study

Semester 2 (Unified)		
ARCH-553DL **Adaptable Structures; Emerging Technologies**	**ARCH-554DL** **Energy Efficiency in Buildings**	**ARCH-555DL** **Retrofitting existing buildings – upgrading for energy performance compliance**
ECTS 10	ECTS 10	ECTS 10
1. Define[1] adaptability in architectural form by observing the characteristics of designs and defining the requirements of related architectural intention. 2. Identify[1] the governing design principles within the context of holistic design[6] in terms of architecture technology, and list the fundamentals of sustainable, adaptive structures. 3. Recognise[1] "adaptable" structural systems and locate related publications (journal articles, monographs, chapters, or books) during a search in designated resources. 4. Become aware[1] of the architectural, spatial, and sustainable potential of deployable structures. 5. Identify[1] scissor typologies reviewing literature and reproduce[2] their form and	1. Explain[2] how sustainable designs are assessed from a regulatory point of view 2. Apply[3] appropriate environmental technologies and design[6] strategies to satisfy environmental specifications of design[6] propositions. 3. Identify[1] design strategies in relation to envelope design, energy use and production, energy efficient technological systems, alternative energy sources and indoor/outdoor environmental quality 4. Describe[2] how energy efficiency relates to issues of energy management, light, temperature, air quality, thermal comfort and psychological aspects of structures.	1. Illustrate[2] knowledge of historic and contemporary theories on issues of sustainably preserving continuity in the built environment. 2. Analyse[4], and critique[5] retrofitting case studies, through text and diagrams 3. Appraise[6] possibilities for building technology upgrading through the study of sustainable strategies. 4. Identify[1], recognise[1] and follow an integrated plan[6] for systems of construction, as well as passive and active elements such us HVACs, plumbing and electrical in existing buildings. 5. Illustrate[2] knowledge of essential building installations and their appropriate interactive installation in historic and

structural characteristics in clear sketches. 6. Predict[3] through case studies, the mechanical behaviour, observing the relationship between action and deformation of structures to construct[3] diagrams that show[3] the related function and/or variation. 7. Analyse[4] and develop[6] adequately kinetic mechanisms to carry out assessments of the design[6] potential. 8. Explain[2] the diagrams for the structural behaviour to produce[3] a rationale associated with the ideal structural models for analysis to prepare[3] sketches. 9. Define[1] the structural problem and identify[1] the critical parameters in order to work towards a solution. 10. Clearly and concisely document[6] technical information; including tables, charts, calculations, schematic drawings, scale plans, and supporting text.	5. Identify[1] and evaluate[5] the main international environmental assessment methods and rating systems (such as BREEAM. Code for Sustainable Homes, LEED, Passive House certification and GSAS). 6. Apply[3] building environmental performance simulation software, such as Ecotect, Fluent, EnergyPLUS, IES VE and Tas. 7. Demonstrate[3] how sustainable designs are assessed from a regulatory point of view.	listed buildings through sustainable strategies. 6. Compile[6] a personalised attitude towards retrofitting for energy performance compliance. 7. Use[3] appropriate environmental technologies and design strategies to satisfy environmental specifications of design propositions. 8. Defend[5] sustainable retrofitting designs from a regulatory point of view.

1: Remember, Knowledge, 2: Understand, Comprehension, 3: Apply, Application, 4: Analyse, Analysis, 5: Evaluate, Synthesis and 6: Create

The final semester is dedicated to the development of a final unified piece of publishable work, that takes the design that has already been formulated in the previous semesters, a step forward. It is shown in Table 4. What is needed to be achieved is by this time specified. The clear and specific criteria for the outcome have been defined and are repeated to reassure that the design proposal brought at the beginning of the final research project (and/or Thesis) would satisfy the interdisciplinary demands of a final unified design of architecture building that will also be structurally and constructionally efficient in terms of sustainable development.

Table 4: Structure of the Program of Study

Semester 3 (Innovative)
ARCH-591DL **Research Project**
ECTS 30
1. Articulate[6] and evaluate[5] new ideas for a sustainable future, or revisit familiar problems but with a new vision and understanding of the environmental potential. 2. Develop[6] their own subject for advanced research based on a clearly-defined research question. 3. Outline[6] methods of inquiry[6] and criticism[6] on current practices and new insights in the field of Sustainable Architecture and Integrative Technologies 4. Compare[4] & Analyse[4] existing literature or case studies in support of the research project, making use of the course material and identifying other relevant resources for the preparation and design of the research project. 5. Formulate[2], interpret[2] and communicate[2] appropriate concepts derived from contextual studies and theoretical research. 6. Apply[3] specialised knowledge into the design of Sustainable Architecture and Integrative Technologies, relative to the field of each student's concentration. 7. Provide reliable, well supported evidence in support of the comprehension[2] of the research topic. 8. Analyse[4] in a 2500-word report outlining the research methodology, findings and conclusions of analysis and critical inquiry prepared. (The report should also include a clearly structured proposal outlining further research aims and activities specifying whether it is carried out as a design project or written research project) 9. Synthesize[6] a 15,000-word essay or a well communicated fully resolved design project of a publishable quality that can educate and inform a wider professional community

1: Remember, Knowledge, 2: Understand, Comprehension, 3: Apply, Application, 4: Analyse, Analysis, 5: Evaluate, Synthesis and 6: Create

2.4. Research Work and Synergies with Teaching

The demand for program staff's research work is vital. Course leaders' volume of workload has to be satisfactorily reduced to ensure that enough research and staff development time is allocated for all programme staff, including early and mid-career researchers. As shown in the list of Table 5, the periods per week are three, their duration is fifty minutes for the thirteen weeks of the semester. The number of ECTS which is additionally considered is ten for all other courses than the Research Project which is allocated with thirty. Therefore, the total periods per academic semester is thirty-nine.
The Research Teaching Faculty involved should share the personality traits of curiosity, critical thinking, creativity, effective communication, and a collaborative spirit. More important they should be scholars known among researchers in the field for being intellectuals. They also should have been mentally active in research and constantly questioning and pondering sustainability issues.

Table 5: List of Courses of the Program of Study and Workload

A / A	Course Type	Course Name	Course Code	Periods per week	Period duration	Number of weeks/ Academic semester	Total periods/ Academic semester	Number of ECTS
A' Semester (3 compulsory) (Total 30 ECTS)								
1.	Compulsory	Advanced Principles of Bioclimatic Architecture	ARCH - 550DL	3	50'	13	39	10
2.	Compulsory	Advanced Environmental Integrated Systems	ARCH - 551DL	3	50'	13	39	10
3.	Compulsory	Research Methodology in Sustainable Architecture and Integrative Technologies	ARCH - 590DL	3	50'	13	39	10
SEMESTER TOTAL								**30**
B' Semester (3 compulsory) (Total 30 ECTS)								
4.	Compulsory	Adaptable Structures - Emerging Technologies	ARCH - 553DL	3	50'	13	39	10

5.	Compul sory	Energy Efficiency in Buildings – certification, policies, strategies and implementation	ARCH - 554DL	3	50’	13	39	10
6.	Compul sory	Retrofitting existing buildings – upgrading for energy performance compliance	ARCH - 555DL	3	50’	13	39	10
SEMESTER TOTAL								**30**
Semester (Total 30 ECTS)								
7	Compul so ry	Research Project	ARCH - 591DL	3	50’	13	39	20
SEMESTER TOTAL								**30**

The evaluation of the Research and Teaching Synergies are targeted to ensure that: -Teaching and learning have been adequately enlightened by research, - New research results are embodied in the content of the program of study, - Adequate and sufficient facilities and equipment are provided to support the research component of the program of study, which are available and accessible to the personnel and the students, - The results of the academic personnel’s research activity are published in international journals with the peer-reviewing system, in international conferences, conference minutes, publications etc., - External, non-governmental, funding for the academic personnel’s research activities, is compared positively to the funding of other institutions in Cyprus and abroad, - Internal funding, of the academic personnel’s research activities, is compared positively to the funding of other institutions in Cyprus and abroad, - The policy for, indirect or direct, internal funding of the academic personnel’s research activity is satisfactory, - The participation of students, academic, teaching and administrative personnel of the program in research activities and projects is satisfactory and - Student training in the research process is sufficient. Teaching Faculty’s Qualifications and total number of teaching periods is shown in Table 6.

Table 6: Teaching Faculty's Qualifications and total number of teaching periods

A/A	Qualifications	Teaching courses		
		Code	**Course title**	**Hr/w**
1.	PhD in Solar Architecture, MSc Architecture, MSc Environmental Design & Engineering, HND Mechanical Engineering, *Professor*	ARCH-554DL	Energy Efficiency in Buildings (2nd semester)	3
2.	PhD in Civil Engineering, MSc in Earthquake Resistant Design of Structures, 5-year Diploma in Civil Engineering. *Assistant Professor*			
3.	Masters in Advanced Architectural Design, Bachelor of Architecture. *Associate Professor.*	ARCH-551DL	Advanced Environmental Integrated Systems (1st semester)	3
4.	PhD in organic Photovoltaic. Master's Degree: Section of Mechanical Engineering – Economics; General Mechanics. Specialization in Thermal Turbo Machinery (Airplane Engine) Specialization in Energy and the Natural Environment. (Emphasis on Renewable Sources of Energy). *Mechanical Engineer Consultant*			
5.	PhD in Architecture Engineering Technology, 5-year Diploma in Civil Engineering: Structural Engineering concentration (equivalent to MEng degree), Master Diploma in General Management: Project Management concentration	ARCH-553DL ARCH-590DL	Adaptable Structures for Energy Dissipation - Emerging Challenges in Structural Systems' Configuration (2nd semester) Research Methodology (1st semester)	3 3

6.	MA in Bioclimatic Architecture, Advanced Diploma in Professional Practice in Architecture (RIBA Part3), BArch(Dist), Bachelor of Architecture, BA(Hons) Architecture, Bachelor of Arts in Architecture. *Associate Professor*.	ARCH-550DL	Advanced Principles of Bioclimatic Architecture (1st semester)	3
7.	PhD candidate. Master's (MArch) and a Bachelor (BArch) Degree in Architecture (2004): *Chartered Architect & Lecturer*.			
8.	PhD in Semiology of the Interior Design, Diploma in Architecture, MA Industrial Design, MBA Human Resources Management	ARCH-555DL	Retrofitting existing buildings (2nd semester)	3
9.	PhD in Heritage Management; MA Managing Archaeological Sites; BA History, Archaeology and History of Art			
10.	Ph.D & Diplomated Architect-Engineer, Post- Professional Master of Architecture; Master of Science in Arch. Studies. *Professor*	ARCH-592DL	Research Project (3rd semester)	9

2.5. Administration Services, Student Welfare and Support of Teaching Work

The indicators for the effectiveness of the administrative mechanisms is assessed on specific criteria related with the effectiveness of the support students with regards to academic and personal problems and difficulties, through Student Welfare Service and with the sufficient statutory administrative mechanisms for monitoring and supporting students. The supporting infrastructure of the program examines the following: - Suitability of books and reputable journals supporting the program; - the existence of a supportive internal communication platform, -the quantitatively and qualitatively adequacy of the equipment used in teaching and learning, -the adequacy and accessibility of teaching materials regularly updated with the most recent publications and –the provision to the teaching personnel of training opportunities in teaching method, in adult education, and in new technologies on the basis of a structured learning framework. Financial Resources are also considered to evaluate the management and allocation of the financial resources of the program of study, which should allow for the development of the program and of the academic / teaching personnel, and the allocation of financial resources as regards to academic matters for which the department is responsible. Finally, a check on the analogy between the remuneration of academic and other personnel between respective institutions in Cyprus and the consistency of the student tuition and fees is expected to complete the evaluation of the administration job.

2.6. Distance Learning Programs

Feedback processes for teaching personnel with regards to the evaluation of their teaching work, by the students are critical for the evaluation of programs that are designed and planned to be offered online. As far as the recruitment of academic / teaching personnel, the process and the conditions for it, should ensure that candidates have the necessary skills and experience for long distance education. The University of Nicosia has established procedures, appropriate training, guidance and support, which are provided to teaching personnel, to enable it to efficiently support the educational process. It is important for the students' performance to be monitored satisfactorily and therefore related mechanisms have been followed by all parties involved.

Additional to this, the faculty prepares a Study Guide, a document of fifty pages approximately, for each course to provide detailed information about the following: 1. Clearly specified aims and expected outcomes of the programme pertaining to thematic sections and activities, in an organised and cohesive manner. 2.Presentation of material per week, with various ways and means (e.g. hard copy material, electronic material, teleconferences, multimedia). 3.Weekly presentation of activities and exercises with clear instructions in terms of submission, discussion and feedback. 4.Self-evaluation exercises and self-correction guide. 5.Bibliographic references and recommendations for further study.6. Number and subject of written work, with preparatory instructions and supplementary study material.7. Synopsis.

3. RESULTS/ DISCUSSION

Following the leading and innovative initiative the program analytics in this paper emphasizes the need for an intensive, critical and analytical approach to the further development of teaching of and learning about sustainable architecture and emerging technologies. Both have a great impact on design decisions that need to be explored and appreciated.

Current and future environmental challenges need to be addressed by future graduates in the field of the built environment and both academia and faculties across Europe should lead and team up with training experts.

Critical thinking on the theory and applications of need to be promoted.

Energy systems, Structural systems and Construction techniques need also to be engaged together with Architectural Design considerations

These are the objectives of the indicative programme presented in this paper for discussion.

We do welcome the readers' recommendations for improvements which will enhance the quality of the programme. We consider the suggestions very helpful and we think that if they are incorporated to the greatest extend possible, then a joint venture will lead to a new proposed program.

New questions emerged after the analysis and presentation of this work:

- What could be the clear identity of the program? The one that students will be attracted to, through advertising and proper marketing of the unique identity characteristics of it.

- What could be a clearer vision of the program?
- Are there other similar programs under research and/or development?
- How is the program unique when compared to other similar programs?
- Is the program coherence satisfactory?
- How can the program be connected with the labour market? And the society?
- What is the nature of the demand for expertise of this nature?
- What is the specificity of the skills and competencies needed?
- Is there an opportunity to engage internationally in this field?
- Do the individual courses interrelate?
- Does the detail of the courses in terms of content and learning outcomes need to be refined to make the goal clearer?
- What are the needs of the society and the labour market that can be satisfied by the proposal?
- What are the characteristics that would justify the appropriateness for an MEng award?
- What are the characteristics that would justify the appropriateness for an MSc award?

5. CONCLUSIONS

a. An enormous amount of effort has been put in the organization and set up of this program. Such programs require such amount of effort at all levels.
b. In order for the staff to develop the student centred character of the program so that it can become a successful master level course, they should show strong commitment, religious concentration and dedication and competence in and endeavour.
c. It is absolutely necessary to promote the design quality of the program and investments in it should be made.
d. Innovative design solutions, which are technically viable and environmentally friendly, in line with current EU and UN ambitions, should be added with sustainability and integrated systems in the content of comparable programs.
e. The uniqueness of the program under investigation can be created through the exploration of the geographic location of Cyprus and the knowledge of regional building environment. It can be unique and seen as a reference in the south Mediterranean area.
f. The program's unique features can be reinforced by the final students' work: a single research project, either delivered as a thesis or deign portfolio, which should be underpinned by robust aims, objectives, review of the state of the art and methodology.
g. A clear program vision should be established. The vision directs the assessment and sequence of the content of each course to cater for different students' backgrounds, avoid duplication and excessive overlap. It might also help in streamlining assessment, reducing staff and student workload.
h. Better coherence can be achieved if each student is required to complete a research project at postgraduate level, presented either in a thesis or portfolio format. In both cases the research project provides evidence of methodological rigour and scientific and creative achievement as well as awareness of context of theories and practices in the chosen study.

i. Further improvements are necessary with regard to advising and informing the students, on their course assignment deliverables and grading.
j. The program should offer distinct and unique elements when compared to other programs.
k. The learning outcomes (i.e. LO) of the program's courses have to be in line with the design expertise existing in the joint venture departments in charge of the delivery. Currently it is designed by the department of Architecture. They need to be revised accordingly.
l. Faculty with special expertise in different selected fields of research and development in sustainable architecture and integrative technologies (SA&IT) are to be attracted to work together as a unified team acknowledging that sustainable practice needs to develop closely through cross-disciplinary collaboration.
m. The exact academic content of the programme in relation to the title award (MSc or MEng) can be improved.
n. The MSc title would require the delivery of strong research-based projects/theses supervised by research active staff at PhD level or equivalent.

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CIVIL ENGINEERS STUDY ON-LINE – TIME TO ADAPT STUDY PROGRAMS TO NEW CHALLENGES. CASE STUDY OF SELECTED COURSES

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Key words: CE curricula, sustainable development, on-line study, challenges

ABSTRACT
Brief description of the study structure and current curricula of the Civil Engineering (CE) field-of-study at the Faculty of Civil Engineering (FCE) of Wroclaw University of Science and Technology (WUST) is presented in a paper. Detailed program content analysis is made for selected study courses: Building Physics, Advanced Building Physics, Sustainable Housing and Energy Efficiency of Buildings, especially in their context to the sustainable development (SD). Some other selected subjects, partially connected with the previously mentioned, as: Industrial Building, Computer Aided Engineering, and Earth Structures and Landfills, are briefly defined. Influence of social lockdown forced by COVID virus and necessity of on-line teaching-and-learning on education process and implementation of the assumed learning outcomes is discussed. Issues related to necessary future modification of selected study programs in context of SD are proposed.

1. INTRODUCTION – CURRENT CE MSc STUDY AT FCE OF WUST

The education of civil engineers at FCE of WUST aims to comprehensively prepare highly qualified engineering technical staff in the widely considered field of civil engineering. Graduates of the FCE at the both levels (BSc and MSc) with the general academic profile are prepared to work independently in the field of organization and implementation of construction processes, managing the maintenance and exploitation of building infrastructure and are also prepared to participate in building structure designing processes. Graduates possess the knowledge and skills necessary to organize and direct a team's work in all areas of civil engineering. Education profiles and diploma specializations prepare students to be able to undertake work in the most wanted market areas: cubature building, industrial structures and also management of building processes (Building Structures; Building Technology), water constructions, ground and underground structures (Hydroengineering; Underground and Urban Infrastructures) and also in the area of transport infrastructure structures (Roads and Airports, Railway Infrastructures, Bridges). Universal basic knowledge enables graduates to flexibly adapt to the changing needs of the labour market. The specialization of Theory of Structures prepares graduates for research and science work, and the specialization Civil Engineering (conducted in English) gives graduates the opportunity to establish cooperation with international construction companies. Two new specializations were introduced lately: BIM and Engineering and Special Structures. The basis of all specializations is knowledge and skills which enable graduates to obtain appropriate professional qualifications.

2. SELECTED STUDY COURSES WITH DIRECT RELATIONSHIP TO SUSTAINABLE DEVELOPMENT

Below there are presented brief descriptions of selected courses partially or fully connected to the sustainable development and environmental issues taught at different specializations and study levels of FCE of WUST.

2.1. Building Physics (BSc level)

a) subject objectives

Students are acquainted with the methods of heat exchange between the building and its surroundings as well as with the principles of designing modern, energy-saving and environmentally friendly residential and public buildings and their elements. Another aim is to give students knowledge on applicable requirements in the field of rational thermal protection, aimed at ensuring the proper thermal, visual and acoustic comfort of rooms for various purposes. In case of practice students develop: ability to design and properly arrange thermal insulation in partitions; ability to prepare the energy performance of buildings and to interpret the results obtained; consolidate the ability to cooperate in a project team in order to combine the form and function of the building with rational use of energy.

b) lecture content

The place and role of 'Building Physics' in contemporary construction. Interdisciplinary nature of building physics. City physics, the heat island. Basics of heat transfer through building partitions. Thermo-physical properties of building materials, types and laws of heat transfer, heat transfer.
Basics of the theory of thermal conductivity - temperature field, transient heat conduction, thermal stability and dynamic thermal properties of building partitions.
One-way heat transfer through partitions. Heat transfer coefficient. Temperature distribution in partitions. Current requirements and trends in the standardization of thermal protection of buildings in Poland.
Energy certification of buildings. Comprehensive assessment of the building's energy performance.
Thermomodernization of residential and public buildings in Poland - technical and legal conditions, scope, formal procedures, energy audit, material and system technologies.
Water vapor diffusion through building partitions - formal description of the phenomena, condensation moisture in partitions, methods of reducing and eliminating condensation moisture and the risk of mold growth.
Principles of designing building partitions in terms of heat and humidity. Thermal bridges in buildings. Influence of thermal bridges on heat losses from buildings.
Thermal imaging of buildings - theoretical basis, rules of execution, measurement errors, interpretation of thermograms.
The microclimate of the rooms. Thermal comfort of people indoors, indicators of thermal comfort. Practical methods of microclimate assessment.
Air quality in buildings. Room ventilation. Building and human health. Housing tightness, indoor air quality, sick buildings syndrome.

Renewable energy sources. Modern technologies of obtaining solar radiation energy and low-temperature soil energy. Ecological aspects of construction. Renewable energy sources. Modern technologies of obtaining solar radiation energy and low-temperature soil energy. Ecological aspects of energy-saving construction.
Daylight in buildings - basic concepts, definitions, laws, units and lighting parameters. The role and importance of daylight in buildings for various purposes in the context of saving thermal energy, passive heating and natural cooling of buildings.
Active and passive methods of daylight transmission to the interior of buildings. Visual comfort for people indoors. Shading systems. Principles of designing architectural sunshades. Shading and energy consumption for space heating and cooling. Shading and thermal and visual comfort. Design tools.
Building acoustics - goals and tasks of building acoustics. Basic information on sound, laws, definitions, units. Principles of sound propagation in open space and in a closed room. Noise assessment criteria.
Basics of acoustic protection of buildings. Sound protection of rooms in buildings, methods of implementation, standard requirements. Acoustic insulation and the principles of designing partitions in terms of acoustics. Sound-absorbing materials, products and systems, general principles of application.

c) lecture assessment

The component of completing the lecture is a colloquium – written test or on-line test.

d) project content

Overview of heat exchange methods between the building and its surroundings. Presentation of the method of calculating the heat transfer coefficient for different types of walls. Calculation examples.
Providing methods of calculating the heat transfer coefficient for the remaining partitions of the building, limiting the heated volume. Calculation examples.
Overview of the graphical and numerical method of calculating the temperature distribution in the partition. Calculation examples.
Discussion of the method of checking the possibility of mold on the surface of the partition and the possibility of condensation of water vapor inside the partition.
Overview of the algorithm for preparing a building energy performance certificate. Overview of formulas for calculating useful, final and primary energy.
Overview of ways to reduce the use of useful, final and primary energy in the building.

e) project assessment

The component of completing the lecture are partial reports from carried out individually done design themes.

f) general comments

Student’s projects are connected with their parallel courses dedicated to design simple buildings.

2.2. Advanced Building Physics (MSc level)

a) subject objectives

Students gain knowledge about design rules of modern, low energy demand, ecological residential and commercial buildings and their details and get acquainted with renewable energy usage possibilities as well as are acquainted with regulations of rational energy preservation with taking thermal, visual and acoustic comfort of different rooms into consideration. Getting basis of design team cooperation to connect form and function with rational energy usage in buildings.

b) lecture content

Advanced problems of steady and transient heat flow through building partitions. Thermal dynamics of building partitions, thermal mass. Rules of proper building envelope design according to heat flow.
Heat flow through windows and glazed facades. Types of glazing, calculation methods, technological possibilities, visual comfort of building users.
New technologies in building thermal modernisation and in low energy buildings. Ecological aspect of energy saving in buildings.
Low energy buildings: rating criteria, classification, design and realisation rules.
The possibilities of renewable energy use in heat balance improvement of different types of buildings.
Earth-sheltered buildings: classification, typical construction details, soil heat flow, heat transfer through ground walls and floors, energy conservation problems

c) lecture assessment

The component of completing the lecture is a colloquium – written test or on-line test.

d) project content

Climate chambers research.
Heat flow measurements through building walls
Infrared thermal camera measurements
Heat flux measurements (pyranometer, pyrgeometer, differential radiometer)
Building Integrated Photovoltaics (BIPV)
Thermal comfort
Computational building physics

e) project assessment

The component of completing the lecture is a final report from carried out laboratory exercises.

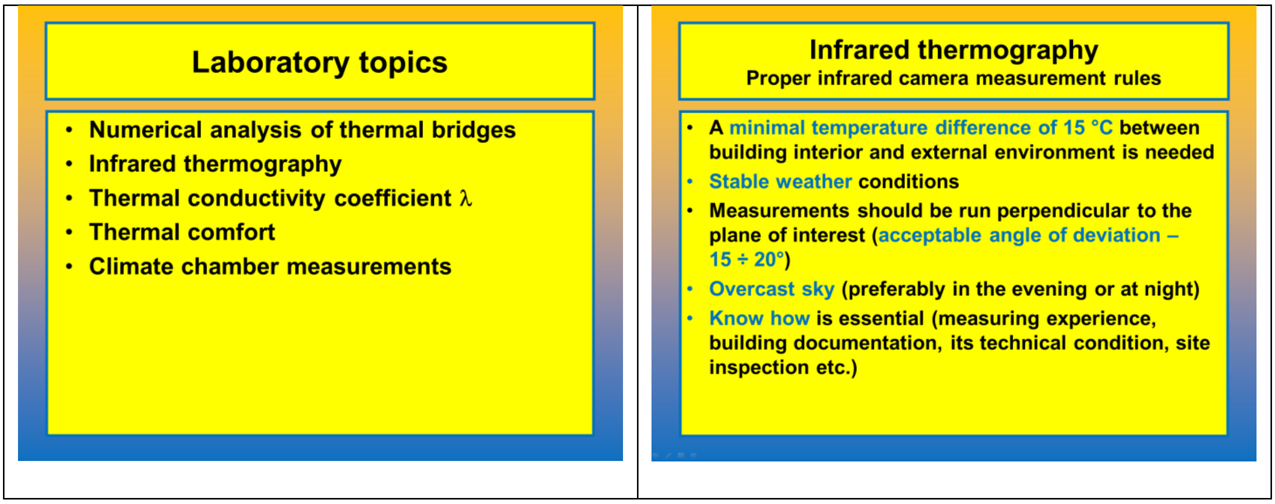

Fig. 1: Sample slides from the presentation of the Advanced Building Physics subject with the topics discussed in the laboratories (a) and an example slide on the principles of taking thermal images (b)

f) general comments

As part of the meetings, students learn new software, can take measurements using measuring equipment (pyrometer, thermal imaging camera, thermal comfort meter or heat flux density). They have the opportunity to see samples of many unusual insulation materials that can be used in construction (aerogels, hemp and cellulose fiber mats, phenolic boards or transparent insulations). The classes are conducted in the most attractive way possible - first, the theory introducing the subject of the problem is presented, then there are practical classes, examples prepared by the teacher and students' own work (on a computer or measurements using equipment). Meetings are held partly in the computer lab, but also in the building physics lab, where measurements are carried out. After completing each topic, students have to prepare a report, i.e. independent analysis of a given problem on the basis of individual computational or measurement data that they receive from the teacher.

2.3. Sustainable Housing (MSc)

a) subject objectives

Students gain knowledge about design rules of modern, low energy demand, ecological residential and commercial buildings and their details and are acquainted with renewable energy usage possibilities as well as with regulations of rational energy preservation with taking thermal, visual and acoustic comfort of different rooms into consideration.

b) lecture content

Sustainable building design basic information. LCA – building life cycle, total building costs. Environmental influence of buildings.
Building environmental impact methods. Social, economic and environmental aspects of sustainable building design. Law regulations
Global and local greenhouse gas emission. Carbon dioxide reduction strategies. Energy production from different fuels. Emission factors. Fuel equity. The primal energy conversion coefficients.
Classification of low-energy buildings. Building shape coefficient. Basic and advanced building design methods. Heat flow through windows and glazed facades.
Building thermal mass. Ventilation system, heat recovery, ground-coupled heat exchanger
Renewable energy resources in global and local scale. Usage in low-energy and passive buildings.
Examples of low-energy and passive buildings. Applied solutions. Possible solutions to carry in buildings in Polish climate.

c) lecture assessment

The components of completing the lecture are: writing an on-line test on the material presented by the teacher; delivering an on-line presentation on a topic related to sustainable construction (eg. passive construction, autonomous buildings, natural insulation materials, spray insulation, daylight redirection and diffusion systems or green roofs).

d) project content

U-value calculations for building partition. Untypical cases
Correct arrangement for rooms with different functions in horizontal and vertical plane. Daylight access.
Building shape coefficient. Building thermal mass.
Optimisation of heat gains and losses in buildings with different purpose.
HVAC (heating, ventilation, air conditioning) and DHW (domestic hot water) systems

Renewable energy sources. Usage possibilities in Poland and all over the world.
Infrared thermography. Thermogram interpretation.

e) project assessment

The components of completing the project are the handing over of two projects and their defense - answering the questions about the issues raised in the projects. Each student received different (unique) computational data (i.e. the architecture of the building and its location, partitions and construction materials of the building) on the basis of which he was to perform the calculations. As part of the project, students designed selected elements of the building, following the idea of "from detail to general in two stages: designing three imposed elements of structural joints in the building envelope (building corners, ceiling rims, method of embedding the window in the wall, connecting the walls with the roof or walls with the floor) in terms of building physics (risk of mold and thermal bridges) using heat flow simulation tools through building partitions; carrying out full energy calculations of the building in a spreadsheet and showing that it meets both the technical requirements for thermal protection and the set energy standard.

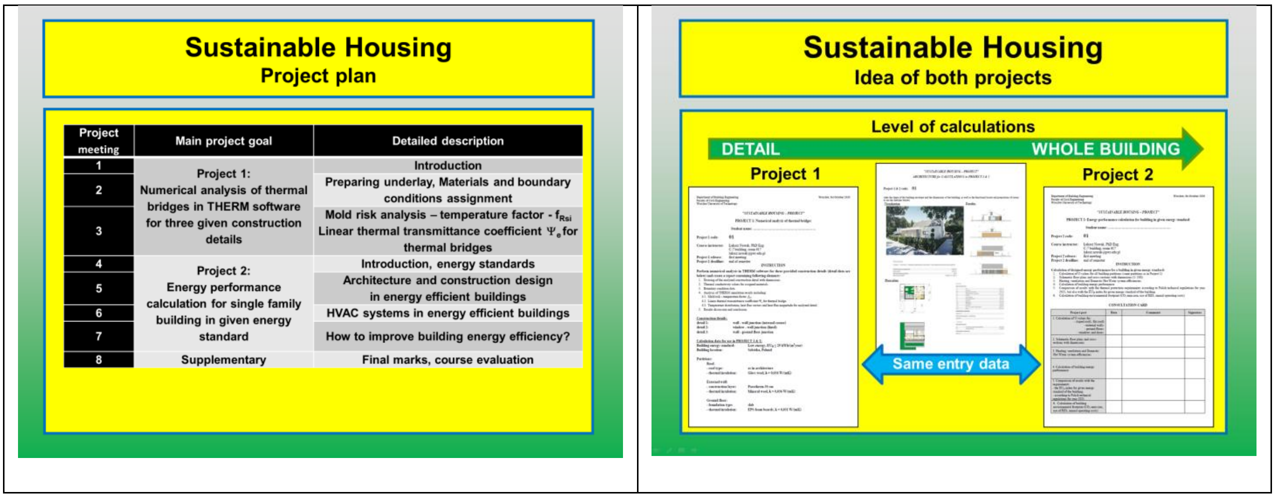

Fig. 2: Sample slides from the presentation of the Sustainable Housing subject with the meeting plan and the topics discussed during the classes (a) and explanation of the idea of designing a sustainable building in details and as a whole as part of design exercises (b)

f) general comments

The lecture was met with great interest, as many foreign students were interested in the differences between Polish regulations in the field of thermal protection of buildings and those applicable in their country and related to a similar, but not identical, approach to designing energy-efficient buildings. As part of the project, students worked independently. The implementation of two projects was to be carried out, under which students designed selected elements of an energy-efficient building so that it had a specific energy standard.

2.4. Energy Efficiency of Buildings (MSc)

a) subject objectives

Students are taught methods of calculating the energy efficiency of buildings and are acquainted with the principles of designing modern, energy-efficient and environmentally friendly residential and public buildings and their elements. Students are introduced to the applicable EU and national legal regulations and with the current requirements in the field of rational thermal protection. The ability to prepare the energy performance of buildings and to interpret the results obtained is also developed.

b) lecture content

Selected legal acts of the European Union and national legal acts concerning energy efficiency. Current energy efficiency requirements for buildings. Energy classes of buildings. Energy-efficient construction and sustainable construction.
Needs of energy-efficient construction in Poland and Europe. Actions for energy-efficient use of energy in buildings and a low-carbon economy.
Methods of calculating the energy efficiency of buildings. Differences between balance and simulation methods.
Methods and indicators of energy assessment of buildings. Methods of assessing the impact of buildings on the environment.
Examples of buildings with different energy standards. Architectural, construction and installation solutions used. Energy and economic efficiency of selected solutions in the Polish climate.
Energy efficiency and environmental burden - emission of greenhouse gases, gases that destroy the ozone layer, gases causing acid rain, solid waste, sewage, the impact of buildings on the area and the environment.
Energy-efficient buildings and the internal environment - air quality and ventilation, thermal, acoustic and visual comfort.

c) lecture assessment

The component of completing the lecture is a colloquium – written test or on-line test.

d) seminar content

As part of the seminar, students presented topics selected from the list concerning a wide range of energy efficiency issues in buildings, such as passive construction, the use of renewable energy in buildings, spray insulation materials, in the form of granules, natural, daylight in buildings, ventilated facades, energy-efficient buildings, high tech or low -tech etc.).

e) seminar assessment

After the presentation, the lecturer asked selected people from the group to evaluate the presentation and to list the advantages and disadvantages of the presentation. It taught a critical but factual assessment of someone's work, and also allowed the presenting student to improve the presentation workshop. The lecturer assessed the quality of the presentation, whether the introduction was presented (main purpose and scope of the presentation), the specific idea (goal) of the solution, its features, including the principle of operation, advantages and disadvantages, examples of use with discussion, encountered construction problems, impact on the building and on the environment, costs of solutions, profitability, further development directions, etc., and finally a summary and conclusions. The time of the presentation was also assessed, which was given and it had to be relatively used, at the same time making sure not to exceed it too much.

f) general comments

The seminar on this subject took place in the last semester of engineering studies, therefore the students' speeches during it were a form of getting used to presenting the content in public, and thus preparation for the defense of the diploma thesis. Many times, there were also questions "from the audience" concerning the presented topics, which indicates the current interest of young people in the issues of the impact of buildings on the environment.

3. SELECTED STUDY COURSES WITH REFERENCE TO THE ISUSSES OF SUSTAINABLE DESIGN

Below there are presented brief descriptions of selected courses partially or fully connected to the sustainable development and environmental issues taught at different specializations and study levels of FCE of WUST.

3.1. Industrial Building (BSc level)

The course of Industrial Building has been implemented at the FCE in the mid-1970s. Currently, it is conducted in the form of lecture and classes. The latter consists of seminar and project parts, which means that students prepare both presentations given in the forum of the training group and perform individually selected calculations, traditionally included in the technical design (loads, structure variants, static calculations and dimensioning). Detailed topics include selected objects found in industrial plants, namely: industrial chimneys, cooling towers, structures carrying transport and communication galleries, tower tanks, silos and bunkers, polygonal landfills, tanks set on the ground and foundations for machines. Currently, issues connected to the environmental impact of different industrial plants as well as designing taking into account sustainability are included in the subject.

Already from 2010 the course is carried out in a mixed form, i.e. traditionally and using e-learning platforms: initially one privately developed, and currently using WUST e-Portal on. In the period of epidemic constraints related to the Covid-19 pandemic, switching to purely remote (real-time) learning did not pose any major problems. Both lectures and exercises were conducted with the use of ZOOM software, enabling the sharing of desktops both by the teacher and the participating students. The verification of the achieved learning outcomes was carried out: - in the case of the lecture, using multiple-choice tests (quizzes, offered by the Moodle learning management system); - in the case of classes, by arbitrarily assessing by the teacher (taking into account constructive critical comments from the student audience) the presentations of individual participants, documented in the form of design documentation.

3.2. Earth Structures and Landfills (MSc level)

Main aims of the course of Earth Structures and Landfills are as follows: presentation of methods for determining the geotechnical characteristics of soil material, developing the ability to select and evaluate the suitability of the material for the formation of earth structures and the use of techniques for improving and strengthening weak soils; acquainting with the principles of mechanization of earthworks and designing earthworks, including the use of new materials and technologies, and taking into account optimization criteria; developing the ability to independently determine the technology of earthworks depending on the type of object and taking into account geotechnical conditions; preparing students for cooperation in a

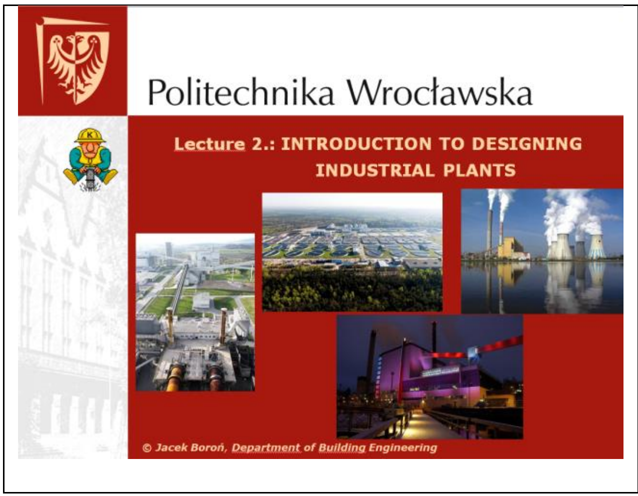

Fig. 3: Sample slides from the presentation of the Industrial Building (a) and Advanced Computer Aided Engineering (b)

project team and awareness of the need to search for new geomaterials and technologies for strengthening and stabilizing soil in earth construction. As constructional activities connected with earthworks and landfills have great impact on environment the aspects of their safe designing and exploitation are one of the most underlined during the realization of this course. Due to epidemic restrictions students completed the lecture based on an on-line test and in case of laboratory had to prepare written reports.

3.3. Computer Aided Engineering (MSc level)

Although this course does not refer directly to the problems of the sustainable design but it is dedicated to teach students how to apply modern, computer aided design techniques and software in the process of designing. Basing on the current design codes as well on the demands of construction of environment friendly structures the course gives students wider view on design process. It is also the first step to apply BIM technology which gives much more objective, precise and interdisciplinary approach to design. During computer laboratories students have to overworked different design problems on different concrete, steel or timber structures, as well have to give self-prepared lectures on structural design. In the epidemic time all labs were on-line ones, with very good interactive collaboration between participants.

4. SOME REMARKS ABOUT ON-LINE STUDY FORCED BY THE COVID PANDEMIC

From the beginning of the summer semester of 2020 till the end f the summer semester of 2021 all the courses at WUST were conducted in the synchronic mode using different internet platforms and applications: TEAMS, ZOOM, e-Portal (WUST own platform), Skype, WhatsApp, and others. The first three of them finally stayed as the main educational tools. Immediate necessity arose to adapt some specific courses, as practical laboratories to the classes-without-touching equipment – a lot of didactic films were recorded, while lectures and projects or seminars were adapted fluently.

The most important part and the most difficult one was creation of proper, flexible and credible system of verifying the students' achievement of learning outcomes, taking into account the distance learning mode. Below there are presented some recommended methods of verification for particular types of didactic activities.

Lectures:

- Exams and tests conducted remotely (using the WUST e-Portal, electronic file transfer, Moodle platforms).
- Oral examinations conducted according to the procedure of videoconferences (with registration) or on-line conversations (e.g. on a platform ZOOM, Discord or via MS Teams).
- Open-Book Exam, modeled on the examinations at the University of Oxford.
- Written exam or tests, cards with answers sent electronically.
- On-line partial tests, tests on Moodle.
- Activity monitoring - using the WUST e-Portal, file download control (big files service of the WUST, educational platform JSOS, e-mail), by means of confirming presence in the mode of teleconference lectures.
- Problem solutions, written studies on a given topic sent by students in electronic form.
- Tests carried out during lectures, tests solved on the e-Portal WUST platform.
- Final quiz at the e-Portal.
- Homework in the form of micro-projects.
- Preparation of a paper, essay, project, poster, presentation - summarizing lectures.

Diploma thesis:

- Individual consultations with graduate students in a remote mode.
- Analysis of experimental and literature data.
- Activity monitoring - using the WUST e-Portal, control downloading files ("Kangaroo" WUST service, educational platform JSOS, e-mail), using confirming presence in the mode of teleconference classes.
- Making an appointment with graduate students in laboratories for making measurements and practical studies.
- Prepared fragments / chapters of work transferred in the form electronic.
- Discussions by videoconference or by correspondence electronic.
- Electronic submission of the final version of the thesis.

5. CONCLUSIONS

In the CE study curricula at the FCE of the WUST there are some courses directly connected with environmental issues, but in many other courses there are subjects which indirectly refer to the aspects of sustainable and design that takes environmental protection into account. Some of these courses were briefly discussed.

Taking into account the influence of epidemic state and totally on-line way of giving classes some methods of verification of achievement the learning outcomes by students were described. It must be stated that both sides of the didactic process: teacher and students, very quickly adapted to the use of IT methods of in teaching.

Currently, from the starting semester a form of hybrid education mode is being introduced: lectures for big groups are presented on-line, and other forms of classes – just as it was earlier. However, all the possibilities of use of informatics educational platforms can be applied. So, there will be a new experience in teaching achieved.

THE RELATION BETWEEN CIVIL ENGINEERING STUDIES AT THE ARISTOTLE UNIVERSITY OF THESSALONIKI AND THE SDGS

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Key words: Education, Environment, Sustainable Development, Agenda 2030

ABSTRACT

Education, as described by SDG 4, is considered to be one of the main instruments for the successful implementation of the Sustainable Development Goals as defined by the United Nations and adapted by all countries of the world under the Paris agreement in 2015. Universities can play a crucial and unique role in the process of the implementation of the SDGs, since, by providing to their students, knowledge, and skills they will be able to contribute to this global goal through their current or future, as professional, activities.

Environmental educational programmes, especially on a postgraduate level, may have significant impact in the implementation of the SDGs, since they can approach several of the goals simultaneously, providing high quality scientific information to mature scientists. The Department of Civil Engineering of the Aristotle University of Thessaloniki operates a postgraduate programme on the protection of the environment under the concept of sustainable development for almost 25 consecutive years. With almost 700 graduates of, not only engineering background, but of other scientific fields relevant to the environment, this postgraduate programme has been established as one of the most important contributors to environmental education in Greece.

At the same time, the undergraduate study program of the Department of Civil Engineering of the Aristotle University of Thessaloniki, in operation for more than 65 years, provides high quality education. The study program is constantly being developed and adjusted to current needs, including the analysis of the SDGs.

In this paper, some of the main characteristics along with the most important milestones and achievements of these programmes are presented along with their relation to the SDGs

1. INTRODUCTION

Important global issues, such as the protection of the environment or mitigation and adaptation to climate change, impose the necessity of a drastic shift in our lifestyles and in the way we think and act. To achieve this transformation, we need new skills and competences, new values that can lead us to more sustainable societies. The important role of educational systems in this aspect lies in the need to define relevant learning objectives and learning contents and to introduce new teaching techniques that empower communicating and understanding. At the same time academic institutions acknowledge the need to adapt and include sustainability principles in their everyday management structures [1, 2, 3, 4].

The new 2030 Agenda for Sustainable Development, as defined by the United Nations and adapted by all countries of the world under the Paris agreement in 2015, includes the vision and the importance of an appropriate educational transformation. Education is described as a stand-alone goal – Sustainable Development Goal 4 "Quality education". At the same time, numerous education-related targets and indicators are also contained within other Sustainable Development Goals (SDGs – figure 1).

Fig. 1: The United Nations' Sustainable Development Goals

Education is both a goal and a means to achieve all the other Sustainable Development Goals. Apart from Goal 4, education plays an important role in communicating, understanding and engaging people, especially the younger generations who are still more approachable through education, in the implementation of almost all SDGs. It is not only an integral part of sustainable development, but also a key enabler for it. That is why education represents, probably the most essential strategy in the pursuit of the implementation of the SDGs [1, 2, 3, 4].

In September 2019, Jeffrey Sachs and his colleagues, published a paper introducing a new approach for the implementation of the SDGs, called "Six Transformations" [5]. The concept is that "The six transformations provide an integrated and holistic framework for action that reduces the complexity, yet encompasses the 17 SDGs, their 169 Targets and the Paris Agreement. They provide a new approach to shift from incremental to transformational change; to identify synergies using sustainable development pathways; formulate actionable roadmaps; and a focus on inter-relationships to uncover multiple benefits and synergies".

In these new six transformations, presented in figure 2, the important role of education is emphasized, and it is included in the First Transformation group of goals.

The first Transformation comprises three sets of interventions to promote education and gender equality and to lower inequalities. Education builds human capital, which in turn promotes economic growth, the elimination of extreme poverty, decent work, and overcoming gender and other inequalities [5].

Of course, this again refers to the direct inclusion of education in the process of implementing the sustainable development goals, being in fact one the goals. As mentioned above, the role of education is multi-fold since through education, one expects to build the tools that will support almost all other sustainable development goals or transformation groups.

Fig. 2: The Six Transformations to achieve the Sustainable Development Goals [5]

2. THE ROLE OF ENGINEERS IN THE PROTECTION OF THE ENVIRONMENT

The introduction of educational programmes focusing on the protection of the environment and the sustainable development in engineering curricula is a very challenging procedure due to two main factors [6]:

a) The fact that, historically, engineers played a very active role in economic development, and during some periods they actually formed the leading force, without although equally developing their social structure as well.
b) It is nowadays demanded by engineers to have broader knowledge and skills than the traditional ones, which used to focus mainly on the construction sector. There is an intense demand for engineers to provide sustainable and environmentally friendly solutions under the concept of Agenda 2030.

The latter is strongly supported by a recent article by Jeffrey Sachs, calling for the engineers to ensure climate safety [7]. According to Sachs “The next stage needs the world’s engineering experts on power generation and transmission, electric vehicles, hydrogen fuel cells, artificial intelligence for energy systems management, urban design for energy efficiency and public transport, and related specialists. Diplomats, rather than engineers, have been at the forefront at UN climate summits for the past 24 years. The time for engineers to take centre stage has arrived”.
Moreover, the importance of educating engineers, to successfully deliver on the SDGs, is highlighted in the recent UNESCO report on engineering: “Engineering education plays a crucial role in overcoming the challenges posed in achieving the SDGs. Achieving these goals necessitates a shift in engineering education away from a focus on academic technical knowledge towards a much broader interdisciplinary and complex problem-solving approach that combines societal and sustainable problem analyses with academic technical knowledge and solutions.” [8].

3. THE POSTGRADUATE PROGRAMME ON ENVIRONMENTAL PROTECTION AND SUSTAINABLE DEVELOPMENT

3.1 Introduction

Acknowledging all the facts described in the previous section, back in 1998, long before all these became an absolute universal necessity, the Department of Civil Engineering of the Aristotle University of Thessaloniki, decided to launch a new postgraduate program under the title "Environmental Protection and Sustainable Development". This postgraduate program, with a clear professional orientation, aims at training engineers and graduates from other related disciplines to the new technologies for the protection of the environment and to socio-economic and institutional issues closely related to the environmental design and structure in accordance with the concept of sustainable development.

3.2 Programme objectives

The main objectives of the postgraduate programme are:

- The promotion of interdisciplinary knowledge and research in the field of environment and sustainable development
- The provision of a high-quality postgraduate education and the promotion of a positive attitude and behavior regarding the sensitive issues of environmental protection and sustainable development
- The training of new graduates and professionals aiming at the upgrade of the human potential of the country in the context of a dynamic economic and technological development policy.
- The intensive specialization in the relevant vital issues aiming at the formation of well-equipped graduates from the programme and providing them with suitable means for professional careers in the public or private sector or for the continuation of their postgraduate studies at the doctorate level.

3.3 The curriculum of the postgraduate programme

The Postgraduate Programme "Environmental Protection and Sustainable Development" consists of course studiesand the elaboration of a thesis. The course studies concern the attendance of and the successful examination in postgraduate courses. Each individual course lasts a semester. Instruction in the courses includes lectures, laboratory work, elaboration and presentation of projects and seminars.

The preparation of an MSc thesis, which constitutes a specialized study under the supervision of one of the professors engaged in the programme, takes place in the summer period, following the spring semester.

The winter semester comprises the following four compulsory courses:

1 Environmental Impact Assessment
2 Natural Resource and Environmental Economics
3 Decision and Risk Analysis
4 Acquisition, Processing and Management of Environmental Data
   4.a Geographic Information Systems
   4.b Photogrammetry, Remote Sensing and Geoinformation Methods and Systems
   4.c Statistical Methods and Techniques

The spring semester comprises eleven courses, out of which each postgraduate student needs to select five. These optional courses are:

5. Sustainable Management of Water Resources
6. Protection and Restoration of Groundwater
7. Systems and Technologies for Waste Management
8. Transportation - Transport Policy and the Environment
9. Environmental Aspects of Spatial Planning
10. Integrated Coastal Zone Management
11. Air Pollution
12. Management of Natural Hazards
13. Environmental Geotechnology
14. Environmental and Energy Approach to Buildings
15. Renewable Energy Sources - Environmental Impacts

During the spring semester, the students have also to attend a seminar-type compulsory course, “Introduction to Research Methodology”. This course offers them the necessary competencies and skills to become successful researchers.

It must be noted that the curriculum of the programme has undergone several changes through times, in order to be more up to date, to include the latest scientific achievements and approaches and to be more attractive to students, always focusing on the goals of protection of the environment under the concept of sustainable development.

According to the current curriculum, the postgraduate programme “Environmental Protection and Sustainable Development” focuses on several Sustainable Development Goals. Apart from Goal 4 “Quality education”, the programme also focuses on Goals 6, 7, 8, 9, 11, 12, 13, 14 and 15, as presented in figure 3.

It must also be noted that the programme is in full accordance with the five of the “Six Transformations” (figure 2) and more specifically with 1, 3, 4, 5 and 6, while it is related with transformation 2 as well.

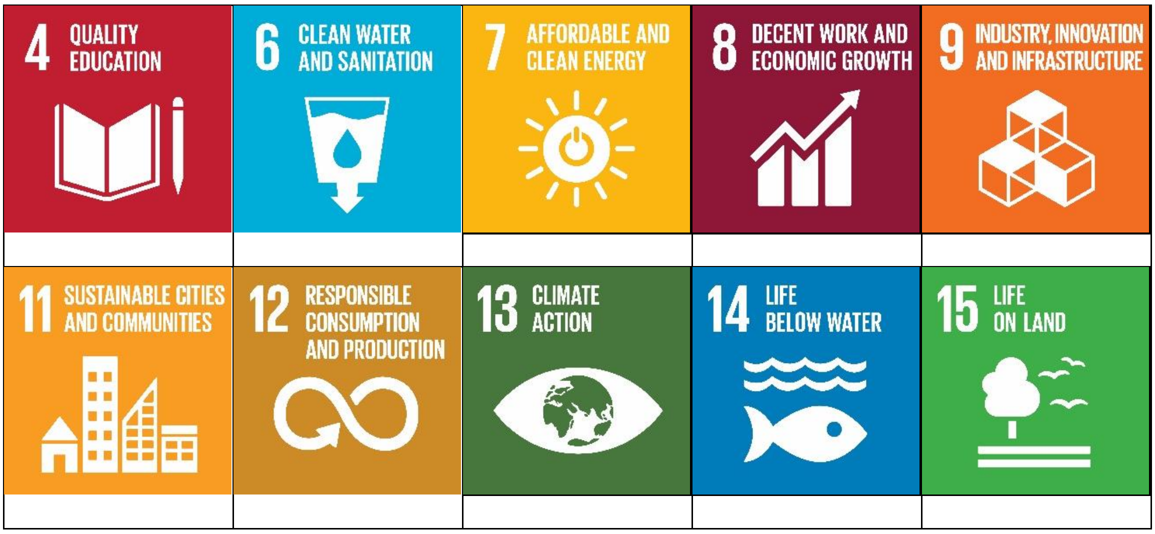


Fig. 3: SDGs related to the postgraduate programme

One of the common approaches to implementing education for the SDGs at the university level is to provide sustainable development degrees, which, being focused on developing expertise in sustainable development and across all the SDGs, aim to develop experts in solving sustainable development challenges, in bringing different stakeholders together to solve these problems, and in influencing organizational and societal change [9]. Our Postgraduate Programme encompasses most of these features to a quite satisfactory degree.

4. THE UNDERPOSTGRADUATE PROGRAMME OF THE DEPARTMENT OF CIVIL ENGINEERING

The Department of Civil Engineering has been educating engineers since 1955. The study program has been constantly being developed and adjusted to the current trends and needs. Through more than 100 courses offered by the Department, students need to attend to 41 compulsory courses and select 13 more, that are more suitable to their interests. The study program has not been built or even based on the approach of the SDGs. However, since the SDGs cover every aspect of our lives, the study program is more or less closely related to them.
In 2020, we performed an analysis, identifying the relation between the more than 100 courses of the curriculum offered by the Department of Civil Engineering, to each one of the 17 SDGs.
A graphical summary of the results of this analysis is presented in figure 4.

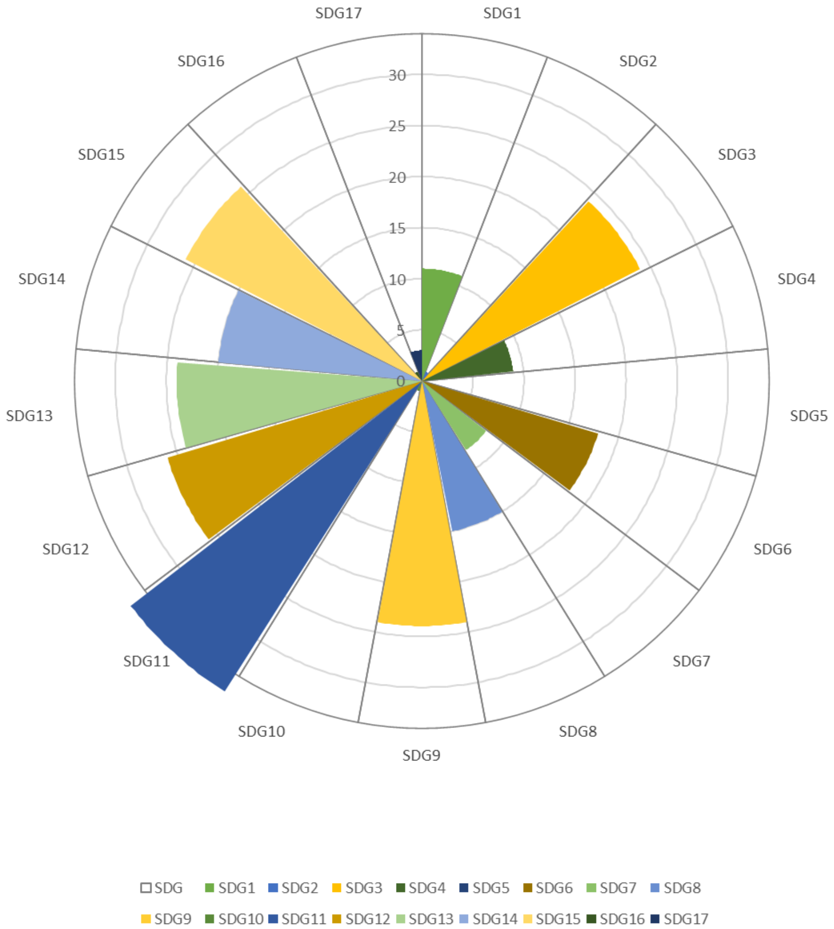
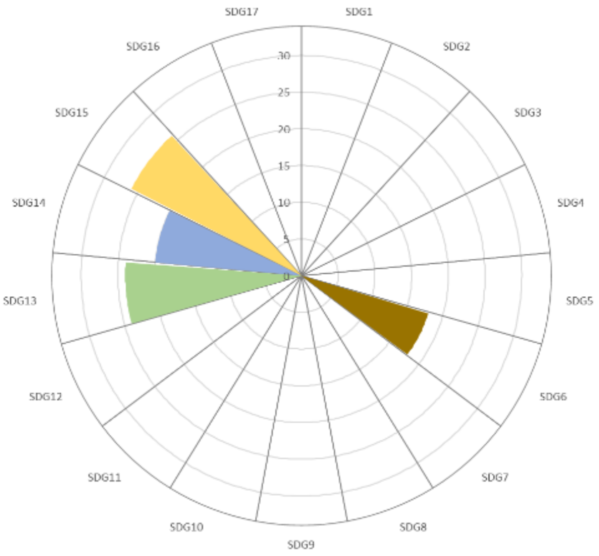
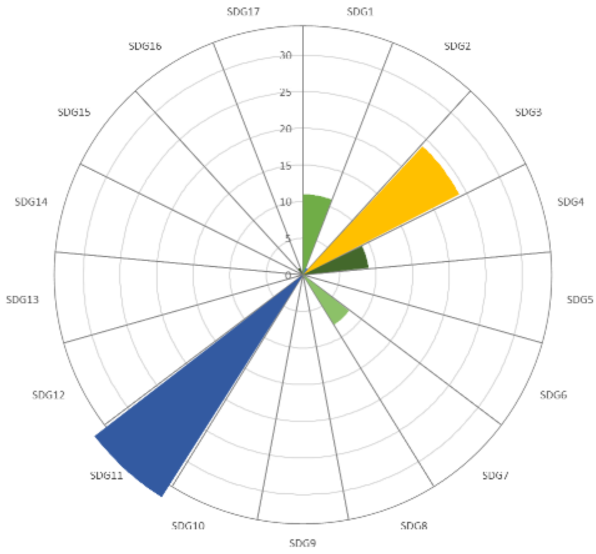


Fig. 4: Relation between the study program of the Dept. of Civil Engineering of the Aristotle University of Thessaloniki and the SDGs

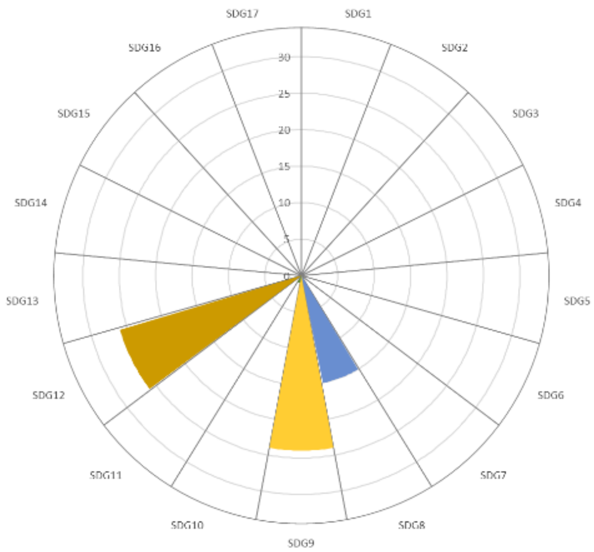
From the graph of fig.4 one can clearly identify that the goal more related to the study program is SDG 11 (Sustainable cities and communities), which is something to be expected from a Department of Civil Engineering. On the other hand, there some SDGs (namely 2, 5, 10, 16 and 17) which, much probably due to their specific targets, do not relate to any of the curriculum courses.
In the following figures (fig.5a, b, c), the relation between the study program and each one of the three pillars (Environment, Society and Economy) is presented.



(a) Environment



(b) Society



(a) Economy

Fig. 5: Relation between the study program of the Dept. of Civil Engineering of the Aristotle University of Thessaloniki and the three pillars of the SDGs

5. CONCLUSIONS

The role of Civil Engineers in the global effort to implement the Sustainable Development Goals is of outmost importance. This is why we need to invest in adapting the education of the new engineers so that they can understand the concept of the sustainable development goals and they can contribute to the process of their implementation.

The Department of Civil Engineering of the Aristotle University of Thessaloniki, along with many other similar institutions from all over the world, acknowledging this necessity, are focusing on the adaptation of their study programs to be as much as possible compatible with the implementation of the Sustainable Development Goals.

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INFUSE TEACHING WITH RESEARCH PRACTICES: A PILOT PROJECT – WELCOME PRESENTATION FOR FIRST-YEAR STUDENTS ON TIME SCALES IN CIVIL ENGINEERING PROJECTS

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Key words: design of educational material, time scales in civil engineering, geology, hydrology

ABSTRACT

The seed motivation behind this paper is the realization that time is not given its due as a concept in Civil Engineering. The corresponding education need is expressed with the question "what educational material can stress the importance of time and how can it be produced?". The approach chosen to answer the first part of the question was to juxtapose smaller and larger time scales and highlight their relevance to civil engineering projects in a video-presentation with the title "Earth, Water, Time and We, the civil engineers". The project described in the paper consists of two products: the video-presentation and the methodology, which addresses the second part of the question motivating the work. The methodology infuses teaching with the research practices of teamwork and peer review, hence the production of the educational material can serve as a pilot for other endeavors to raise the standing of education relative to research.

1. INTRODUCTION

This paper and the accompanying video-presentation address different thematic fields of knowledge and different physical perspectives within the civil engineering domain and its specializations, such as structural, geotechnical and hydraulic engineering. The scientific focus of the paper is time and time scales, notions known to pose perceptual difficulties as discussed in Section 3.5. The paper has a complementary target, namely, to outline a procedure of teamwork for the production of peer-reviewed educational material. The framework of the study is Civil Engineering Education, and hence the educational material developed concerns civil engineering projects. The paper belongs also in the interface of Philosophy of Science and Philosophy of Civil Engineering, since it focuses on the concept of time, a major topic in Philosophy, and its manifestations through civil engineering projects. The paper was written for an audience spanning the aforementioned thematic fields, aiming to attract instructors in departments of civil engineering as main interlocutors for the exchange of ideas.

The methodology followed for the production of peer-reviewed educational material, i.e. the video-presentation, involves three main steps: first choosing to focus on the general concept of time scales in Civil Engineering, then dressing it with a lecture, and finally executing the video-presentation following good practices. An analogy from literature would be to first choose the theme of a novel (e.g. for Anna Karenina: the relative power of romantic love against unshakable social conventions), then dress the theme with the plot and the characters, and finally write the novel [1]. Using the video-presentation as an example, the paper aims to: (1) propose an alternative way to choose content, i.e. not among topics of individual courses but, instead, to follow threads running through the entire curriculum, (2) demonstrate the practice of developing educational material that incorporates peer review and (3) prove the feasibility of teamwork for the production of quality educational material with an effort that can be accommodated in the busy schedule of a university instructor without remuneration.

2. EDUCATION PERSPECTIVE

Almost three decades ago, the renowned educator Lee Shulman [2] published his article "Putting an end to pedagogical solitude", in the suitably named journal *Change*. Shulman calls for an end to the solitary practices of most educators and the concomitant low respect commanded by education when compared to research. Shulman's main message to all educators is simple: *do education as we do research*, thus changing teaching from private to community property. Specifically, Shulman [2] suggests three strategies that can guide educators in this transformation. (1) Educators need to reconnect teaching to the disciplines (corollary: domain-general education tips will not command high respect). (2) If teaching is going to be community property, it must be made visible through artifacts that capture its richness and complexity. (3) If something is community property in the academy, and is thus deemed valuable, then educators will view it as something whose value they have an obligation to judge.

Guided by the three tenets put forth by Shulman [2], we produced a presentation with these characteristics: (1) a topic that unites different civil engineering subfields and highlights the omnipresence of the concept of time; (2) a product that is an artifact, captured in its final form in video format following rehearsals; (3) a procedure based on multiple peer reviews, as explained in detail in the paper.

3. DEVELOPMENT OF EDUCATION MATERIAL

The production of the video-presentation had a trajectory with several iterations and some zigzags. Four important factors made possible the collaborative work of the authors on a project that was not an explicit part of their duties.

(1) The core of the presentation was partially founded on pre-existing material (see Section 3.1 and Table 1: Section 5 of the Presentation) and the research interests of the second author, the more senior of the group, who was the instigator of thinking deeply about suitable time scales to study physical phenomena relevant to civil engineering projects.

(2) The first author, who has a publication record in Engineering Education, had prior experience in successfully drawing engineering faculty in engineering education projects.

(3) The occasion to deliver the presentation was offered by the 1st-year class of civil engineering students at the National Technical University of Athens (NTUA), who would start their studies online

in the fall of 2020, without being physically together with their fellow class mates and their professors. Since freshmen have just graduated from high school, the target audience also includes high school students in their final year. To this end, team members deliberately abstained (more or less successfully) from the use of specialized technical language (see also Section 3.5), in order for the presentation to be informative and, hopefully, attractive also for high school students contemplating studies in civil engineering.

(4) While working on the presentation, all authors became aware that the omnipresent time is often given secondary status as a concept in civil engineering. This realization strengthened their resolve to create a presentation worth attending for civil engineering instructors as well, since it highlights cross cutting aspects of time scales relevant to many civil engineering subfields (Shulman's first strategy). Standards were thus set high in order to have an educational product worth the time of peers offering review and worth writing a paper about (Shulman's second and third strategies). The ultimate goal is that this pilot project can serve as an example for other teams of civil engineering faculty to produce additional presentations on topics from the core of Civil Engineering, accessible to audiences broader than the students enrolled in the specific civil engineering courses.

3.1. Theme development and team formation

The title of the presentation is "Earth, Water, Time and We, the civil engineers" and its subtitle is "Time scales in civil engineering projects and their relevance in Geology for Engineers (1st semester) and Engineering Hydrology (5th semester)". The reference to specific courses of the civil engineering curriculum at NTUA and corresponding semesters is meant to offer freshmen a preview of their studies. However, the presentation is not tied to specific courses. If the presentation were a play, its main actor would be time. The choice of the theme was prompted by a presentation given for a broad audience of scientists and engineers by the second author, which included observations of earth temperatures as far back in time as measurement and proxy records go. The decision to focus on time followed from discussions between the first and the second author. "Time and change" was also a theme discussed by the first and third author in a previous collaboration for the production of educational material. The third and fourth authors are co-instructors of the course "Geology for Engineers" taught in the 1st semester of the civil engineering curriculum at NTUA. But, the presentation is not meant as part of a geology course. The representation of diverse subfields of civil engineering within the author team made possible to showcase the relevance of one theme (time & time scales) to different areas within Civil Engineering, thus offering to novice students a semblance of a bird's eye view of their chosen field. Figure 1 contrasts the unifying approach to content followed herein to the frequent practice of presenting concepts in individual courses without drawing attention to connections to other courses of the same curriculum.

3.2. Content development and review

To ensure that the separate contributions form a coherent whole, the authors developed the presentation by gradually dressing the theme with layers of garments, so to speak. To this end, authors proposed ideas highlighting the theme in their area of expertise. Some ideas had to be pruned, both to keep the duration of the presentation to about forty minutes, and to ensure flow between the sections of the presentation and create a coherent plot. With the plot more or less fixed, the next step was the creation of a storyboard, in the form of titles of PowerPoint Slides and rough descriptions of each slide. Finally, once the storyboard was finalized, the PowerPoint Slides were produced and a full script was written by two authors.

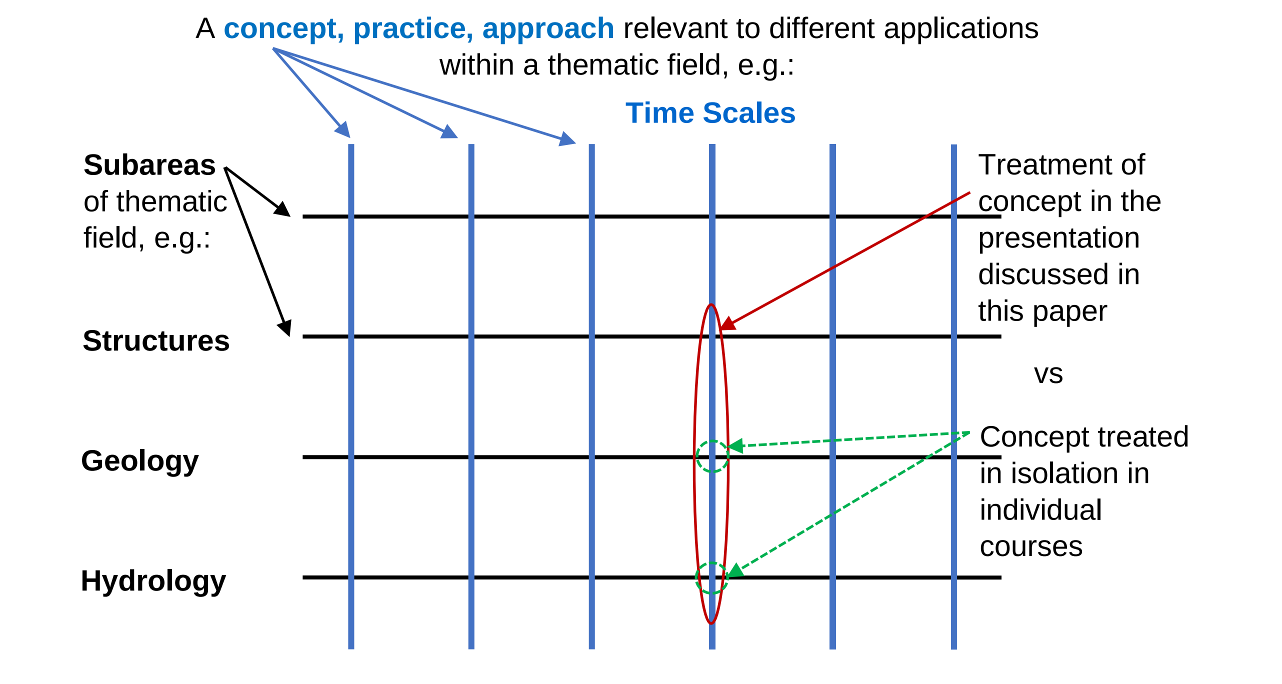

Fig. 1: Presenting a general concept in the thematic field of Civil Engineering (e.g. Time Scales) spanning different subareas of the field vs discussing the same concept in apparent isolation in individual courses (e.g. Structures, Geology, Hydrology).

Review was a structural component of the methodology for content development. Internal review (within the team) was done according to the three musketeers' motto "One for all, all for one". The first four authors commented on each author's contribution at two stages of the development of the presentation: at the storyboard stage and at the stage of the PowerPoint presentation. Only the final script was reviewed solely by the first author. This close collaboration between the authors made them responsible for the entire presentation, so that each one could deliver the entire presentation.
External review from civil engineering faculty was sought during the first delivery of the presentation on October 29, 2020, through an online platform. Reviewers were asked the following questions: (1) Does the presentation have an authentic "civil engineering taste"? (2) Did you spot in the presentation elements offering to high school students – candidate students in our program a preview of their studies? (3) Do you disagree with some technical content, or do you have a modification to propose? Comments were received from two colleagues who were generally positive about (1) and (2) and had no disagreement with technical content. An important comment was that it would be desirable to make the presentation less conceptual and more applied, in order to make it more attractive to high school students. In response to this comment, the second author invited the fifth author, who was responsible for (i) identifying a suitable case study for the hydrology part of the presentation (flood protection work at Spercheios River: Section 5 in Table 1), (ii) writing the full script for Sections 4 and 5 of the presentation (see Table 1) and (iii) producing the video for the last three sections (Sections

4, 5 and Epilogue). The video-taped lecture of October 29, 2020, was reviewed one last time by all the authors before recording the final video-presentation.

3.3. Final video-presentation

The presentation consists of five main sections, demarcated by slides with the titles of each section (Table 1), preceded by an introduction and followed by an epilogue. The final presentation was produced by joining separately recorded videos and has a total duration of 42 minutes. The video is in Greek and is available at this link. The supplementary files (slide titles with full script, and presentation, in Greek, with slide-by-slide references are available at this link). The section titles and main points of the final presentation are included in Table 1 and its plot is summarized below.

The Introduction familiarizes students with the faces of the instructors, who are not visible during the presentations, and prepares them to attend an extended trailer of their future studies. The subtheme of Section 1, "Age of contemporary civil engineering works", was chosen as a student-accessible introduction to the notions of time and time scales. It draws content from Structures and invites students to guess "how long civil engineering structures live" before introducing the concept of useful life of a civil engineering work (of the same order of magnitude as human life). At this point, students are encouraged to (i) search –after the presentation– for civil engineering projects in Greece that interest them, (ii) choose one and note its actual age and (iii) submit this information as an optional assignment (see Section 3.4). Section 1 ends by juxtaposing the age of the buildings and the age of the earth they are built on, thus providing a segue to Section 2. The main idea of Section 2 is that "the earth is alive". However, we often need to speed up time to perceive the changes of geological environment, whether these changes are fast or slow (in a geological sense) in more or less active geologic environments, respectively. Soil- and rock-forming processes and rates are mentioned as specific examples of gradual changes and as an introduction for students to guess the soil vs rock coverage of the land surface in Greece. Section 3 alerts students to the possibility of rapid changes of the geologic environment with the subtheme "Civil engineering works and their dynamic relationship with geologic time". Section 3 showcases the challenges posed by geological environments to infrastructure projects and concludes with the Vajont Dam catastrophe. Following the discussion of time scale issues relevant to earth, Section 4 provides a pivot point for the presentation with its general theme "We study the past to predict the future", in particular different elements of the future that will affect different civil engineering works, e.g. flood flow for a bridge. Then, Section 5 alerts students to the possibly unanticipated finding that we observe "different trends of temperature-sea level & rainfall at different time scales". Finally, the Epilogue encourages students to be unafraid of change, since civil engineers have become quite adept at counteracting the effects of natural phenomena, hence the subtitle of the Epilogue is "Sanctus for engineers".

Table 1: Structure of presentation "Earth, water, time and we, the civil engineers"

Section title	**Section Main Points**
Introduction	• Introduction of instructors with photographs at their offices • Scope of the talk: a cohesive preview (trailer) of civil engineering studies
1. Age of contemporary civil engineering works	• The concept of useful life of civil engineering works (50 – 100 y), of the same order of magnitude as human life • A prompt for attendees to search for civil engineering works and their age • The need to consider longer time scales since civil engineering works are constructed on earth and earth is very old (how old?)
2. The earth is alive – the geological environment and its changes through time	• Difficult to perceive geologic changes in our lifetime, impressive changes in fast forward (180 million years ago → today) • Contrast of more and less active geologic environments at the present geologic time • Rates of soil formation through rock disintegration and rock formation through soil diagenesis • How much soil vs rock on the land surface of Greece?
3. Civil engineering works and their dynamic relationship with geologic time	• Section overview: ongoing geologic changes due to earthquakes, fast geologic changes due to rapid sedimentation and landslides • Kakia Skala, West Attica, Greece: the need to accommodate active faults in the design of transportation works • Thermopylae, Spercheios river Delta, Central Greece: narrows in 480 BC, soft sediment flatland today • Vajont Dam, North Italy: a rock slide of 270 $x10^6$ m^3 earth material creates overflow of 30 $x10^6$ m^3 water, killing 2000 people
4. We study the past to predict the future	• We need long time series of measurements to design our structures, e.g. of flood flow for a bridge, of wind velocity for a skyscraper • Based on past measurements, we use probability theory to construct potential future loadings for our structures
5. Different trends of temperature-sea level & rainfall at different time scales	• Trend of temperature increase in the last decades? How big is it? How does it compare with past temperature trends? • Estimates of global temperatures based on Ice Cores from Greenland correlate well with estimates of global sea levels and go back to 20 000 BC. • Over the last 10 000 years, i.e. the span of human civilization, temperatures have been, compared to the past, elevated and relatively constant. • Rainfall measurements in the last 70 years reveal no trend. A 150-year record of rainfall peaks shows increased frequency of such events in 1960-1980. • How do civil engineers manage such peaks? By lessening their consequences with structures like the flood protection works for the Spercheios River.

Epilogue – Sanctus for engineers	• By going far back in time, we understand better natural phenomena and can make better predictions. • Earth is ever changing, but change is not necessarily bad, especially considering civil engineering achievements since 1900: deaths from droughts and floods have dropped drastically. • By choosing to study civil engineering, you follow on this great tradition, which you can further improve.

3.4. Intended audience and learning activities

A lecture with an unusual subject requires explicit mention of the main and secondary audiences envisioned for the video-presentation, the respective purposes for the different audiences and the desired activities resulting from attending the presentation. The primary audience is freshmen at the School of Civil Engineering at NTUA. By attending the presentation early in the first semester, the students get a preview of their studies, as already mentioned. More than that, they also get a glimpse of the philosophy of the School: the pride in being and becoming a civil engineer (see Epilogue in Table 1) and the opportunities given to the students for closer involvement with the School (even a welcome talk has optional homework). From about 100 freshmen attending the presentation in the Fall of 2020, seven submitted the optional homework assignment (their names are included in the acknowledgements). The care students took in describing their favorite project made clear their enthusiasm for their chosen field of study. In a virtuous feedback loop, submitted homework motivated the first author to broadcast this enthusiasm back to the School, by creating a 3-page "bouquet of civil engineering works" that was uploaded to the School's webpage. The bouquet consists of the following notable projects: a 465 m-long concrete box girder bridge built in 1970 over an artificial lake created by a dam, a 490 m-long steel bridge built in 2016, a 3580 m-long tunnel built in 2009, a 910 m-long underwater tunnel built in 2002, a complex of cylindrical apartment buildings built in 1974, a 103 m high rise building built in 1972 (the tallest building in Athens, and one of its very few high rises, known affectionately as "the Tower of Athens"), and the monumental building of the Academy of Athens built in 1885.

Another envisioned audience for the video-presentation is high school students contemplating studies in Civil Engineering. These students can watch the video in their own time, or together with one of the authors, or with any other civil engineering faculty willing to discuss the contents of the presentation with students and answer questions they may have about civil engineering studies and the profession.

Lastly, a very small but very important audience for the video-presentation is civil engineering faculty considering the possibility to create additional stand-alone video-presentations for audiences broader than the students enrolled in specific civil engineering courses.

3.5. Good practices followed and lessons learned

The presentation consists of short sections, as recommended for online materials [3]. The total duration of the video-presentation is 42 minutes, but the sections are self-contained and the separate slides introducing the subtheme of each section are suitable break points for watching the video in segments.

As already mentioned, technical terminology (jargon) was avoided to the extent possible. Technical terms, with their proper definition, serve the purpose of scientific accuracy and precision and are crucial for experts in a thematic field, also facilitating communication among them. As a result, experts often do not realize the extra cognitive effort required by non-specialists to follow texts and presentations including technical terms, especially if their meaning is not transparent. This frequent inability of experts to recognize the learning difficulties of novices is described in the education literature with the very transparent term “the expert blind spot” [4].

When the presentation was first delivered with streaming, it included four multiple-choice quiz questions, three of which were presented as poll questions. To save time, one question was presented as a “guessing question”, followed by a pause for the students to make a note of their answer (although not asked to respond, quite a few students answered anyway using the chat function). Research has shown that short quiz questions strengthen learning [5]. Self-quizzing also has beneficial effects on learning [6]. In the final static version of the presentation, all four quiz questions are delivered as guessing questions, followed by short pauses and discussion of the answers.

The last piece of good practice concerns full attribution of sources, in order to set an example for the habits students are expected to develop during their studies. Full references of all sources used in the slides are included, slide by slide, at the end of the presentation, for every third-party material used in the presentation, including creative works (videos, photographs). Creative works used are either accompanied by a Creative Commons license or, if not, permission was asked and granted by the copyright owner, and the permission is acknowledged.

Lessons learned include the practical realization that quality education materials produced collaboratively require significant production and coordination time. What is more, the focus of the presentation on time highlights a perennial difficulty of the human brain to perceive time. According to a major synthesis study on learning of science and engineering topics, students have incorrect understandings about fundamental concepts, particularly those that involve very large or very small temporal and spatial scales [7]. The philosopher Aristotle, following on the footsteps of Plato and differentiating himself from his teacher, stated that without perceiving some movement or some change, humans cannot perceive time. Or, more succinctly, “without change, there is no time” [8]. This cognitive limitation is very relevant to slow-moving processes, as is the case in geology: time is passing but we humans often do not see change in our life time. When the human brain cannot reconcile seemingly non fitting entities, it discards those that do not fit and are easiest to discard. So it discards change. This need to better understand change may be more salient for Civil Engineering, where dynamic processes are often analyzed with pseudo-static models.

4. CONCLUDING REMARKS

The work described in this paper was motivated by the two-part question “what educational material can stress the importance of time in Civil Engineering and how can it be produced?”. The first part of the question is answered by an example, the video-presentation described herein, while the second part of the question is answered by offering a methodology that can be adapted for the production of similar material.

- The video-presentation was produced as a transferable educational product, i.e. a product usable by instructors other than those developing it. To enable transferability, the open access video-presentation is accompanied by (i) the statement of the educational need it addresses (to offer a trailer for civil engineering studies and to highlight a cross-cutting theme) and (ii) condensed descriptions of the product. To this end, we codified the structure and the content of the presentation in a table format so that, in conjunction with the full list of the slide titles, PowerPoint Slides (in Greek) and references provided (online), any part of the presentation can be used by other instructors.
- The main elements of the methodology are (i) close teamwork, (ii) selection of an important theme, (iii) development of the presentation in stages, starting from the theme and progressing to the ideas (subthemes) supporting the theme, to the storyboard, to the plot and finally to the full script, (iv) peer reviews, provided by each team member at intermediate stages and by external reviewers for the final presentation, and (v) the incentives of visibility and recognition, within the School of Civil Engineering at NTUA (announcement through the School's webpage and permanent links for the video and the accompanying files) and within the civil engineering education community (publication of this paper).
- Freed of the constraints of individual courses, the authors were able to choose as a theme an eternal big idea and frame it with civil engineering projects. The collaborative production of educational material on the cross-cutting theme of time gave the authors the opportunity to ponder at an abstract level its nature and to realize the perceptual difficulties posed by time, already recognized at the beginning of the philosophy as an organized discipline by Plato and Aristotle and, more recently, by researchers on education in science and engineering.
- The recognition of difficulties in perceiving widely varying time scales and their relevance to civil engineering instruction guided the authors to mitigate these difficulties by talking about the essence of time effects mostly with examples familiar to students and without using jargon.
- By showcasing a methodology employing the research practices of teamwork and peer review, we propose that the project presented herein serve as a pilot for the production of peer-reviewed educational artifacts.

5. ACKNOWLEDGEMENTS

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EDUCATING CIVIL ENGINEERS FOR ACHIEVING SUSTAINABILITY IN THE BUILT ENVIRONMENT

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Key words: building energy and environmental performance, building physics, SDG11

ABSTRACT

The last decades the role of the built environment on achieving sustainability goals has gained much attention. It is not only the energy performance of buildings that is being widely discussed, but also the synergies between the building and its immediate surroundings, their impact on the environment during their life cycle, as well as their interactions with future estimated climate conditions. At the same time, the built environment directly influences the health and the wellbeing of the citizens, while the decisions for its configuration have also strong social and economic extensions. Based on the above, it is clear that there is a need to promote the efficient design of buildings and built areas, so as to mitigate the climate change impacts, advance sustainability and ensure a better future for all.

Within this context, the Civil Engineering Department of the Aristotle University of Thessaloniki has introduced relevant courses in the curricula of both the graduate and the postgraduate study programs. In this presentation, the educational approaches and the expected learning outcomes of the courses underlying the relationship between sustainability and built environment are presented. At the same time, an outlook on the theses elaborated on the field of sustainability in the built environment is given, highlighting the individual fields within the specific area. Additionally, further educational actions taken for graduate and postgraduate students, such as introducing them to research projects and outcomes, promoting their participation in national and international conferences and events in the field, as well as supporting partnerships and communications within the academic community, develop the knowledge, skills, values, awareness and global thinking towards more sustainable patterns, both at a personal and at a professional basis.

1. INTRODUCTION

From the appearance of humans on earth till today, engineering has contributed to protect man from natural hazards, provide shelter and infrastructure, cover the basic needs of water and sanitation, promote health and quality in life, manage and produce resources, etc. It is not an exaggeration to say that engineering is combined with every axis and activity of human life, especially today, when engineering and technology are interconnected and practically unified. In fact, engineering is considered as one of the basic pillars of the economy.

However, unlike the previous centuries, when natural sources were regarded as unlimited, nowadays engineering has to contribute and promote sustainable development, "through which the needs of the present are met, but without compromising the ability of future generations to meet their own needs".

The new role of engineering demands not only the basic technical and scientific knowledge of the engineering disciplines, but requires strong backgrounds on new subjects, including social and environmental issues, within the context of sustainability, as well as new skills that will empower them to evaluate and solve critical challenges.

The biggest challenge of our era is undoubtedly climate change, the impacts of which are global in scope and unprecedented in scale. The latest scientific report by the IPCC finds changes in the Earth's climate in every region and across the whole climate system [1]. The report clearly acknowledges the role of human influence on determining the current climate system, but it also highlights its potential for determining the future course of climate as well, pointing to strong and sustained reductions in emissions of carbon dioxide and other greenhouse gases to limit climate change.
Within this context, the built environment, i.e. the buildings with their surrounding open spaces, has an important role. It is responsible for a significant share of the consumption of energy and resources; in Europe, 40% of the consumed energy and 36% of CO2 emissions are associated with the building use, while 50% of all extracted materials and 30% of water are consumed during the construction and use phase of buildings [2]. At the same time, the embodied carbon in the built environment has been estimated to 10-12 % of total carbon emissions in several member states. Construction and demolition waste are one of the heaviest and most voluminous (25%-30%) waste streams generated in the EU. These figures clearly indicate the importance of sustainable buildings and construction approaches along with energy and resource efficiency throughout the supply chain.
The importance of sustainable housing is also acknowledged in the UN's SDGs. Among the SDGs, the 11th is focused on making cities and human settlements inclusive, safe, resilient and sustainable. Within this context, affordable, healthy and efficient housing, in terms of energy and environmental performance, along with green and attractive open spaces, are among its main targets; in fact, their significance is justified not only by their relevance to climate change adaptation and mitigation, but also by the fact that the world built-up area per capita is increasing consistently and very fast.
Many civil engineers allocate their activities on the built environment through the study and the construction of new buildings and open spaces, the renovation of existing structures, as well as the conservation and restoration of monuments. In order to provide sustainable solutions in the construction industry, future and present civil engineers should be accordingly trained; on one hand, awareness should be raised and on the other hand a compact scientific background on relevant topics should be built; for future civil engineers significant knowledge can be obtained through the curricula of their engineering schools, while present engineers could utilize life long education modes, such as seminars, symposia and short-term schools in order to get the required information.
The Laboratory of Building Construction and Physics of the Aristotle University of Thessaloniki is educating students and engineers on topics associated with the sustainability in the built environment. For communicating the knowledge, the members employ several educational tools and activities. They will be described in the next sections in detail, along with SDG11 objectives.

2. SDG11: SUSTAINABLE CITIES AND COMMUNITIES

Cities are hubs for ideas, commerce, culture, science, productivity, social, human and economic development. Urban planning, transport systems, water, sanitation, waste management, disaster risk reduction, energy use, access to information, education and capacity-building are all relevant issues to sustainable urban development [3]. The importance of urban development is depicted in SDGs, as a stand-alone sustainable goal is devoted on urban issues.

Fig. 1: SDG11 and its targets [4].

The individual targets for SDG11 (Figure 1) concern:

- access for all to adequate, safe and affordable housing and basic services and upgrade slums,
- access to safe, affordable, accessible and sustainable transport systems for all, improved road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons,
- inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries,
- efforts to protect and safeguard the world’s cultural and natural heritage,
- the number of deaths and the number of people affected and the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations,
- the environmental impact of cities, by paying special attention to air quality and municipal and other waste management,
- the universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities, together with
- the support of positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning,
- the increase of the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and
- the support of least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials.

From the above targets, several are directly related to buildings and their immediate environment; indeed, green and sustainable built environments contribute to safe and affordable housing, protection of the environment through the decrease of conventional energy sources and decrease of pollutants, limitation of the environmental impact of cities, resilience, protection of cultural and natural heritage, as well as adaptation and mitigation to climate change impacts.

Yet, it must be highlighted that urban issues have a cross-cutting nature and apart from SDG11 they are approached in SDGs 1, 6, 7, 8, 9, 12, 15, and 17, among others.

3. THE STYDY PROGRAM OF CIVIL ENGINEERING DEPARTMENT OF THE ARISTOTLE UNIVERSITY OF THESSALONIKI

The undergraduate studies of the Civil Engineering Department of the Aristotle University of Thessaloniki comprise a five-year course of study, divided into 10 semesters. The aim of the study programme is to initially provide the graduates with the necessary knowledge, so as to acquire a robust theoretical background in Civil Engineering, as defined by modern technical, social and economic reality. The core compulsory courses are spread over the first 7 and part of the 8th semester. The specialization, which begins in the 8th semester, continues through the 9th semester with the attendance of courses. It is completed in the 10th semester with the elaboration of the diploma thesis that has a research character and lasts one semester, in the division that the student has selected. However, it is possible for the student to select and prepare an interdisciplinary diploma thesis with the collaboration of professors from different divisions of the School. There are four basic specialization areas: Structural Engineering, Hydraulics and Environmental Engineering, Geotechnical Engineering, Transportation and Project Management.

To be awarded the Diploma, students are required to attend and successfully pass examinations in 54 courses (41 core courses, 6 compulsory elective courses and 7 non-compulsory elective courses) corresponding to at least 300 ECTS credits. Due to this specialization and the study program's organization, the diploma of the civil engineering is equivalent to a master's degree.

Graduates of the School of Civil Engineering, upon successful completion of the study programme requirements, further to the basic knowledge of their science and their profession, have also been trained so as to have the ability to 1) apply their knowledge in practice, 2) search, analyze and synthesize data and information using also the necessary technologies, 3) adapt to novel situations and make decisions, 4) work independently or in groups in international and/or interdisciplinary contexts,5) generate new research ideas, design and manage projects, 6) respect the diversity, multiculturalism and the natural environment, 7) demonstrate social professional and moral responsibility and sensitivity on gender issues, 8) view themselves as well as others critically, 9) promote inductive and deductive thinking.

In 2020 the undergraduate program was submitted to the external evaluation & accreditation process and inspected by a Committee of Independent Experts. According to the report of the Committee and the certification decision of ETHAE, the Undergraduate Program of the Department of Civil Engineering, AUTh. **fully complies** with the quality assurance principles of the European Higher Education Area.

4. EDUCATING FOR SDG11: THE PARADIGM OF LBCP

In the study programme of the Aristotle University of Thessaloniki, the courses that are related with structures cover a significant share (33%) over the total number of offered courses. Civil engineering profession encompasses building design, construction and management through its life cycle. Within this context, the Laboratory of Building Construction and Building Physics has a significant educational role, with a special focus on sustainability.

4.1. The Laboratory of Building Construction and Building Physics: a short description

The Laboratory of Building Construction and Building Physics (LBCP) belongs to the School of Civil Engineering and covers the areas of building construction methodology and details, industrialized building systems, building physics, energy conservation, energy performance and conscious design of buildings, environmental assessment of buildings, use of passive solar systems, fire protection and safety, restoration of historic buildings, as well as architectural design.

Since the Laboratory's foundation in 1958, its presence in the scientific community is constant, due to the organization of international conferences and events, participation in national and international research projects and associations. The activities of the Laboratory are mainly performed by its 5 members of the educational staff, 5 PhD and the post-doc researchers.

More specifically, the Laboratory contributes to various applied research programmes with the use of state-of-the-art measurement and recording systems, such as meteorological stations for measuring solar radiation, air temperature, humidity and air velocity, infrared cameras for measuring thermal flux and locating thermal bridges, thermal conductivity meters, heat flux meters, systems for infiltration/ ventilation measurements, luxmeters, CO2 measurement devices, etc. Apart from monitoring techniques, the Laboratory members use up to date simulation tools, which are used to model the building's performance.

The research activities of the Laboratory expand over a broad thematology and cover every area of building physics, i.e. thermal performance of the building envelope (including the analytical and experimental study of thermal insulation and water proofing materials), daylighting, comfort (including thermal, visual, sound, IAQ), design and evaluation of passive solar systems and bioclimatic buildings, nature based solutions, monitoring and evaluation of the energy performance of buildings, energy renovation of existing buildings, advanced glazing, solar protection, environmental assessment, life cycle analysis, and sustainability in the built environment in general.

Members of the Laboratory have participated in the elaboration of the policy framework and the regulation for the building energy performance in Greece and Cyprus, which include the requirements for the thermal protection, infiltration and ventilation, solar protection, etc.

4.2. The educational activities of LBCP in the Civil Engineering Department

The members of LBCP offer courses in the graduate and postgraduate program of the Department of Civil Engineering, the postgraduate programs organized by other departments of the Polytechnic School of the Aristotle University of Thessaloniki and the Hellenic Open University, as well as in lifelong educational activities for engineers.

4.2.1. In the graduate level

The education of civil engineers in sustainability in the built environment starts with the core courses **Building Construction I** (https://qa.auth.gr/en/class/1/600193053) and **Building Construction II** (https://qa.auth.gr/en/class/1/600192928), which are taught at the 4^{th} and 5^{th} semester of the graduate studies program. They are both a significant introduction to the main subjects of constructing a building project, i.e., defining the construction steps and methods, designing in full detail the building elements in order to comply with safety, comfort and energy performance criteria, making justified decisions on the selection of materials, etc. More specifically, the content and the learning outcomes of Building Construction I and Building Construction II are presented in Table 1. Being core courses, they are attended by all students.

After the background is set, the students have the opportunity to delve deeper into the context of sustainability in buildings by participating in the elective courses offered by LBCP:

- **Fire protection of building structures** (https://qa.auth.gr/en/class/1/600193077) offered in the 8th semester,
- **Special topics in building construction** (https://qa.auth.gr/en/class/1/600193059) offered in the 8th semester,
- **Energy saving design in buildings** (https://qa.auth.gr/en/class/1/600192936), offered in the 9th semester
- **Environmental architectural design in buildings,** offered in the 9th semester (https://qa.auth.gr/en/class/1/600192924).

Each one of these courses specialises in different axes of building physics, the understanding and assessment of which leads to sustainable building environments. The content and the learning outcomes of the elective courses are presented in Table 1. The competences acquired through the successful participation in the courses is listed on each course website (given above).

The elective courses offered by the Laboratory are rather popular among the graduate students; this is due to their consistently updated context and their direct connection with the civil engineering profession. More specifically, although the students can choose their elective courses among a total number of about 68 elective courses, almost 1/3 of them choose to learn more on subjects relevant to the sustainability in the built environment. It is worth mentioning that the participation rate on such courses (shown in Figure 2, for the last 5 years) shows an increasing trend, especially as regards the courses that focus on the building energy performance.

The figures and trends gain more significance, if one takes into account that the courses “Fire safety of building construction” and “Special topics in building construction” are offered in the 8th semester, among 27 other elective courses from all sectors, and the student can only choose 2 out of them. Accordingly, the courses “Energy saving design in buildings” and “Environmental architectural design of buildings” are offered in the 9th semester, among 41 other elective courses, from which the students can only choose 5.

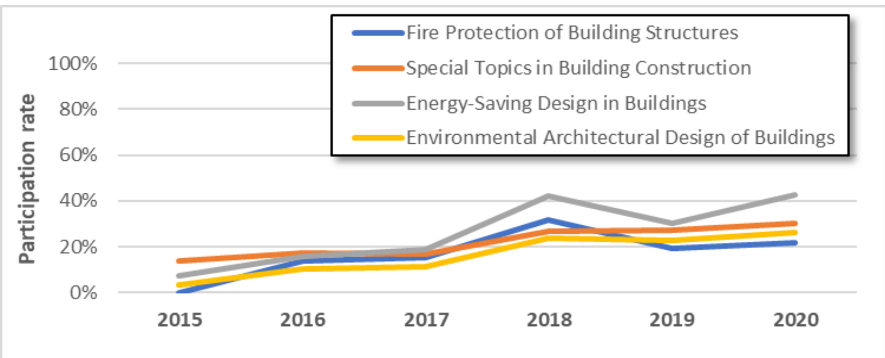

Fig. 2: The participation rate of the graduate students in the elective courses offered by LBCP.

Table 1: The content and the learning outcomes of the core and elective courses offered by LBCP.

Courses	Content	Learning outcomes
Building Construction I	● Building foundations: types, ground water control, waterproofing. ● Bearing structure of buildings: Types, materials, building components. ● Stairs: Elements, types, design, construction, support. ● Masonry: Types, materials, thermal, noise and moisture protection. Finishes. Wall and ceiling lining. ● Fenestration: Types and functions, criteria of selection, thermal and optical properties, shutters, details. ● Roofs: Flat & inclined roofs, types and morphologies, structural elements, thermal and moisture protection of roofs, design, details.	● Know all necessary works for the construction of a building project ● Understand the hygro thermal requirement for each element of the building envelope and be in a position to propose specific design solutions. ● Design in full detail stairs that satisfy all building regulations, safety and comfort requirements and provide alternative design solutions. ● Design sloped roofs, flat roofs in all design scales and provide various alternative construction details for their construction according to all requirements.
Building Construction II	● Thermal protection of buildings. Thermal balance, thermal comfort. Thermal insulation materials. Thermal capacity, thermal bridging. Regulation for the Building Energy Performance. Requirements and standards. ● Domestic plumbing services: Cold water supply system and installation, drainage and sanitary systems. ● Moisture protection: sources of moisture in buildings, condensation, vapour barriers, calculations. ● Floors: types, materials, constructional techniques, details. Stairway and balcony finishes. Handrails and balustrades of balconies. Outdoor floor finishes.	● Understand specialized areas of building physics and its performance against natural phenomena, as well as their influence on the building envelope design. ● Know the properties of thermal and moisture protection materials. ● Determine the layers composing a building element. ● Conduct the study of thermal insulation of a building. ● Acquire new knowledge and experience related to the formation of healthy and comfortable conditions indoors.
Fire protection of building structures	● Fundamental principles of fire. ● Evolution of fire technique. ● Ignition in natural combustions. ● Heat transfer and mechanisms. ● Basic approaches of buildings' fire protection. ● Framework of fire safety regulations in Greece (national legislation). ● Reaction to fire and fire resistance tests. ● Analytical methodologies to determine the fire resistance of building components. ● Eurocode 1. Software.	● Understand the fundamental principles regarding fire (fire development and spreading). ● Understand the fire enclosure dynamics issues and their complexity. ● Obtain the necessary scientific background on the adequate design of buildings against fire. ● Be aware of the National Regulations about the Fire Safety of Building Structures. ● Analyse building structures against fire actions based on the Eurocodes.

Special topics of building construction	• Energy performance of buildings. Energy balance. Energy flows, calculation algorithms and procedure. Energy audits of buildings. • Thermal protection of buildings.	• Acquire the theoretical background of building physics and building energy performance assessment. • Conduct a building energy performance study. • Conduct a building energy inspection.
Energy saving design in buildings	• Climate, energy and buildings. • Energy and thermal balance of buildings. Heat flows in building shell. Thermal mass. Shading of buildings. • Principles of energy conscious design of buildings. Passive Solar Heating systems, Systems and techniques for natural cooling. • Advanced building energy simulation methodologies.	• Understand the nature and parameters of the thermal & energy budget of a building. • Relate this knowledge to all building construction studies. • Provide optimum building design solutions of high energy performance.
Environmental architectural design in buildings	• Building sector and environment. • Elements of the New Building Regulation (N.O.K.). • Implementation of sustainability principles in the building sector. • Environmental performance of buildings: dimensions, parameters and assessment (criteria, methods and computational tools). • Life cycle analysis of buildings, building components and materials. • Service life duration of buildings and building components (deterioration factors, etc.).	• Understand the relationship between architectural design and buildings environmental performance, • Have a sound knowledge on the basic requirements and provisions of the New Building Regulation (N.O.K.), • Understand the concepts and tools of buildings environmental performance and its assessment, as well as of building components and materials life cycle analysis, • Understand the basic elements of the Greek regulation for sound protection/insulation (in the context of the analysis of the quality of the indoor environment)

Apart from the courses offered within the graduate study program, students become more familiar with issues concerning sustainability in the built environment through the elaboration of their diploma thesis. From 2015 till 2020 a number of 994 students completed their diploma thesis in the Civil Engineering department; 94 of them elaborated their diploma thesis on subjects relevant to the sustainability of the built environment, under the supervision of the members of the Laboratory of Building Construction and Building Physics. Their topics included the hygrothermal performance of buildings, the building energy performance, life cycle analysis, fire protection, prefabrication, energy conscious design, conservation of historic buildings, open spaces and microclimate, etc.

4.2.2. In the postgraduate level

The members of LBCP participate in postgraduate programs with a focus on sustainability in the built construction, which are organized by the Departments of Civil Engineering and Architectural engineering of the Aristotle University of Thessaloniki, as well as by the Hellenic Open University. More specifically, the postgraduate courses are:

- “Environmental and energy approach to buildings”, offered as an elective course in the postgraduate program Environmental Protection and Sustainable Development, which is organized by the Civil Engineering Department of A.U.Th.
- “Environmental management I” and “Environmental management II”, offered as core courses in the postgraduate program Environmental Architectural Design, which is organized by the Department of Architectural Engineering of A.U.Th.
- “Issues of buildings construction and building physics in old and historical buildings. Pathology and restoration intervention”, “Special topics of historic building construction”, “Fire protection for the historical buildings and complexes”, offered in the postgraduate program Protection, Conservation and Restoration of Cultural Monuments, which is organized as an interdepartmental program by the Department of Architectural Engineering of A.U.Th.
- “Environmental design of Buildings”, offered in the postgraduate program Environmental Design, which is organized by the Hellenic Open University.

Apart from the above courses taught by the members of LBCP, postgraduate students have the opportunity to elaborate their diploma thesis on the subjects of sustainability in the built environment within the LBCP.

Doctoral theses are also elaborated in LBCP. Recent topics include the analytical studies of advanced building elements, life cycle analysis, performance optimization, microclimate, climate change mitigation, etc.

4.2.3. Lifelong educational programs

Informing engineers on the developments on the topics of building performance and sustainability are among the main objectives and scopes of LBCP.

Within this context, the Laboratory members have organized and participated in numerous seminars, symposia and conferences. More specifically, some of their recent activities focused on:

- **Seminars** on the Regulation of Building Energy Performance. In collaboration with the Technical Chamber of Greece, LBCP organized 7-day seminars in various cities of Greece in order to train engineers on the requirements of the new building energy performance regulation and the energy inspection of buildings.
- **Seminars** on the Thermal protection of buildings. In collaboration with the National Centre for Public Administration & Local Government, members of the LBCP train public servants on the studies of thermal protection and building energy performance.
- **Seminars** on the nearly zero energy buildings. Within the framework of the EU H2020 project MEnS Meeting the energy performance skills, LBCP members participated with lectures in seminars dedicated to the design of nZEB in Greece.
- **Symposia** organized by public entities, such as the Technical Chamber of Greece, the Association of Civil Engineers, the Centre of Renewable Sources, etc., as well as by private companies, such as FIBRAN, ISOMAT, ALUMIL, etc., with the objective to inform the participating engineers on the new advances in building construction, performance requirements, methods and codes.

- **Conference organization** by LBCP. Since 2016, LBCP organizes, in a three-year cycle, regional SBE conferences, which is directly related to SDG11. The first conference (SBE16-Thessaloniki) focused on the Sustainable synergies from buildings to the urban scale, while the second one (SBE19-Thessaloniki) dealt with sustainability in the built environment for climate change mitigation (Figure 2). Currently, a new SBE-Thessaloniki conference is organized for 2022, under the theme “Sustainable built environments: Paving the way for achieving the targets of 2030 and beyond”. The participation in the conferences organized by LBCP are free for graduate and postgraduate students.
- **Participation in conferences.** The members of LBCP are active in participating in national and international conferences related to sustainability in the built environment.

Fig. 2: The international conferences on Sustainable Built Environment organized by LBCP in 2016 and 2019.

4.3. The educational tools and methods

For achieving the learning outcomes for all the above educational activities, several educational methods are employed, such as:

- Lectures, offered face to face.
- Project preparation and meetings with the supervisors on a weekly base (Figure 3).
- Real scale models of building elements (Figure 3).
- Site visits.

The educational approach is student-centred, given that all instructors adjust their teaching in order to satisfy the students’ individual needs and a participatory mode is encouraged through the group projects and open discussions. The teaching material includes books, notes and presentation slides. Notes and presentation slides are available digitally, through the webpage of the course available in Moodle. The same webpage is used in order to communicate with the students.

The workload of all offered courses is carefully calculated in order to deliver appropriate ECTS to the courses and represent the real effort of the students. The student’s assessment is based on written exams, usually with problem solving questions, as well as on the project’s quality and the oral exams that accompany the project’s submission.

The diploma theses elaborated in LBCP are research orientated. The students are expected to use the specialized software or monitoring equipment of the Laboratory to accomplish their goals.

The participation of students in research projects is considered as a priority, for acquiring research experience and deepening their scientific background in the specific fields of sustainability.

Fig. 3: • Real scale models of building elements and meetings with students for consolidating the learning outcomes.

5. CONCLUSIONS

It is widely acknowledged that the greatest challenge of our era is fighting against climate change. Engineers can play a vital role in ensuring a sustainable approach across all axes of development and for this reason it is critical to equip engineering graduates with the relevant knowledge and skills to effectively address today's challenges.

Improving engineering students' sustainability literacy will not only increase their environmental awareness as citizens but will also ensure that they are in the position to make informed judgements and propose solutions that meet specified needs with consideration of the environment, public health, safety and welfare, taking into account cultural, social and economic factors.

The graduate and postgraduate programs offered by the Civil Engineering Department of the Aristotle University of Thessaloniki have the above-mentioned objectives and include many sustainability related courses. They cover each sector of civil engineering activity, such as water management and sanitation, transportation, construction, resources and waste management. As far as building structures and their surrounding environment are involved, the Laboratory of Building Construction and Building Physics has a leading role. Through its educational activities LBCP attempts to build a robust scientific background along with problem-solving and critical-thinking competencies not only for its graduate and postgraduate students, but also for engineers through lifelong education schemes.

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EXTENSIVE ROOF GREENERY AND CLIMATE CHANGE

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Key words: extensive greenery, flat roofs, urban heat island

ABSTRACT

The extensive roof greenery is one of the ways to reduce the extent and impact of urban heat islands. The prerequisite is the correct design and operation of both the structural and vegetation part of the roof. If adequate maintenance, especially irrigation of greenery, cannot be ensured, the use of extensive roof greenery can also be counterproductive.

The case study to be presented deals with problems of a flat roof with extensive greenery above an underground garage under Central European climate conditions. An infrequent irrigation leads to extremely high temperatures of the substrate in the summer and makes the purpose of this roof pointless. The contribution is analysing the reasons of failure of the vegetation part of the roof claimed to be maintenance-free, points out fire safety issues and suggests improvements that might be considered in similar cases.

At present time, marked by the climate change crisis, there is a large social pressure to build green roofs. However, if it is not possible to ensure their perfect functionality, it is perhaps better to use classic, proven types of roofs.

1. INTRODUCTION

The notion “heat islands” describes densely built areas that are significantly warmer than its mostly rural surroundings. An average annual temperature of this kind of areas in cities with 1 million citizens can be 1°C – 3°C warmer, during evening hours even 12°C warmer. The heat islands negatively affect people, energy consumption, cooling costs and environmental pollution; they also indirectly contribute to the production of greenhouse gases and significantly increase sickness rate and heat-related mortality. [1]

Roof greenery is one of the ways to reduce the extent and impact of urban heat islands. The green roofs are mostly seen as architectural components having a positive influence on quality of life, particularly in urban settlement structures. This positive effect is manifested at the macro level through improving air quality and also reducing effect called urban heat islands and at the very buildings by raising their interior comfort, especially floors directly under the roof. The precondition for effectiveness at macro level is particularly healthy green converting carbon dioxide to oxygen, casting a shadow on the flat roof and moisturizing surroundings in the summer. In the winter, it has particularly aesthetic and psychological importance. The care of greenery is of paramount importance, while in larger areas it may also be quite costly affair. The operation of green roofs may over time exceed possibilities of small investors, which is then reflected in a gradual decline of greenery and counterproductive change of the roof into a dusty surface with negative impacts in the environment. A correct design of greenery reflecting the roof structure and location of the building is therefore very important.

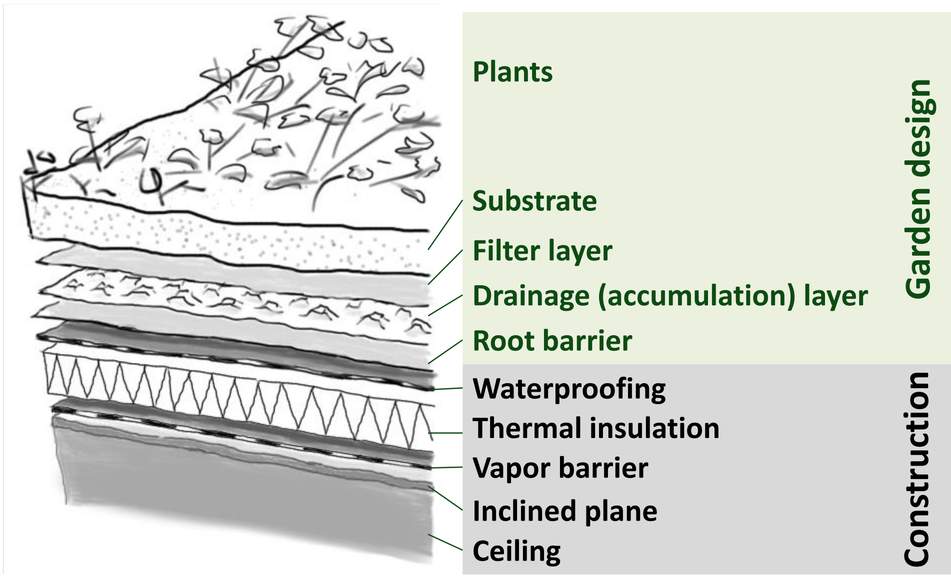

Fig. 1: Layers of a vegetation roof

In terms of the quality of the internal environment the greenery itself is more or less non-significant factor, a more important role plays the substrate, which can contribute to the thermal protection of the internal environment in the summer and winter as well. In summer, it is especially its ability to accumulate solar radiation and thus prevent overheating of the under-roof space. In winter time period, the substrate is contributing to the improvement of thermal resistance of the roof structure, even though it has to be ignored within calculation of the roof's thermal resistance as it is not its integral part. From legal point of view, hence, an improved thermal protection of under-roof spaces is a secondary effect of the green roof and as such should not play a major role in the decision-making process during the green roof design (even though in case of wooden roofs it can be quite an important factor). More important is to consider whether the cost of its construction and operation will return in the form of more attractive and healthier environment, but this is easier said than quantified. The essence of green roof is greenery and its positive health and aesthetic effects on humans. It can, however, only be achieved, if the greenery is truly functional. Under the climatic conditions of Central Europe with four approximately equal seasons, cold winters and relatively warm, and often dry, summers are the plants in artificial conditions, under which the green roof can be considered, subject to extreme temperature fluctuations. Even plants typical for the Central European area that thrive in this environment can be difficult to survive. If adequate maintenance, especially irrigation of greenery, cannot be ensured, the use of extensive roof greenery can also be counterproductive. In such a case, it is more appropriate to reach for other solutions, e.g. traditional roofs, provided with surfaces with high reflectivity of sunlight. These are much more affordable and can significantly reduce the surface temperature of the roof in summer.

2. POTENTIAL OF INCREASING THE REFLECTIVITY

Measurements in 1992 in Sacramento, US, were done while using aerial photography. These measurements have shown ratio of each individual units in the city - 28% were roofs, 16 % streets, 14% parking lots, driveways or pavements. Based on reflection of these materials the potential change of reflectivity was estimated to 18% [2]. The simplest solution is to change colour of roofs and facades to white. There are several highly reflective materials that are available on the market, e.g. thermoplastic polyolefin (TPO) based membranes or light gravel for roofs. Pavements and other surfaces can contain additives of white [2]. The following case study shows that the most important properties of a green roof in the summer - cooling by evaporation of water and shading by greenery, are getting lost, if the roof is not maintained by regular watering. The dry greenery makes the substrate, which is naturally dark, stand out. The substrate becomes the warmest part of the roof, increasing dust and fire hazards. In such case, the considerations of a classic flat roof with a reflective top layer would be highly justified.

3. CASE STUDY

The aim of the case study was to find out what are the temperatures of different surfaces of a green roof. Furthermore, we wanted to know the correlation between the temperatures of these surfaces and their estimated reflectivity. Measurements, using Voltcraft infrared thermometer, were performed on a green roof above an underground garage in Bratislava (Fig. 2) during peak summer. The reflectivity of individual materials was estimated on the basis of information from the literature [3].

Fig. 2: Top view of the green garage roof

The measurements depict clearly the lowest temperatures indoors, followed by outdoor air temperatures. As is obviously visible from measurements (Fig. 3), the temperatures on substrate / dry lawn were the highest followed by temperatures measured on concrete tiles and white gravel. These results support ideas mentioned in this article, to be more specific, influence of colours of materials on surface temperatures, since as is visible in the picture, flat roof had the highest surface temperatures measured on lawn, which is quite of opposite of desired state.

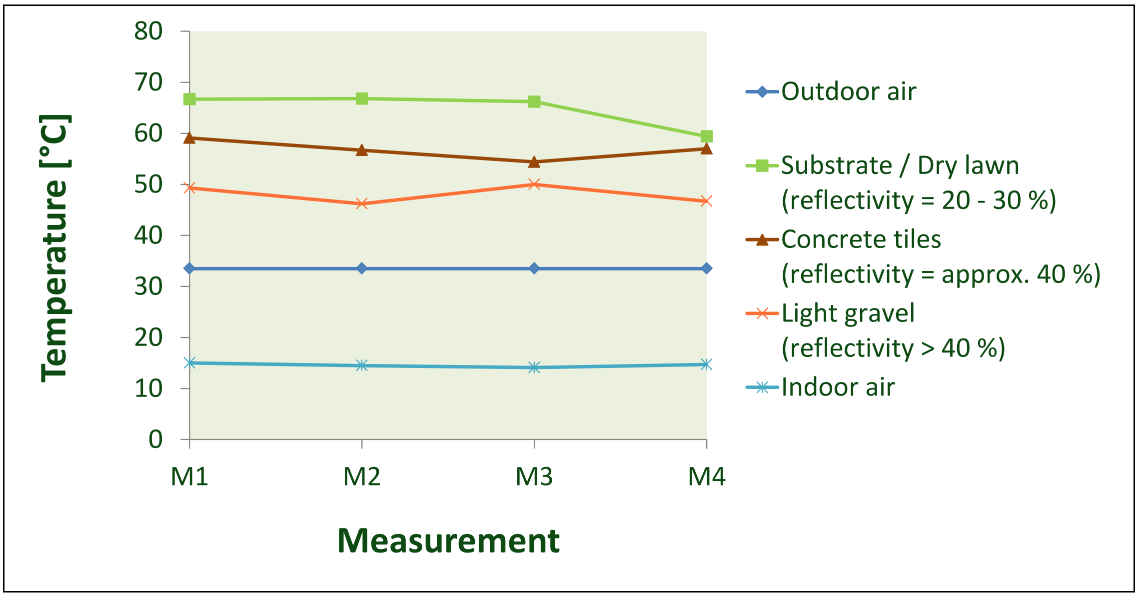

Fig. 3: Temperatures on the garage roof on early July afternoon, measured using Voltcraft infrared thermometer. In brackets is the reflectivity based on literature sources [3], the real value may slightly differ.

The roof also shows several commonly known design mistakes such as non-existing strip of gravel layer around ventilation shaft from the garage (Fig.4) or incorrect anchoring of handrail to construction (Fig. 5).

Fig. 4: Missing strip of gravel layer around ventilation shaft

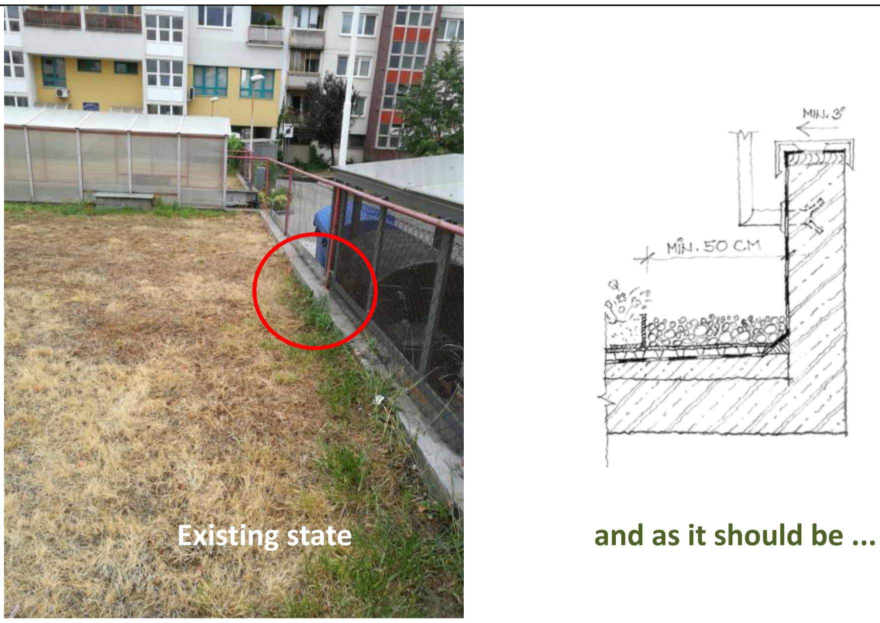

Fig. 5: Incorrect anchoring of handrail to construction

In the case depicted in Fig. 5 the vertical wall terminating the roof should be higher and the railing anchored to the side. Missing is also a protective gravel strip in close proximity to the vertical wall, protecting the bend of the waterproofing.

4. CONCLUSIONS

In climatic conditions of Central Europe with four seasons of the same length, approximately, with cold winters and relatively warm, and often dry, summers are plants in artificial conditions, for which the vegetation of the roof can be considered, subject to extreme temperature variations. Even plants typical for central European area that thrive in this environment can be difficult to survive. In contrast to the plants rooted in a common ground, the temperature of which oscillates during the year in the depth of one meter under the surface between 0° and approx. 16° Celsius, i.e. in the range of approx. 16 Kelvin, the roots of vegetation planted on roofs are exposed to a much wider temperature range. From the described study of the typical roof with extensive greenery is obvious that temperatures on the roof may be exceedingly high during the peak summer. The selection of suitable plants is therefore extremely important because their root system is exposed to highly contradictory requirements. On the one hand, it must withstand dry periods with high temperatures and on the other hand long periods of cold and wetness. When using subtle plants, we also recommend vegetation layer thickness of a few centimetres higher than recommended. The period, during which an extensive green roof has primarily fulfil its function i.e. reduce dust and ambient temperature, oxidize and humidify the air, is namely summer.

Even though extensive vegetated roofs are considered (and promoted) in Central Europe as maintenance- and irrigation-free they need both – a year round maintenance and regular irrigation during summer months. The inclusion of an irrigation system and green maintenance in the roof project is highly desirable - also with regard to climate change towards higher atmospheric temperatures.

If ensuring the regular maintenance and irrigation of roof greenery is not possible, then a classic flat roof with a highly reflective upper surface is certainly a more suitable solution. Such a roof can reduce the temperature of the roof surface by 10 - 15 ° C compared to a non-functional substrate and, hence, contribute more to the reduction of the effect of heat islands.

When creating details, special attention must be paid to fire safety, protection against the growth of roots, and the selection of suitable plants (not simply some kind of succulents). The design of green roofing is a complex matter, which requires highly professional attitude and strong cooperation between architect/planner on the one hand and garden designer on the other hand. Even though there is not too much standardization and legislation regarding the roof vegetation, the recommendations of specialized professional associations should be kept.

5. ACKNOWLEDGEMENTS

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"The role of education for Civil Engineers in the implementation of the SDGs"
1st Joint Conference of EUCEET and AECEF

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EDUCATING CIVIL ENGINEERS FOR SUSTAINABLE URBAN STREAM MANAGEMENT

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Key words: Urban streams, flood protection, sustainable development, case studies

ABSTRACT

Stream management is a complex and important technical, environmental, financial and social issue around the world. In urban areas stream management problems are often more acute, especially when human activities result in the encroachment of the natural space of streams, reduction or complete disappearance of parts of their riverbed, and degradation of their role in flood protection.

In this paper we discuss the multiple benefits (environmental, social, financial, etc.) that streams can offer to urban areas, besides their basic role as "natural" parts of the respective drainage systems. Then we focus on the necessary topics that should be included in civil engineering curricula, to prepare the students, in order to cope, as future civil engineers, with sustainable management of urban streams. In this framework we also examine the educational role of case studies. Moreover, the collaboration with related scientific disciplines and the evaluation of their input to urban stream management problems is also discussed.

1. INTRODUCTION

The way urban streams are managed today should be a matter of reflection and investigation, by the stakeholders of all countries, at a global level. Regardless of the particular climatic conditions and the special geomorphological characteristics that different urban streams may have, there is a common concern for the future perspective as well as the evolution of surface and groundwater resources.

Urbanization is one of the most important factors that contribute to the enhancement of surface runoff, the degradation of the quality in the level of the water resources, the poor distribution of their quantity and the disruption of the normal intensity of their flow, which result in floods and the reduction of water penetration into the aquifer are problems which continuously surface. In this light, it is necessary to evaluate and manage the behavior of urban streams in each urban area separately.

This text aims to highlight the role of urban streams and the relationship and interconnection of their elements with sustainable development. Next, emphasis is placed upon modern training approaches but also on the knowledge and equipment that Civil Engineers must carry with them for the integration and management of streams. In addition, there are successful examples of stream management at an international level, the didactic aim of which is to highlight the role of the Engineer. For this purpose, the main body and analysis of this work consists of four sub-parts. The first part refers to streams and cities, and demonstrates the benefits of urban streams and the effects of urbanization. The second part makes extensive reference to the university courses offered in civil engineering which relate to hydraulic and integrated stream management. The third part records the current trends and practices followed by a Civil Engineer, as regards the management of urban streams, while the fourth part presents examples of urban stream management at an international level.

2. URBAN STREAMS AND SUSTAINABLE DEVELOPMENT

The operation of urban streams facilitates a wide range of purposes which are related to factors of flood protection, drainage of urban streams, aesthetics, the conservation and improvement of aquatic life, as well as fresh water supplies. On such a basis, urban streams function as shapers of the dynamics and the character of urban ecosystems, as well as the diversity and productivity of the flora and fauna, as recipients and conduits of water and generally as elements which carry with them social and cultural implications for the community [1] , [2].

In a global environment which is dominated by economic factors, an analysis of the emerging benefits of the operation of urban streams cannot ignore the aforementioned factor, in addition to the factors concerning the environment and society, as mentioned before. In such a context, the social environmental and the economic benefits - which are the tripartite of sustainable development – which derive from the operation of urban streams, are the following [3], [4].

In terms of the social benefits:

Urban streams, along with lakeside areas, are open spaces of free access, within cities, for individuals. On such a basis, people are given the opportunity to have direct access to and contact with nature and the element of water, and are thus able to participate in leisure activities such as walking and sports in an environment which is strongly connected to nature. As a result, through leisure activities people, who participate in them, enhance their mental well-being within the cities in which they live and this seems to enhance their social benefits too.

Through the development of social contact and interaction in the areas in which urban streams exist, social cohesion is strengthened, which is additionally stimulated through the strengthening of the active participation of citizens in activities which relate to the protection of urban streams and the environment in general. Thanks to the direct contact with nature, individuals are trained in the ways of protecting the environment better, while for children, this direct contact seems to present an educational function, in terms of their learning about the elements of nature and their physical characteristics.

Waterways are timeless elements which relate to the cultural evolution of mankind, taking into account their use as a criterion for the demarcation and settlement in the specific areas in which waterways exist. In addition, in many settlements, rivers have a strong religious significance and are an inspiration for art and culture. Today modern cities are constructed by brick and mortar, urban streams, on the other hand, are a reflection of the natural environment within the aforementioned

cities, and this seems to have a direct impact on the improvement of the aesthetics of these cities and the enhancement of the natural elements which exist in them.
In terms of the environmental benefits:
Urban streams offer natural flood protection to river basins as they act as recipients and pipes of rainwater discharge from the underground sewer network of cities, which is otherwise unable to cope with extreme weather conditions. This reduces the risk of flooding following sudden and prolonged rainfall. The existence of urban streams in cities contributes to the improvement of the microclimate and the air quality, as well as to the balance of the hydrological cycle and the connection of the urban greenery with the green suburban environment.
Streams also act as a lever to restore environmental balance in particularly congested urban environments. Streams are habitats with a strong ecological value for many animals and plant life as, more often than not, they ensure aquatic biodiversity within the stream. At the same time, riparian vegetation provides protection against corrosive phenomena and often contributes to the natural cleaning of surface runoff.
In terms of the financial benefits:
Communication and proximity to the element of nature and, in this case, to water, is a factor which aids in the enhancement of the value of land and real estate, with a direct impact on the economic prosperity of the individuals who reside in the particular community. At a local level, the existence of a healthy urban stream or river in an urban area, which is usually surrounded by dense vegetation, can become the center of attraction for residents, visitors and tourists, with a direct impact on the enhancement of the economic benefits which the aforementioned people carry with them to the area.
At a national level, an urban area which has strong natural features and in which the element of water predominates, can, more easily, attract investment propositions and activities, as well as businesses in the area, thereby boosting public revenues through taxation. The shielding of the streams from floods also contributes in this direction. For example, a stream which withstands extreme rainfall is a pole of attraction for many activities, which will not be susceptible to economic damage caused by extreme floods [5].

3. CIVIL ENGINEERING CURRICULA AND SUSTAINABLE STREAM MANAGEMENT

The need to integrate the notion of sustainability in civil engineering curricula has been recognized many years ago (e.g. [6]) and substantial progress has been made to meet this need.
Regarding stream management, civil engineering curricula regularly include courses on:
Hydrology
Open channel hydraulics
Natural hazard mitigation (including floods)
Sewer and sewer treatment works.
All these topics are relevant to urban stream management, as streams are essentially part of urban drainage systems. But, in sustainable cities, streams have many additional functions, as described in the previous section. Fulfillment of these functions presupposes:
1. Maintenance of a minimum flow during the dry season.
2. Protection of stream water quality.

3. Protection of stream beds and banks from trespassing.
4. Protection and restoration of cultural monuments (e.g. old bridges and water mills) along the stream banks.
5. Adaptation of works to the natural environment - use of environmentally friendly materials.

Relevant topics can be included in civil engineering curricula, in the form of elective courses, such as urban rainwater management. Additionally, core courses on sewer works should be enriched, to include elements of ecological rainwater management techniques. Incorporation of field trips in these courses can be very useful, too [7]. Moreover, successful examples of urban stream management, as those described in the following section, can have a major educational role. Actually, incorporation of best practices available, at an international level, should be a constant goal of evolving civil engineering curricula.

Above all, though, civil engineers should be trained to communicate efficiently with other scientists (e.g. architects, urban planners, landscape specialists, even electrical engineers if small scale energy production is foreseen), since stream management is an interdisciplinary issue, and civil engineers are expected to play a coordinating role.

4. SUCCESSFUL EXAMPLES

4.1. The example of the Somer Channel in the United Kingdom

The Somer Canal in the city of Midsomer Notor in the United Kingdom, runs parallel to a main road in the city and is the recipient of its rainwater.

Prior to its restoration, the bottom of the canal was covered with concrete and had a four-level elevation which was connected by three small-scale waterfalls. The intervention aimed at improving the flow conditions, so as to deal with the floods, to reduce the number of sediments that remained at the bottom of the canal, as well as the flourishing of the flora and fauna. These aims were met through the smoothing of parts of the riverbed which were elevated, the dismantling of the concrete material and the conversion of the flow of water from a straight line to that of meandering.

For the new configuration of the riverbed, materials from a local quarry in the area were used, with the accumulated mud being used as a base for the planting of vegetation at the edges of the new canal. The selection of plants was made based on both aesthetic and technical criteria in order for the canal to be attractive, in its appearance, but also so as not to impede the flow of water during possible floods. The intervention ensured a dynamic flow of water which essentially eliminated the need for regular cleaning of the riverbed from the concentrated mud, thus reducing maintenance costs significantly, while, at the same time, enhancing the development of aquatic systems which supported the cultivation of freshwater shrimp and brown trout [8].

Figure 1: The Somer Canal before and after the intervention (European River Restoration Center, 2021.

4.2. The example of the Kallang Channel in Singapore

The Kallang Canal in Singapore has been transformed into a natural river embedded within Bishan Park, which is an area, within the urban fabric, which has high levels of traffic. During the restoration of the canal, the main aim was to transform the original straight-lined artificial canal, which served purely functional purposes and was effectively cut off from the park, into a natural and fully accessible river, which crosses through the park while at the same time it also provides for new spaces for use by the public.

Public spaces are especially important for a city-state, such as Singapore, which is facing a significant problem because of lack of space. Thus, the spaces that were utilized and included in the operation of the park, include restaurants, playgrounds, as well as a platform from which passersby enjoy the view, and which was built exclusively from materials which derived from the old canal. The new river provides the necessary coverage from floods, while modern techniques for the optimal management of urban streams have been adopted and applied, including the creation of vegetation ditches and filtration systems for the treatment of rainwater [9].

Figure 2: The Kallang canal before and after the intervention (World Architecture News, 2021)

4.3. The example of the city of Zurich

In order to ensure for the overall management of urban water, both surface and groundwater, and the sustainable management of water resources, the city of Zurich has implemented a program to build a separate network for clean - rainwater, which takes up the most part of the open streams [10].

The most important difficulty which had to be addressed in the implementation of this program was the limited space which was available for maneuvering open canals, combined with the growing demand for urban wastewater management. To resolve this issue, it was decided that, where there was sufficient space available, new streams would receive the flood flow as a whole. In case that there was of lack of space, the water would be channeled to the existing mixed network, where rainwater and sewage were drained into the same system.

In the latter case, the new open channels were used exclusively to serve the mainstream, thus significantly reducing the demand for space. In addition, where there was sufficient space, there was provision for the expansion of the basins which were near the open canals in order for them to absorb the excess water when heavy rainfalls occurred. Finally, the open canals that emerged from the implementation of the intervention, were accompanied by vegetation and appropriate plants, thus becoming popular free spaces for the citizens of the area and its visitors [11].

Figure 3: Open stream in the city of Zurich (Stadt Zurich, 2021).

4.4. The example of the Arcadia Creek Channel in Michigan – United States of America

Figure 4: The Arcadia Creek canal after its revelation (City - Data, 2021).

The restoration of heavily modified streams can prove to be a very costly process that must be decided upon in a more holistic way, but in the long run it can demonstrate benefits that outweigh the initial hesitations, to take action, which may have existed [12].

This is the case with the Arcadia Creek underground canal in Michigan, in the United States of America. It was decided to uncover this stream, rather than replace the damaged conduit/canal, due to the fact that the initial feasibility study showed that continuous flooding in Kalamazoo, Michigan, caused a financial damage to its business center which was much higher than the cost of disclosure, and by also taking into consideration that, in the long run, this would reduce floods in the future. In addition, significant economic and social benefits surfaced, in the sense that events were conducted in the newly formed space, thus making the area a place of high preference thanks to the revelation of the stream.

In light of the above, the revelation of the stream was the best solution for its management, despite the initial hesitations because of the high cost [13].

5. CONCLUDING REMARKS

Streams are valuable assets of urban environments. Their management must take place within the context of a holistic approach, which should take into account all 3 aspects of sustainable development, namely the environmental factor, the cost, and social benefits.
As civil engineers have (or should have) a central role in the management of urban streams, their training should be properly enriched, as discussed in this paper.

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CLASSIFYING CONSTRUCTION RELATED INFORMATION: AN UNIFIED SYSTEM CONSIDERING NATIONAL INDIVIDUALITIES

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Key words: classification, Estonia, CCI, Baltic Sea Region

ABSTRACT

Digitalising our everyday activities is there. BIM is step-by-step introduced in construction management. This situation demands new tools and methods to be prepared and introduced in the construction sector as well.

Using computers when managing construction sector requires unified language to be used for exchange of information. Therefore, a reliable classification system is required that will support digitalisation, but will be also handy and understandable for common users in the sector. Not much has been discussed about the cultural and national aspects when classifying.

The current paper is based on the experiences of the project run currently in Estonia since 2018 for developing the Construction Classification International (CCI) system. This system is designed especially for small societies running the information in their own national languages and English is used only as the communication language there. The paper discusses the process of developing and implementing the system jointly with international and local partners.

1. INTRODUCTION

People have constantly classified everything that is surrounding them – happenings in the environment, artefacts, but also different social and economic processes and activities. When data is systemised, it will allow us to analyse the concurrent information the best way. It is truism, that information is effective only if available at the right time and at the right place. Anyhow, when the required information must be retrieved and correlated from various different sources via distinct types of information systems, then much of the knowledge may be lost. At the same time classification schemes in the industry have been under regular review due to developments in the society and innovations of technology.

Similar is the situation in the construction sector. Formerly, construction processes were needed to develop mostly relatively simple buildings and structures. Today construction has become a complex of activities that has changed to a gigantic production sector using complicated production technologies and joining large number of different (partner) organisations. Therefore, demand for standardised concepts and terminology rapidly increases not only for the narrow construction sector, rather for much broader built environment sector. Internationalisation of industry and increasing use of computerised information systems are decisive factors in this development. Classification systems have become cornerstones in ontology development, they concern both concepts and terminology, and have a decisive influence in establishing common language for actors and stakeholders in the sector. [1, 5, 10, 18, 27]

Massive change to using BIM in construction has become increasingly important in most of the countries world-wide. [5, 7, 10, 15, 20, 22, 23] To manage the accompanying information flows, it is necessary to systematize all information related to the sector to ensure fast and correct data processing when using computers. Main intention for involved parties is to ensure quick, impartial and reliable systemizing of building lifecycle related information for user organizations. Therefore, this target for creating a common language for construction becomes remarkably more important when communication is run using different computer software solutions. [2, 6, 14, 21, 25]

Construction and facilities management sectors are run following local administrative frameworks and procedures, however, more often there are international actors involved when developing construction projects. Common understanding between construction project development related parties is needed, not only when following the standards for designing (e.g. Eurocodes), but also for managing construction project activities and providing relevant documents. More generally – it is important to exchange sector-related information starting from single bolts up to the maintenance of the major load-bearing structures during the whole lifecycle of the buildings and for organisations related to these processes.

There are several papers about the ontology and semantics of construction industry classification systems. [8, 19, 27] It is not the purpose of the current paper to analyse, or to develop the principles of classification. Rather the aim is to provide an overview and analysis of challenges and conflicts when developing an international multicultural classification system for built environment.

What is an international multicultural classification system is currently kept in mind?

Firstly, it is a multinational system, that has identical structure for all participating countries. Anyhow, all the countries involved can use their own national languages when working in their home-country, and when developing construction projects of national importance. English, but also perhaps any other commonly acceptable language – e.g. German, Spanish, Russian, French – may be used only as the communication language between national languages.

2. WHY AN INTERNATIONAL CLASSIFICATION SYSTEM IS NEEDED?

When studying the political map of Europe, one can discover several relatively small countries with their national languages and cultures. These are the markets where totally different legislations are used there. Anyhow, economic activities of these countries are still more and more interrelated due to joint EU market and free mobility possibilities for companies and workforce.

This is also the case for construction sector, for major international and cross-border projects. Anyhow, for national projects there may be central EU funding provided following the identical application rules, there are Cross-European tenders carried out and for designing Eurocodes, and EN (CEN) standards are followed. In parallel, administrative side of construction sector management follows deep historical and cultural traditions in each of the single country with documentation provided in their national language. As for governance of these project management processes, the built environment and land usage issues traditionally belong to the competence of local authorities.

After WWII, classification of construction related information became of crucial importance for the sector in Europe especially, and the first general guidelines were proposed introducing enumerative Universal Decimal Classification (UDK) system, in addition some basic principles were proposed. [9, 11, 13, 18, 20] UDK has still perhaps the most extensive use in several smaller classification systems. Step-by-step different countries started to follow these principles to tailor their national systems of construction classification, however they have always added their national input due to different traditions in national terminology and legislation.

Many different classification systems have been developed in Europe during the last sixty years and the primary purpose has been to support data exchange between the partners in building construction projects in traditional document based collaboration processes. However, these processes have changed, new model based design approaches have been developed and, therefore, new demands for classification systems have been raised.

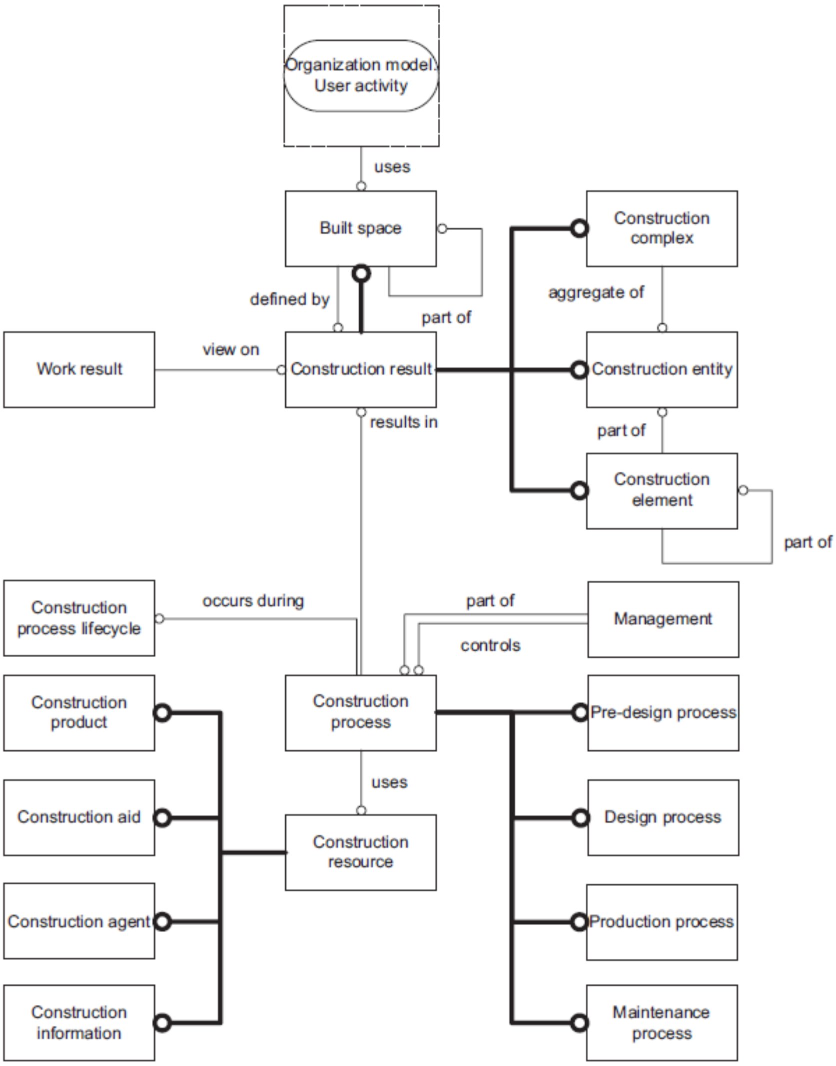

Fig. 1: Classes and the general relationship between them according to ISO 12006-2:2015

ISO 12006-2 from 2001 and 2015 [16, 17] have defined a framework of a faceted classification system with generic classes to be used for built environment sector. [look figure] It is intended to be used as the starting point for development of further classification frames in detail. By today, the latter of these standards has been also accepted as the EN standard (EN ISO 12006-2:2015). Several European countries have translated this document and have accepted it as their national standard. ISO 12006-2 has the purpose to establish a foundation for development of effective information systems for construction and facilities management sectors.

Therefore, we can see rather contradicting situation in the marketplace there – European construction market is emerging towards closer cooperation, however there are very strong administrative barriers that have been developed to protect national markets to lessen interventions of entrepreneurs from other countries to national ones. Different classification systems that are used for projects cause the partner organisations additional costs. They must spend more resources for translating the tender documents to different national languages of these countries. [24, 26, 34]

A good example for international cooperation in construction classification is the development of Uniclass system developed for British Commonwealth countries. Benefits of using this system are clear – improving the level of cooperation between countries belonging to British Commonwealth. The major precondition of using this system for this aim is that these countries have common English language, also historically professional education system for construction and for terminology are used there. [10, 12]

As English has become the major communication language for built environment sector worldwide, we have studied the suitability of using Uniclass family system to introduce it as a new classification framework for Estonia as well. It has become clear, that due to especially cultural differences it is the main reason why massive introducing of Uniclass is not viable for small markets. There is similar problem for the other countries with strong national identities as well. Also risk of Brexit has created "new", potential administrative barriers for working with UK. Therefore, it will be difficult to build up long-term development programme based on Uniclass.

Rail Baltica, an international railway project through the Baltic countries still uses Uniclass for its activities. Most of the railway projects worldwide have been international ones – crossing the boarders and using the international highly specialized contractors. As railway construction and maintenance technologies in fact are universal, also Uniclass can join the efforts of different countries for this project where English is the leading working language there.

There have been intensive discussions in Estonian building construction industry about developing a new classification system meeting especially current needs for digital data processing. This has led to observations that there are many misconceptions about classification systems. Many building industry professionals do not distinguish between the process of classifying individual objects and developing classification systems. A major confusion seems to be that no clear distinction is made between composition and classification, which are regarded as two fundamental abstraction mechanisms.

3. LOOKING FOR CONSTRUCTION CLASSIFICATION CONCEPT IN ESTONIA

There have been long and deep cultural roots in Estonian society related to German culture, anyhow, 50 years of Soviet occupation has introduced Russian to be used massively in construction sector. After regaining the independence (in 1991), especially construction rather quickly sector accepted nearly totally Finnish practice and activity models based on Western economies. Emerging process started from accepting the contemporary technologies and everyday management principles, in addition to this there was also massive transfer of knowhow to our construction sector professionals.

Accordingly, Estonian national construction cost management UDK based classification system was developed in 2005 following Finnish TALO (Construction) classification framework principles. This classification system was developed especially for cost calculations of buildings, and by today this system has been in use for more than 15 years already as the Estonian national standard. The system has become the basic document for compiling public tenders, and during this time there have been no changes done there in this standard.

Relatively recently, in 2015, a decree by the Ministry of Economic Affairs (further: Ministry) has introduced UDK based classification system of functional purposes of structures. Though society and construction sector are encouraging the measures to transfer the sector to BIM, the original roots of this classification system date back to the seventies of previous century. Original principles of this system have been prepared by UN for international statistical purposes, anyhow, relatively recently Eurostat has recommended it also for contemporary statistical purposes. As this system has been published in Estonia as a legal document, accordingly it has quickly become a constitutional part of the national administrative system in construction.

The recently changed situation in the construction market and rapid trend to digitalisation have put pressure on the Ministry to encourage national level relevant research to prepare necessary tools for digital change in the sector, including introducing a contemporary classification system. Clear message was given in the brief from the Ministry when initiating the classification project – a new system has to be fully international and suitable for digital information exchange.

The requirements of internationality have been formed based on the following considerations.

- Estonian construction market is small. Anyhow, in parallel to relatively small local projects, there are major infrastructure projects there, where international tenders have to be carried out and international actors may be involved. Therefore, totally unique classification system will create additional administrative barriers for contractors, and consequently construction management costs will increase.
- The concept of internationalisation has to be based preferably on relevant construction sector ISO standards.
- Estonian construction sector has the most efficient contacts with the countries located in the Baltic Sea Region (BSR), especially with the Baltic and Nordic/Scandinavian countries. Therefore, cooperation in classification with these countries would be especially beneficial.

- In long-term, when the classification project will be successful, there will be hopefully more countries accepting the participation under the same umbrella. This will create preconditions for large IT developers to include this new classification system also to their software solutions.
- All relatively small countries located in the BSR have their national built environment related terminology, also cultural habits related to construction processes and their clearly historically developed different legislations. Professional English will be not the solution for reliable terminology as potential partners for the classification system will need classification frame based on their own national language. Therefore, classification system to be developed has to allow multilingual usage.

In parallel to these internationality criteria Ministry tender documents for classification system development included also the flowing two basic technical requirements to be considered:

- lifecycle principle – as any construction project is developed and maintained during several years running different activity stages, accordingly classification system has to be unified for all these stages
- holistic principle – in construction sector construction works are always divided into buildings (houses) and civil engineering structures (roads, pipes, bridges, etc.); new design possibilities have widened the borderline between these two traditional major groups, anyhow, in parallel different new administrative frames have appeared in the sector; this kind of division is not of importance anymore, and should not be followed as the major criteria in classification systems

4. COOPERATION PRINCIPLES FOR CLASSIFICATION

For the case when there are and will be several countries interested in a classification system, there must be clear rules prepared as each of these countries entering the classification consortium has its own national interests to be considered. They all will be the participants/partners and the users of the joint system. Therefore, it is needed to have an organizational structure to manage the sustainability of the developed system in long-term. It was decided (in 2020) to establish an international NGO named Construction Classification International Collaboration (CCIC). Currently (August 2021) the members of CCIC are Estonia, Check Republic, Poland and Slovak Republic. Anyhow, there are the active supportive members – Denmark, Sweden and Lithuania, who are participating in the Technical Committee meetings and providing their knowhow input to improve the classification system.

Classification system’s acronym is CCI (Construction Classification International) and each country adds its country identity. CCI-EE for Estonia, CCI-CZ for Check Republic, CCI-LT for Lithuania, and similarly any other country involved.

There is the central body (Assembly of Trustees) of the organization which has only coordinating role. There are no moneys (participation fees) collected and accordingly, there is no central budget and financial management there. Each participating country has to cover its own costs and expenditures related to participating in CCIC activities.

In the Assembly of Trustees, participating countries are represented on equal principles. By the Assembly of Trustees, there is a Technical Committee consisting of classification professionals who represent the interests of their country. Technical Committee prepares documents to keep the classification system updated.

Each country participating in the organization (CCIC) has to organize adequately their own national institutions and activities, but they are totally free when deciding about relevant procedures. For sure, there should be some type of central administrative body there. Moreover, a professional body will be required to keep track of national needs. In addition, analysing the proposals done by partner countries is required to avoid conflicting proposals to be done for the CCI system. All these aspects are not centrally regulated – partner countries have full autonomy when managing their national institutions.

5. DISCUSSION POINTS AND PROBLEMATIC ISSUES

Though, ISO 12006-2:2015 gives the general frame for built environment classification, the holistic view of total internationality is still not possible. As all the countries have very clear cultural and legal differences, this fact cannot be underestimated. This influences ontology and professional terminology together with definitions of terms used.

When working with the concept of CCI it was decided to split the whole ISO 12006-2 classification system into two parts:

- classification tables for spaces, structures, buildings and components are considered as the core ones and will be more or less identical for different countries;
- classification tables for management, processes, resources and even lifecycle are considered as the national ones, where each partner-country can furnish these tables independently.

ISO standards are generally considered as reliable sources for international cooperation. Anyhow, standards are not forever – there are some reasonable time-lags when standards need to be updated. Updating of standards is a normal process in the society – technology and business environment inevitably change, and this has to be reflected also in the standards. For ISO standards lifecycle on standards may be reasonably long – for about 10 or sometimes even more years.

Conflicting point is that everyday users of classification systems need updating of classification tables and documents to be done more often than that of standards. Therefore, there will be a situation where there is the originally accepted standard, and the real life driven document with several amendments done there. However, not only the amendments – even during the preparatory work on the classification system different points of view are to be considered. There have been several situations when also the necessity of corrections has been discussed on Technical Committee level – human beings may make mistakes when compiling even the standards and the professionals cannot be fully neutral when proposing the concepts.

The main problem is inconsistency in several of the classification tables proposed by ISO standards. ISO technical committees are not always composed in a way that they are able to represent all sectors of economy and built environment related activities of the society. Shortly – construction and built environment related tables provided in ISO standards are quite unevenly furnished. Sometimes subclasses describe unique structures, in other cases only a broad description of structures is provided. Also, names of these technical committees often do not refer specifically to these areas for which standards have been developed. Therefore, ISO classification documents used for CCI are developed at rather on common knowledge level without deeper background justification.

Today, it is indisputable that English has taken over the role of international communication in several fields, while the local language of administration is still the national language. The situation is similar in the countries of Baltic Sea Region. In Nordic and Baltic countries, the national administration is in national language. Consequently, the development and maintenance of an international classification system in our region should in any case be provided in parallel at least in two languages. When more countries are involved, the number of languages will increase. National language has the clear priority for each participating nation, English can be used only as an intermediary language.

Cooperation so far in CCI Technical Committee shows that management of international classification in the national languages over English involves additional problems and risks. It is generally possible to find several synonyms in English to any term defined in a national language, and translating all of them into another national language often leads to the loss of the original meaning. Accordingly, there are always the problems of interpretation. Though, official dictionaries claim that these are completely correct translations of terms, anyhow, professionals have constant discussions about the content of these terms.

Consequently, similar problems will arise in the future when organizing the everyday work of CCI Technical Committee. Working language of the committee is English. All partner countries come with their own national issues, which are described in English. Where is the guarantee that the origins of an issue will be clearly described and provided in English? In such a situation, it takes much longer to reach consensus. It can also lead to unjustified disagreements, the consensual resolution of which is one of the main responsibilities of CCI Technical Committee.

6. FINDINGS AND CONCLUSIONS

Work with CCI is very unique one – there are several classification systems that have been translated into some other languages according to the users' needs. Anyhow, these cases are not multilingual and multicultural systems there, where one has considered also different national interests. When developing digital tools for BIM and tailoring any classification system one should not underestimate the national traditions of the user society when working with terminology and definitions.

Though different standards, especially the international ones (ISO, EN), follow certain procedures for gaining consensus, not all interested bodies are always involved and the working commissions represent only their own rather narrow professional interests. Therefore, these standards cannot be considered as dogmas – these documents are developed by human individuals and may include also errors that are to be amended or corrected before one starts to follow the standards in practice.

7. ACKNOWLEDGEMENTS

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IMPACT OF AUTOMATED RESOURCE STANDARDIZATION SYSTEM FOR ENERGY-EFFICIENT CONSTRUCTION ON SUSTAINABLE DEVELOPMENT GOALS AND EDUCATION FOR CIVIL ENGINEERS

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Key words: energy-efficient construction, resource standardization, sustainable construction, productivity improvement, education

ABSTRACT

This paper presents the goals of a project named Development of automated resource standardization system for energy-efficient construction (NORMENG) and how it is in line with the Sustainable Development Goals and the education of civil engineers. The project itself was started with the idea of modernising the construction industry in Croatia. Lack of up to date, automated system for resource standardization is a significant setback in all areas of construction, from education to practical work. Bringing changes in the education of civil engineers is a first step, one significant for the future of the construction industry in Croatia because educating a new generation of engineers, giving them proper tools to keep up with new ways of building, solutions for new problems they might come across. Educating a new generation of civil engineers will help the whole industry to increase productivity and to generally move forward. The project itself is related to the following topics of this conference: SDG4 – improving quality of education for civil engineers; SDG8 – increasing production should lead to increased decent work and economic growth; SDG9 - Industry, innovation and infrastructure as a project is focused on innovation in the construction industry of Croatia; and because of projects focus on green building, it is also related to SDG11 – sustainable cities and development and SDG13 – climate action as well. The project not only aims to develop labour productivity standards and to improve productivity, but it also aims to do so for those types of construction works that are important for green building. The construction industry is usually seen only as a danger for the protected environment due to the nature of the works, but that can be changed; there is a lot of space to reduce negative effects on the environment and to help preserve it at the same time. Hopefully, with the successful conclusion of this project and the application of achieved results in practical work, contractors from Croatia and the region will see benefits in green building and decide to change their policy of work, as green building is not only important for preserving the planet and reducing climate change effects, but this project will also try to prove it as cost-efficient compared to traditional ways of building.

1. INTRODUCTION

From its beginning in 2015 United Nations 2030 Agenda with its 17 Sustainable Development Goals (SDGs) inspired many governments, educational institutions, and people overall to change their old ways, to stream for new, improved, planet-friendly options in order to achieve a shared vision of sustainable development [1]. The University of Zagreb Faculty of Civil Engineering shares this vision and aims to start the changes in the construction industry in Croatia, by increasing ecological awareness as well as improving general productivity in construction.

The construction sector is one of the main pillars of any economy and a source of economic growth and development, because it, directly and indirectly, affects many other industries and employs a large number of people [2]. The construction sector also has a huge impact on the environment. A significant share of non-renewable resources in the world is used in the construction sector. In *Energy-efficient buildings multi-annual roadmap for the contractual ppp under horizon 2020* [3], it is estimated that buildings in the European Union consume approximately 45% of energy and produce approximately 40% of greenhouse gases. Also, buildings are responsible for 35% of construction materials consumption and 35% of construction waste in construction [3], which makes this sector unsustainable in the long run and creates the need to change the old principles. But on the other hand, the construction sector has the greatest potential for saving natural resources, increasing energy efficiency and greater use of renewable energy sources.

The main purpose of this project is to establish and define labour productivity standards in construction, namely those related to energy-efficient construction. Today, when there are numerous examples of long applied and successful models from which construction standards are made, the basic question is how to develop the Croatian standardization model, which corresponds to the institutional, legal and economic frameworks of the environment of the Republic of Croatia and the principles of green building at the same time. The current use of standards when planning new projects and calculating works is at a low level in Croatia. The reason for this lies mostly in the fact that the latest editions of building standards date back to 1986 [4]. Since then, great social and economic changes have taken place, new building materials, work procedures and machines have entered the construction industry. After the completion of the project, it is planned to maintain and adapt the defined standards to new technologies in the future.

The existence of standards, in addition to ensuring the required quality of work performed, protects workers from excessive exhaustion and ensures normal working environment conditions. Taking into account the requirements of the European Union, as well as increasing awareness of sustainable "green building" and energy efficiency in construction, in 2012. the project called CROSKILLS began [5]. CROSKILLS [5] was aimed at lifelong education and training of Croatian workers in the field of energy-efficient building and identified 6 primary construction occupations in energy sustainable construction - these are masons, carpenters, facade workers, house painters, roofers and drywall fitters. These professions are those which will be the focus of NORMENG project and whose labour productivity will be measured.

A comprehensive approach to environmental protection consists not only of covering one of the aspects (energy efficiency of buildings, recycling and waste disposal, etc.) but of a holistic approach consisting of production materials, construction, use and removal of the building [6]. Achieving the objectives of the project will allow end-users to see how much resources are spent in the execution of works. Those resources include not only construction materials, but also the people and machinery used in the construction process. Knowing the required amount of resources to perform construction activities is a first step in optimizing their consumption and rationalizing their use. The additional benefit of the project, which is in line with the conference title, is the education of civil engineers. Bespoken education will bring benefits both to the students and to the construction sector. Future civil engineers will gain knowledge about updated construction standards and transfer that knowledge to the construction companies. That kind of knowledge transfer will contribute to sustainable development and thus is very important in the implementation of sustainable development goals which will be mentioned further in the paper.

2. SUSTAINABLE DEVELOPMENT

"The concept of sustainability was originally coined in forestry, where it means never harvesting more than what the forest yields in new growth" [7]. Over the years this definition of sustainability has been developed and expanded. "Sustainability is the term chosen to bridge the gulf between development and environment. Originally it came from forestry, fisheries, and groundwater, which dealt with quantities such as "maximum sustainable cut," "maximum sustainable yield," and "maximum sustainable pumping rate." How many trees can we cut and still have forest growth? How many fish can we take and still have a fishery functioning at the end of the time period? How much ground water can we draw and still have a viable aquifer at the end of the pumping period?" [8].

Over time there was developed a need to establish a unique system of ecologically acceptable way to the economic and technological development on a global scale. "The report of the World Commission on Environment and Development entitled *Our Common Future* is widely considered to have been key in putting sustainable development firmly into the political arena of international development thinking. It used the term 'sustainable development' extensively…" [9]. After the first appearance of the term in 1987, various experts and scientists published their definitions of the term. "Literally, sustainable development refers to maintaining development over time. However, there are possibly hundreds of definitions of the term currently in circulation, many divergent interpretations and thousands of variations applied in practice." [10]. Although there are hundreds of definitions the one from the report entitled *Our Common Future* is one of the most commonly known. "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." [11].

Moving on from the early stages of sustainable development we are witnessing the time when the emphasis is on sustainable development goals. Implementation of SDGs is the key to maintain the correlation of overall development and wellbeing of the environment. "Sustainable development goals (SDGs) have set the 2030 agenda to transform our world by tackling multiple challenges humankind is facing to ensure well-being, economic prosperity, and environmental protection. In contrast to conventional development agendas focusing on a restricted set of dimensions, the SDGs provide a holistic and multidimensional view on development." [12]. The overall development includes a vast number of areas in society, but the emphasis of this paper is the construction sector as one of the most important branches of every country's economy.

„The SDGs concern many areas of society, including the construction sector. To achieve the goals of global sustainability in the sense of the SDGs, there is a need for redeveloping the construction sector." [13]. The construction sector is "consuming 40 to 75 percent of the total value of materials extracted" [14] globally. According to figures given by the Global Status Report 2018 of the Global Alliance for Buildings and Construction [15] shows that 36 percent of final energy use, as well as aproximately 39 percent of emissions in 2017, was caused by the buildings and the construction sector. Moreover, estimated trends of the same report show that energy usage, besides improvements e.g. in building systems or building envelopes, is still growing. The emissions related to the buildings stagnate, due to the achieved energy efficiency in buildings as well as the decarbonisation of the power sector, and balance out development in population growth and the floor area growth. This means further reductions are necessary if targets of the SDGs want to be achieved [13]. The Annex Report 57 of the International Energy Agency [16] is stating the fact that embodied energy and embodied energy emissions produced by the construction industry account for 20 percent of the global energy consumption and CO2 emissions. This also means that depletion in embodied energy and CO2 emissions can result in a significant global decrease in energy consumption and CO2 emissions. Having all that information in mind, the Faculty of Civil Engineering in Zagreb is anticipating that the development of an automated resource standardization system for energy-efficient construction will play a key role in further reduction of resource and energy consumption in Croatia.

3. PROJECT EXECUTION

The proposed project is planned to be implemented over a period of 36 months through two phases. The first phase would be industrial research lasting 24 months, followed by an experimental development phase lasting additional 12 months.

Industrial research within this project is divided into 3 basic activities. The first activity of industrial research will gather knowledge in the field of development and maintenance of General Technical Conditions and Construction Standards through interviews with significant industry experts both from Croatia and from other members of the EU. Focus groups will also be formed, consisting of public entities in Croatia (Ministries, agencies, local self-government units, educational organizations/institutions, etc.), professional associations (Chamber of Crafts and Commerce, Chamber of civil engineers, etc.), and representatives of the construction industry (contractors, consultants, equipment/technology manufacturers, etc.). This part of the research is trying to formulate the concept of the construction standards model while including components essential for the successful application of environmental goals. A unique methodology for calculating materials, labour, and the amount of machine work for the identified essential works will be developed.

The second phase of industrial research envisages the analysis of existing technologies and trends in the field of standardization of energy-efficient construction. Analytical studies of new technologies for the implementation of works related to environmentally sustainable construction will be conducted, which would result in the formulation of a conceptual form of a model for the standardization of energy-efficient construction. Standardization of the procedure is the key to the comprehensive applicability of standards, and at this stage of industrial research, innovation is expected in defining the standardization procedure using new technologies for measuring quantities of work performed in chosen unit of time.

In the third phase of the industrial research, the validation of the standardization model will be applied using modern technologies set in the earlier phases of industrial research. The formed concept of standards for environmentally sustainable construction, as well as the concept of standardization with new technologies, are validated in this phase of the project on individual works in laboratory conditions using the collected data from the test site. A test site will be established where previously defined activities will be monitored and an attempt will be made to prove or deny their accuracy.

After the completion of the industrial research within this project, an experimental development lasting 12 months is envisaged. Experimental development is divided into two basic phases. After the methodology of standard development has been defined in industrial research and has been experimentally proven, in the first phase of experimental development, standards will be validated and demonstrated in the relevant environment. The goal of this first phase is to validate the methodology of standard development in the operational environment and demonstrate its functioning in the real environment. Resources required to carry out this activity include the equipment such as photogrammetry equipment and software, laser scanning equipment and software along with other equipment for processing the collected data. These resources will be used on construction sites to collect and process the data needed to develop standards, in a manner defined in the activities of industrial research. The results obtained from data processing will be used to develop standards and demonstrate the developed technology in a real environment.

In the last phase of the research, the digitalization of the database on standards and the development of a software solution will be carried out. For developed standards to be applicable in the economy, it is necessary to digitalize the previously created database of standards and create a user interface of a software tool that would enable the application of standards in the operational environment. The goal of this project activity is to prove the applicability of the developed standards in the operational environment, especially in the application of real examples in the construction industry.

4. RESULTS

The goals that can be expected to be achieved by the end of this project are:

- a defined standardized list of costs for construction works along with the standardized summed-up description for each of the items,
- defined general technical conditions,
- created database of standards (material, machine, work) in printed and digital form, which would be aligned with the IFC BIM standard and EU standards,

- development of an automated solution for levelling and checking the previous three objectives,
- proof of the applicability of new technologies in the process of standardization (production methods).

All of the above-mentioned goals have the potential to contribute to the implementation of sustainable development goals mentioned in the topics of this conference. For example, SDG4 – improving quality of education for civil engineers; SDG8 – increasing production should lead to increased decent work and economic growth; SDG9 – industry, innovation and infrastructure as the project is focused on innovation in the construction industry of Croatia. Furthermore, because of projects focus on green and sustainable building, it is also related to SDG11 – sustainable cities and development and SDG13 – climate action as well. The project not only aims to develop labour productivity standards to improve productivity in terms of economics, but it also aims to improve productivity in those types of construction works that are emphasising the importance of green building by educating future civil engineers.

4.1. Discussion of results

The results of the project are intended to enable a more precise calculation of the usage of all necessary resources, which, in addition to rationalizing the use of resources and reducing waste, also brings benefits in the form of reducing disputes over material consumption. In addition, the establishment of a unique standardization methodology in energy-efficient construction would significantly facilitate both investors and contractors in defining all requirements and costs and encouraged them to focus on "green building", which would contribute to the further recovery of the construction/economy, as well as solving climate challenges. Greater activity in the construction sector would also enable business development, including the creation of new jobs, both in the construction sector and in related activities. Not to forget, the results of the project would bring significant improvement in the education of civil engineers, giving them updated knowledge they need in order to successfully apply green building techniques once they graduate.

The application of new technologies for the development of modern standards of energy-efficient construction would certainly contribute to the attractiveness of the construction sector as a profession, which could be a positive impact on attracting labour to a sector where it is currently lacking.

Further on, the project will enable greater transparency and efficiency in the implementation of green building projects, which will indirectly encourage a faster and more efficient transition to green building. This will affect:

- minimizing energy consumption at all stages of the life of the building,
- integration of technologies for the application of renewable energy sources and to achieve lower CO_2 emissions into the environment,
- reducing waste and increasing reuse through recycling

- health and well-being of building users (providing high air quality through good ventilation and avoidance of materials and chemicals that create emissions).

5. CONCLUSIONS

Sustainability is no longer the far future as some may see it; it is today. All industries and especially construction need to do all they can to adapt to Sustainable Development Goals, to accept innovations, to continuously search for better, cleaner ways of working.

The general idea behind the NORMENG project is to introduce green building into the construction industry in Croatia and even neighbouring Eastern European countries. The project is promoting new methods of sustainable development as not only ecologically needed, but also as a more advanced, faster and in the end even economically viable way of construction. Changes like this are usually hard to promote, especially in less developed regions where people or in this case contractors are afraid and reluctant to leave behind all they know, the very same way of construction they have been using for years. Successful execution and application of end results in this project will help a major part of the contractors and other participants in the construction industry to realize the benefits of green building and to accept it as a new, better way of building. The main limitation for this paper was an early phase of the project, not many results have been achieved to substantiate theses brought in the paper. Additionally, we could predict limitations for the application of project results. Some of the main reasons to be against changes in the construction industry are inexperience, lack of knowledge, lack of professional literature in the native language, impossibility to use your existing databases, templates and so on. For that reason, created base of standards, general technical conditions along with professional guidance and help is a key to making this transition as painless as possible. None of the construction companies would have to start again from scratch, they could just take created standards once they are finished and build upon them, shape them accordingly to their needs, their workers, their machines and equipment, update them as they gain experience and progress further into the sustainable building. And even more importantly, at the same time, new generations of engineers will be educated accordingly to new methods and technologies of green building in order to spread and apply that knowledge in real world and to achieve the vision of sustainable development.

For future research and development, more energy-efficient types of work could be included in automated resource standardization system while continuously updating ones already done. Additionally, education of civil engineers could be even more focused on SDGs; introducing them to students, giving them proper knowledge and tools to apply them in practice, showing them how to successfully achieve those goals, all that would improve implementation of SDGs in the construction industry once those students are employed.

6. ACKNOWLEDGEMENTS

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DIGITAL CONSTRUCTION: CHALLENGES FOR CIVIL ENGINEERS

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Key words: Digital Construction; Civil Engineering; BIM; Training

ABSTRACT

Predicting the impact of current technological trends is a speculative and error-prone exercise. Nevertheless, digital transformations in the Construction sector are already sufficiently established to allow for some predictions about future impacts and challenges for Engineers and other Construction professionals. These transformations transcend the most obvious technologies, many of which are adapted from other areas of activity, and include less visible aspects such as the development of technical specifications and standards or the training of new professionals. This article begins with a very brief historical perspective on the process of digitisation in construction, comparing some of the current challenges with those encountered when similar technological transformations occurred in other sectors of activity. Standards, education, and training are discussed as factors that help explain an uptake in the interest for digital construction and present new challenges and opportunities for Civil Engineers.

1. DIGITAL CONSTRUCTION: "THE FUTURE"?

Digitisation is a long-standing aim for the Construction Industry, which has been described thoroughly in the literature for decades. It is also an elusive goal since continuous technological development, and the existence of previous comparable initiatives from other areas of the economy have long inspired generations of Civil Engineers who wish to automate construction tasks or otherwise improve information management. Current examples of trending digital solutions [1] are often the result of adapting long-existing technology. For example, Laser scanning emerged in the 1960s, Building Information Modelling (BIM) was initially developed during the 1970s to the 1990s, or more recently, Digital Twins were described for the first time in the early 21st century. Even other technologies which are often associated with Industry 4.0, such as sensors or Artificial Intelligence, have a long history of application in various sectors, including Construction.

Over the past twenty years, several studies and opinion articles have sought to estimate the importance of digital technologies in the Construction sector, comparing it (often unflatteringly) with other areas of activity [1-3]. Some studies have suggested a relationship between productivity and the degree of diffusion of these technologies [4-6], underlining the growing gap between Construction and the rest of the economy for over half a century. Given the Construction Industry's global economic and social relevance, increasing productivity and reducing waste in this field through technological upgrading and innovation is critical in achieving the 2030 United Nations Sustainable Development Goals (SDG), particularly SDG 8 [7].

1.1. The productivity paradox

Despite continued technological development, productivity in the sector (measured by Gross Added Value per hour of work) still lags behind that of the economy as a whole. In this regard, it should be noted that the economic and social impact of a technology often occurs years or even decades after its invention. Even innovations that are now central to the economy have required a favourable context for their effect to be clear – to the point of rendering obsolete the technologies that preceded them.

For example, the economies of scale, the obvious changes in our consumption habits, and even the organisation of many coastal cities that resulted from the widespread use of shipping containers only occurred decades after Malcom McLean introduced them in 1956 [8]. It was necessary to wait for standardised solutions, and the construction of appropriate vessels and port facilities.

The electric motor and computers also motivated the perplexity of contemporary observers, who noticed the gap between the perceptible pace of innovation and the delay in achieving productivity gains [9]. If in 1987, economist Robert Solow observed that "the computer age was everywhere except for the productivity statistics" [10], computer networks and the Internet, as well as the gradual adaptation of companies, altered this reality significantly during the following decades. Indeed, the feasibility of a new disruptive technology often depends on the context in which it is adopted, and may require compatible technical and organisational solutions.

Considering that digitisation is a decades-old transformative process, it is important to reflect on the causes of the growing interest in this field from researchers, educators, and construction professionals. Recent innovations have increased interest in digital construction, enabling the greater dissemination of these technologies. The following section describes some of these advances that create a more favourable context for the productive adoption of information technologies in construction.

2. DEMANDS FOR NEW SKILLS AND RULES

The development of digital models of buildings and infrastructure that share many characteristics with their physical counterparts is arguably the main result of the ongoing digitisation process. While the most critical hardware and software components for creating digital models have been available for over two decades (with continuous improvements since then), some less visible requirements have only more recently seen significant developments [11]. Indeed, the productive adoption of digital models requires standard workflows and skilled human resources, as described in the following paragraphs.

2.1. Standards

The pioneering adoption of BIM in countries such as the United Kingdom has resulted in national rules, which have influenced the international standards that followed them. The ISO 19650 series, published from the end of 2018, describes what a BIM model is, how it can be organised and what role actors play in different stages of the construction lifecycle [12]. Other, even more recent standards describe how to specify information requirements, thus enabling contracts for BIM services based on standard rules. Specifications are available for geometrical and non-geometrical requirements for model elements, for relationships between these elements, among many other aspects. These rules are very general, so their adaptation to national standards, legislation, or even those frequently cited but insufficiently defined "rules of good practice" will require further effort from interested parties in each country.

2.2. Education and training

Human resources with adequate training and experience are another critical requirement for companies moving towards digital work processes. Topics such as BIM or Digital Twins were only formally included in the curricula of most Civil Engineering courses a few years ago. As a current example, the two largest Civil Engineering Masters degrees in Portugal offer optional BIM and digital technologies courses to first-year students [13, 14]. No specific courses on BIM are offered in Civil Engineering bachelor degrees in these universities. Hence, many students continue to graduate with no experience with BIM tools and, more critically, with no knowledge about standard digital construction processes or rules that are applied around the world, often compulsorily.

Thus, although this reality is changing as the offer of graduate and undergraduate training in the field of digital construction increases, technicians with knowledge and experience in this area remain scarce. This shortage of professionals may prove to be an obstacle to the adoption of new work processes.

2.3. New professional roles

Also within the scope of human resources, digitisation creates new roles and transforms existing ones. Although their names vary, these roles can be grouped in three main categories [15]: Operational (often model development, requiring expertise with specific IT tools), Development (requiring programming skills), and Management (responsible for integrating BIM at the level of a work team, a company, or a project).

This wide variety of possible roles and related skills within each of these categories is largely compatible with the functional organisation of most construction companies. Still, the transition towards digital construction processes requires a suitable approach from Higher Education Institutions when preparing students for future careers. Indeed, as each type of role demands different levels of understanding about the underlying work processes, digital construction topics should be included at different points in a Civil Engineering curriculum and should preferably be integrated within existing Curriculum Units instead of compressing Operational, Managerial and Strategic issues into a single module.

Companies must identify existing skills and available human, hardware, and software resources, and prepare accordingly for the expected changes in workflows. In Portugal, the number of companies that have already started this journey has increased sharply. Still, many others are yet to take the first steps, even knowing that the use of BIM in many countries is already mandatory in public works.

2.4. Construction owners

Construction owners will have a key role to play in the transition towards digital processes. The proper definition of information requirements before contracting BIM services can make the difference between receiving a valuable digital asset or a model of no use for the intended purposes. A BIM model can be used to obtain quantities automatically, perform different types of simulations, support Facilities Managenent, or many other common tasks, but only if it has been prepared for this.

Thus, if construction owners can fail by under-specifying information requirements, they may also err by over-specifying requirements in the procurement phase. Adding successive layers of information to a model results in a very significant increase in preparation and management costs. The risk of unnecessary requirements in procurement processes may be compounded if, for example, the construction owners simply transcribe information requirements from one project to the next without critically assessing the value of each option.

Thus, construction owners, particularly public entities, should prepare themselves to hire and receive digital models. While the number of consultants available to support BIM implementation in companies or individual projects is increasing, construction owners must strive to develop their own skills in this area.

3. CONCLUSIONS

Digital Construction is by no means a novelty, but several factors contribute to an increased awareness of the importance of adopting digital solutions in the construction industry. Although the hardware and software needed to conduct surveys, prepare models, or conduct simulations have been available for years or decades, the construction sector has only recently had access to suitable standards and human resources.

In many countries, BIM use is already mandatory in public works. This requirement will likely spread to more countries, particularly in Europe. Even in regions where legislation does not impose BIM use, construction owners who recognise the value of digital assets increasingly demand it.

Digitisation provides significant opportunities and challenges for Civil Engineers. New roles are emerging, which require technical and management skills that have only recently been introduced to many Civil Engineering courses. Although students are often keen to develop modelling skills, these are not required for all new digital processes. Software Development and Information Management skills are also increasingly valuable skills. Project Managers must also accommodate this growing variety of profiles within work teams.

Technology is evolving to lower barriers for Civil Engineers. Immersive Virtual and Augmented Reality interfaces provide easy access to complex 3D building models, and Visual Programming Languages allow many tasks to be automated without steep learning curves.

It is almost a truism to say that there are no good projects without good construction owners, and digitisation gives these agents an even more central role. Owners, and in particular public entities, should be prepared to procure and manage digital models. They are responsible for defining the objectives of digital processes, without which the usefulness of information models is compromised. The adequate development of information requirements is a particularly critical task for owners when hiring BIM services.

Reducing wasted effort and increasing productivity are common goals for all entities that transition towards digitisation. Following the past example of other activities, achieving this purpose depends on a coordinated effort of the construction sector, including companies, public entities and higher education institutions.

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USE OF SENSORS, MOBILES AND COMPUTER VISION IN EXPERIMENTAL STRUCTURAL DYNAMICS

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Key words: structural dynamics, accelerometers, embedded sensors, computer vision

ABSTRACT

In Civil Engineering, traditional approaches for teaching concepts of structural mechanics include dense yet sequential theoretical development of proofs and exercises. Often, in the specific case of structural dynamics, lessons are taught experimentally in laboratories as well. It implies equipment such as wave generators, data-acquisition systems and deployments using different sensors. In this paper, the gathered experiences in experimental structural dynamics using sensors, embedded sensors (mobile phones) and computer vision are presented. The paper describes the lessons learned during the implementation of teaching experiences within the framework of a basic course of structural dynamics. The course is prepared for civil engineering students and it includes both experimental and theoretical methodologies as part of the preparation for more advanced courses such as vibration of structures, earthquake engineering or seismic design. The design of activities is conceived in such a way that accessible, affordable and replicable experiments are achieved.

1. INTRODUCTION

For civil engineers, the study of vibrations and dynamics is an important milestone. The vibration of beams and frames represent topics that are discussed in courses of structural dynamics. It allows students to prepare their theoretical background for subsequent use in structural design. In particular, this knowledge is used in Earthquake Engineering or Vibrations in bridges and footbridges. In structural dynamics, basic concepts such as damping, frequency, resonance or isolation are of an utmost importance when understanding more complex phenomena related to single- or multi-degree of freedom systems.

Open electronics have become considerably popular among entrepreneurs, designers, computer scientists, hobbyists and more recently, engineering educators. A vast array of low-cost, open source microcontroller platforms are nowadays available. These platforms, together with easy-to-use programming codes, allow bridging the existing physical-to-digital gap in civil engineering students. They provide an accessible source of technologies that are nowadays used in different educational ecosystems. Sensors and actuators of various sources can be coupled and controlled via i) open platforms ii) free and/or commercial Software iii) open platforms aimed at developing mobile application iv) open Computer Vision applications. Active online communities are nowadays feeding the web with endless possibilities related to coding, electronics and many forms of cyber-physical systems. Together with additive 3D printing, subtractive laser-cutting and many other Construction 4.0 emerging technologies, accessible and affordable sensors are paving the way for more experimentally-rich activities in engineering education.

Moreover, mobile devices became ubiquitous in society. In less than a decade, a quite considerable amount of creativity from developers around the world has flowed to mobile applications. The social connectivity provided by mobile devices is unparalleled in human history and they are becoming highly influential in all facets of our existence. Nowadays, a considerable proportion of people are hyper-connected to mobile phones on a regular basis. Even if the opportunities for creation using mobile devices are abundant, this connectedness becomes pervasively oriented towards consumption of content. Recognizably, all aspects of human interaction are being disrupted by mobile phones. Education is not an exception. Nonetheless, the systematic educational use of mobile phones within classrooms as human-experiment interfaces has not reached massive implementation.

Computer-vision is a broad term that encompasses interdisciplinary scientific fields that deals with how computers can gain high-level understanding from digital images or videos. Computer vision tasks include methods for acquiring, processing, analysing and understanding individual or sequences of digital images. Subsequently, extraction of data from these images produces numerical or symbolic information. Understanding in this context means the transformation of visual images (the input of the retina) into descriptions of the world that make sense to thought processes and can elicit appropriate action. This image understanding can be seen as the disentangling of symbolic information from image data using models constructed with the aid of geometry, physics, statistics, and learning theory. Sub-domains of computer vision include scene reconstruction, object detection, event detection, video tracking, object recognition, 3D pose estimation, learning, indexing, motion estimation, 3D scene modelling, and image restoration. In this particular research, the focus is on motion estimation of simple systems in the context of a structural dynamics course.

A collection of experiences in which sensors, embedded sensors and images are used to track motion of single- or multi-degree of freedom systems is presented. All activities and deployments have been fully or partially implemented as experimentally-rich lessons at both Bachelor and Master levels. The study encompasses three aspects: i) identification and/or construction of physical systems, ii) measurement of relevant magnitudes in those systems and iii) structural dynamic identification of the systems based on the obtained results. Topics and concepts such as: free vibrations, oscillatory motion and arbitrary pulses for both single and multiple degrees of freedom systems represent the core of the experiments. The case study shows how experimental structural dynamic identification of systems reinforce understanding of concepts using open, available, affordable and accessible tools, which is linked to the SDG # 9. Building resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

The paper is organized as follows. First, we summarize the educational platforms typically used for structural dynamics. Next, we present the experiments designed for the Bachelor and Master courses given at the School of Civil Engineering (UPC). Following that, the instrumentation implemented in the educational experiences is briefly detailed, along with an overview of the sensors available in the mobile devices. Finally, details regarding our first attempts on computer vision techniques for structural dynamics are given.

2. REVIEW OF THE EARLIER WORK

The importance of structural dynamics gives the topic a major position in engineering. The use of platforms related to structural dynamics and education is not infrequent in academia. The vast majority of academic publications show a prevalence of desktop platforms based on simulations and physics that are used in advanced courses of design. As a matter of fact, these applications presume students are acquainted with basic concepts taught in prior courses. For instance, [1] provided an educational Matlab-based computational tool for the seismic analysis of reinforced concrete elements, which is an advanced topic. The desktop-based platform allows the user to analyze building structural dynamics with a particular emphasis on soil-structure interaction. It is a design tool that allows users changing design parameters and perform what-if questions. Another desktop-based application is the Java-based virtual laboratory for linear and nonlinear structural dynamics proposed in [2]. The platform mimics data acquisition from up to 8 sensors. Signals (from files) can be added, as well as white noise in a particular time discretization. The platform provides understanding of data-acquisition and modal analysis of tall buildings. Educational research involving the use of FEM and gamified platforms for the understanding of structural analysis are proposed in [3]. In this context, computational numerical methods for structural analysis are combined with computer graphics to provide a qualitative and quantitative understanding of the structural behavior of simple and complex systems. Another design tool for training on nonlinear earthquake and general linear dynamics called ENGLTHA is provided in [4]. The tool is conceived for a broad audience in terms of levels (Bachelor and Master). A Java structural dynamics educational Software with the name of Dynosoft is proposed by [4], which is used as a generator of synthetic dynamic systems in which modal analyses can be performed and visualized. In a more experimental educational approach, shake-table tests based on web control and Labview visualization were proposed by [6] and by [7]. For the former, any person connected online can generate experiments and gather data on one-story and two-story structures subjected to both oscillatory motion and arbitrary earthquake pulses. The latter consists of a one-directional shake table on which scale-reduced structures are installed, sensored and analysed together with students. Furthermore, in a blended physical-digital space, a set of experiments with their corresponding digital replica were developed using Arduino boards and Processing-based graphical user interfaces by [8]. A particular case of use of embedded sensors for understanding body dynamics using a developed mobile application was presented recently in [9].

3. DESIGNING EXPERIMENTS IN STRUCTURAL DYNAMICS

A set of specifically designed experiments for both single and multi d.o.f systems is yearly deployed at the Laboratory of Experimental Structural Analysis. Figure 1 illustrates the overall design of the set which consists of three parts: i) Free vibrations, ii) Oscillatory motion and iii) Arbitrary pulses.

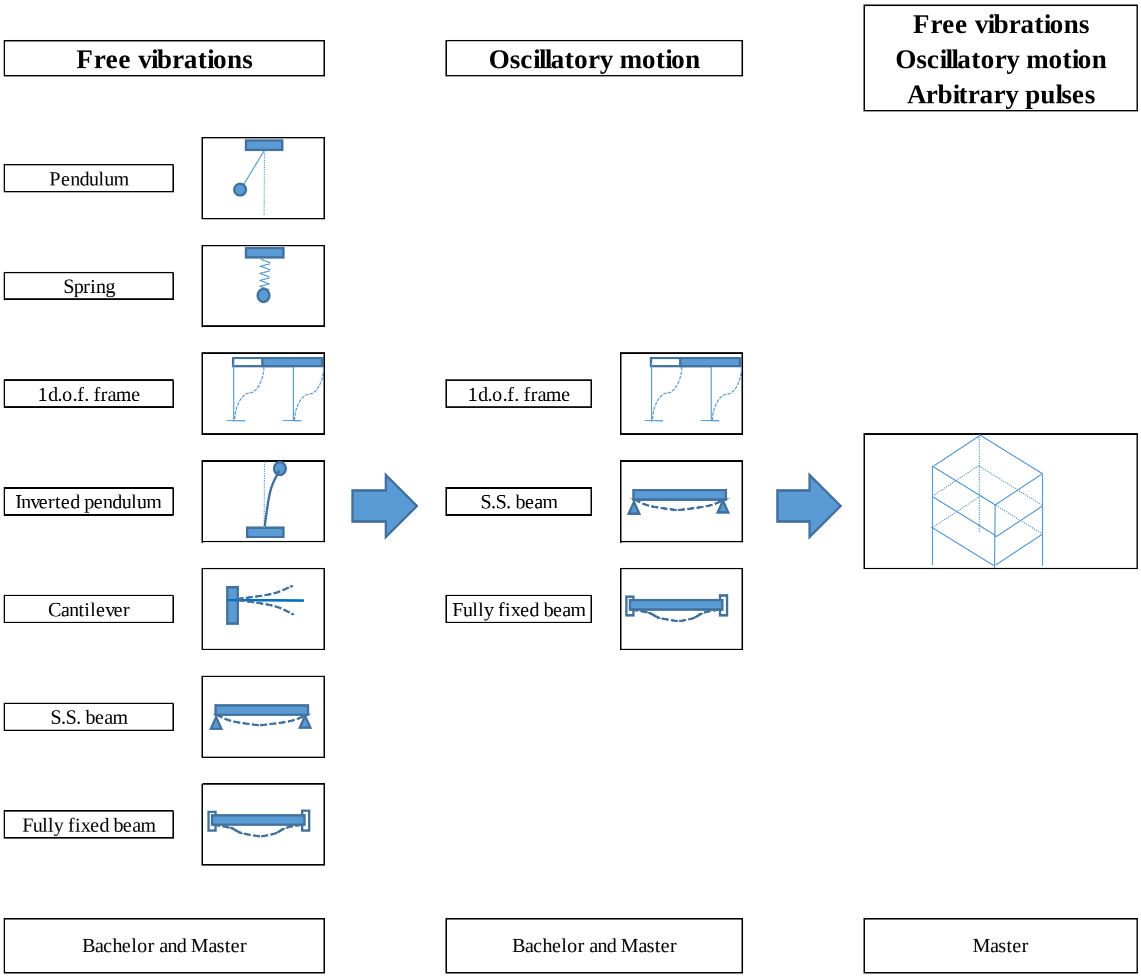


Fig. 1: Overall design of the experiments

Free vibrations are studied using up to seven simple single d.o.f. systems. A set of simple demonstrators including steel beams (cantilever, pinned and fixed supported beams), simple frames, pendula and springs were deployed. The demonstrators can be easily replicated in educational laboratories at a very reduced cost using steel, rods, wood or similar materials. Oscillatory motion is studied by means of three systems and these experiments require more sophisticated equipment. Wave generators and motor engines with eccentric masses were used in these particular cases. As a more complex topic, arbitrary pulses were studied in multiple d.o.f. systems. This was only experimentally analyzed at the Master's level. The experimental set consisted of a CNC controlled bi-axial shake-table located at the School of Civil Engineering. A four-storey 3D frame with a 1700 mm x 1700 mm base was used systematically for the application of different loading protocols. Three types of instrumentation have been implemented in educational experiences in recent years. In the following, a brief description is provided.

4. SENSORS. ACCELEROMETERS, SIMULATIONS AND MICROCONTROLLERS

For several years, Processing [10] and Arduino [11] have been used as Software and Hardware combinations for the development of the educational experience at the School of Civil Engineering. Processing is an open-source language and development environment built on top of the Java programming language. It allows generating computer simulations and visual graphics from scratch. In this context, Processing is used for developing object-oriented physics simulations. Moreover, Arduino is an open hardware-prototyping platform. It is used for connecting accelerometers to simple vibrating devices. Microcontrollers are nowadays available for accessible prototyping using sensors and other peripherals. A set of analogic and digital pins are available in these boards. Connection to computers is performed via USB (for uploading programs or providing power) and an alternative power supply connection (batteries or similar) may also be used in boards in which programs are already uploaded. The board is open and any program following the Arduino syntax can be uploaded and erased as needed. The board can be programmed to sense the environment by receiving analogic inputs from many sensors, and/or to affect its surroundings by controlling lights, motors, and other actuators or digital devices. The laboratory sessions using sensors include the construction of the system, connection of the instrumental equipment, data gathering and development of a simple simulation. Many of the experiences using simple systems and physical-to-digital applications have been published and thoroughly depicted in [8] and [12].

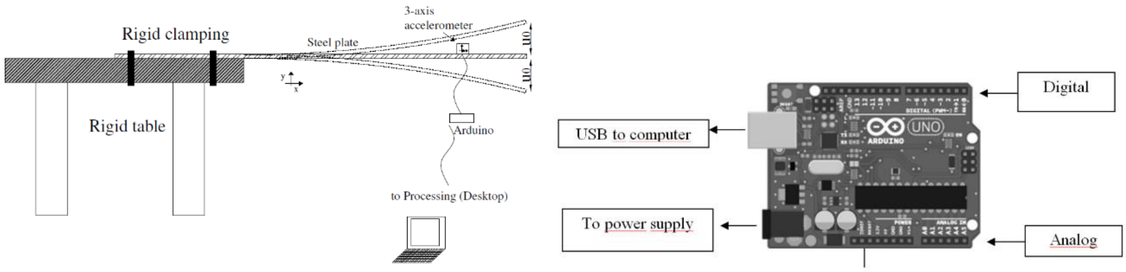


Fig. 2: Connections and general view of an illustrative example of free vibrations experiment

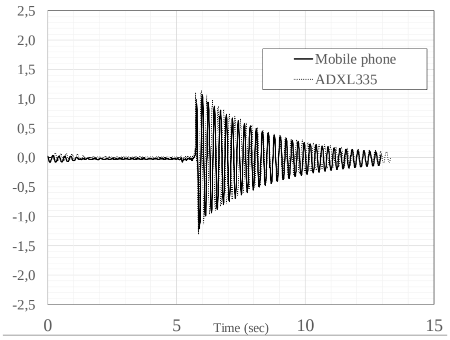
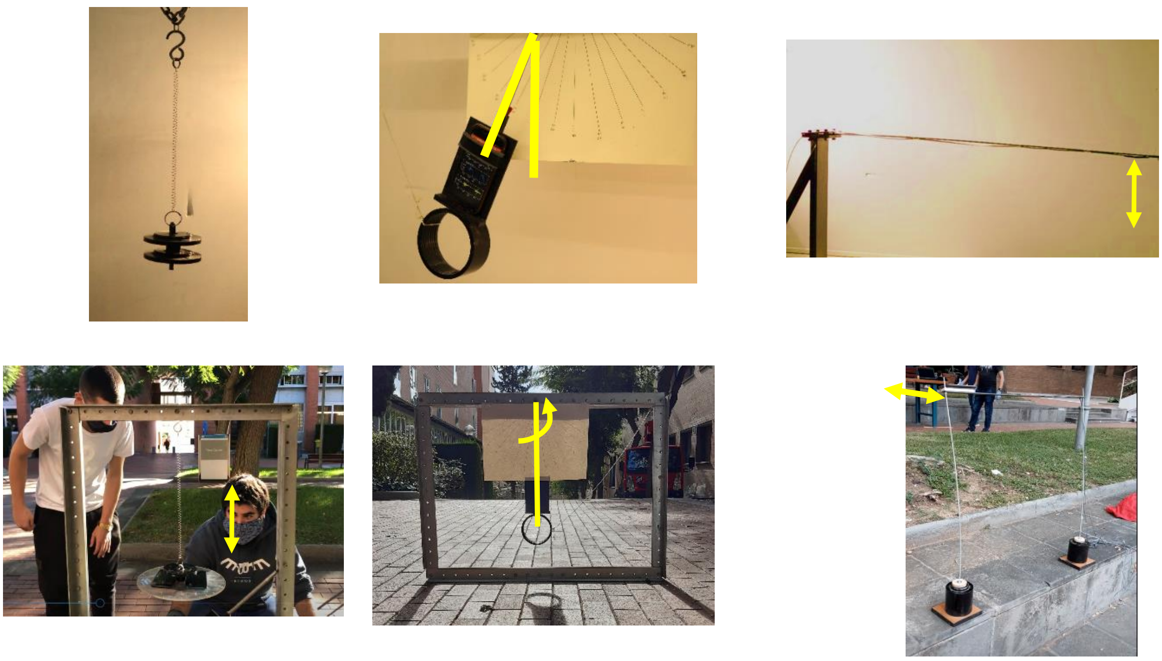


Fig. 3: Measured accelerations in the illustrative experiment on free vibrations

5. EMBEDDED SENSORS IN MOBILE DEVICES

The primary measurement tools are the accelerometers embedded in smartphones whose data is acquired by means of Phyphox [13]. Phyphox is a mobile application developed in RWTH Aachen at the 2nd Institute of Physics. It allows using different sensors from the mobile phones for a vast array of experiments. The application provides capabilities for saving, exporting and/or sharing the data. The platform includes an interface for remote control of the experiment using a web application if needed. Thus, the mobile app can be controlled remotely from a notebook. The data analysis is customizable, so that each step of the analysis can be reviewed and modified by each app user. All students install Phyphox in their own devices in order to access to embedded accelerometers. It is worth pointing out that other platforms for accessing to the raw data are also available in the market. Figure 4 displays springs, pendula, beams and frames in a hands-on, outdoors lesson.



Springs Pendulum Beams, frames

Fig. 4: Simple systems and mobile phones.

The systems are provided with mobile phones and measurements are undertaken. Identification of structural properties are thus developed by students. Reports on damping, frequencies, masses, stiffness and other variables describe. In addition, students are entitled to compare measurements taken with embedded sensors with other benchmarks (Figure 5). This has been implemented in last two academic year with a high degree of success among students. It has been particularly effective in the post-pandemic year since it was necessary to minimize the use of common equipment. Since each student could use his/her own device, the interaction during the laboratory session was safely developed.

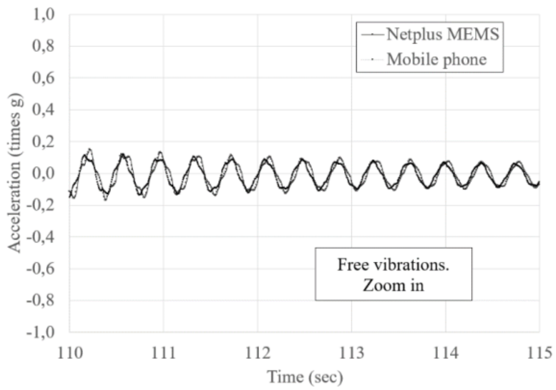


Fig. 5: Comparison between measurements (professional device and mobile phones).

6. COMPUTER VISION

First attempts of developing image recognition techniques in structural dynamics classrooms have been undertaken at the Laboratory. Using high quality slow motion video and simple systems, the goal has been to reproduce the response of the system under free vibrations and oscillatory motion. Figure 6 shows a planar system (relatively flexible one d.o.f. frame with a concentrated mass). The mass is characterized in Processing using methods for computer vision. With highly contrasted images, the colour of the mass became black. Using the method get(i,j), the colour of each pixel within all images are stored in an array. The centroid of the mass is thus calculated from the array using basic weighing. As a result, the position of the centroid of the mass is tracked from one image to another. Position (or displacement) in the time domain plots can be reproduced (Fig. 7). It is worth pointing out that this has been possible using slow motion videos (180fps) and flexible systems in which the position of the moving element is sufficiently large (or the image resolution high enough). Further developments using openCV [14] applications for Python are under development for enhancing the lessons. In either case, this first approach becomes an interesting application of computer vision for civil engineering students. Other examples of such applications have been identified in recent literature [15].

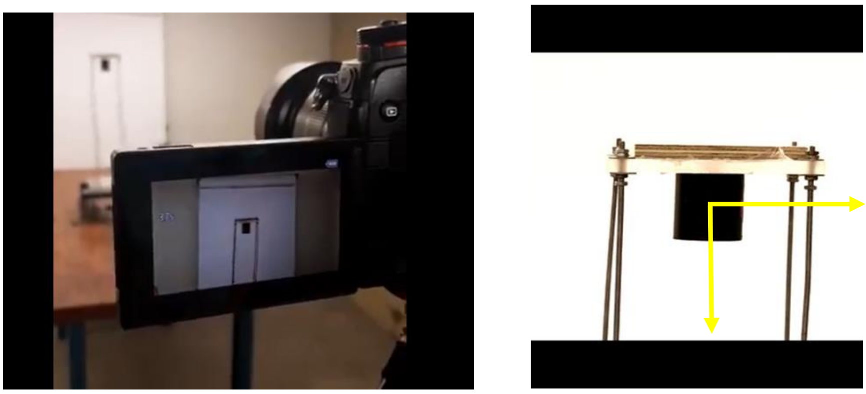


Fig. 6: CV deployment for the identification of systems.

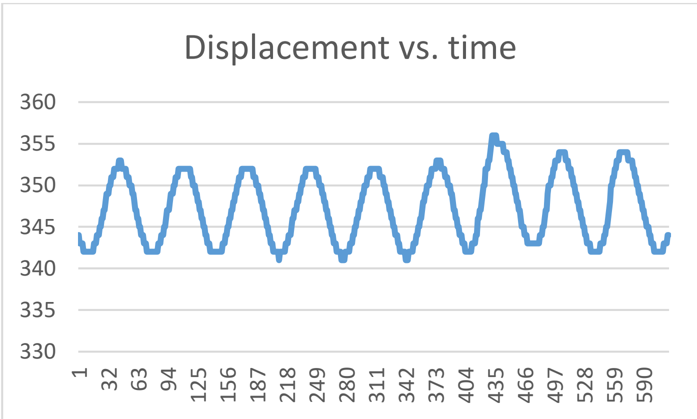


Fig. 7: Displacements in the time domain.

7. CONCLUSIONS

In this paper, some experiences and learning outcomes from the implementation of experimental dynamics are presented. Namely, sensors and microcontrollers, embedded accelerometers and image recognition techniques have been used for enriching basic courses in structural dynamics. Free vibrations, oscillatory motion and arbitrary pulses are covered. Many ways for broadening instrumentation and control tools in civil engineering classrooms are available in an open-source, affordable and accessible manner. Microcontrollers and sensors provide enormous potential for data acquisition and the development of more complex measuring and visualizing prototypes. Mobile devices are owned by the incumbent students and their implication in monitoring structures increases their motivation. Simple video recognition techniques open a way for civil engineering students to acquire ideas about computer vision. Their usage, though, is not broadly known in civil engineering classrooms. Specific remarks related to the implementation of this case study in a structural dynamics course are pointed out:

Technically, the use of peripheral and embedded sensors proved satisfactory. Comparisons between results obtained with different platforms showed similar levels of accuracy and precision when it comes to inferring results from measurements. Calculations and characterization of structures related to damping, natural frequencies, transmissibility and resonance practically matched for single and multiple d.o.f. experiments.

Educationally, observations suggest that monitoring simple systems was fundamental for ensuring proper understanding of the physical phenomena. Comparisons between experimental and numerical results challenged certain students differently. For some students, it represented an effective way to familiarize with concepts in structural dynamics. For other students though, it was observed that theoretical formulas were sometimes correctly applied but no engineering judgement was observed when presenting the results. The comparisons between experiments and analytical solutions was necessary in such cases for ensuring proper understanding of these theoretical solutions. Measurements provide a phenomenological insight of the problem that requires proper matching with analytical solutions and adequate understanding of the corresponding theoretical descriptions.

8. ACKNOWLEDGEMENTS

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"The role of education for Civil Engineers in the implementation of the SDGs"
1st Joint Conference of EUCEET and AECEF

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INTERACTIVE PROGRAMMING ACTIVITIES FOR 1ST YEAR STUDENTS OF CALCULUS IN CIVIL ENGINEERING

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Key words: Calculus, Interactive Programming, Differentiation, STEAM

ABSTRACT

In Engineering, traditional approaches for teaching Calculus include a sequential development of proofs and exercises related to functions, differentiation, integration and partial differential equations. Often, in the specific case of functions and differentiation, lessons include programming in different coding languages as well. In this paper, a set of interactive activities in which programming, art and mathematics is presented. These activities represent one alternative among the palette of exercises developed by 1st year students at the School of Civil Engineering in Barcelona, Spain in the area of Calculus. These activities belong to the "MATES to STEAM" project, whose aim is to bring Science, Technology, Engineering, Art and Maths together not only through outside activities but encouraging a more interdisciplinary curriculum for regular subjects. Seldom, the use of interactive programming with a focus on artful outcomes is present in engineering schools. The paper describes the lessons learned during the implementation of teaching experiences within the framework of a basic course of Calculus. The course is prepared for civil engineering students and it includes both theoretical and programming methodologies as part of the preparation for more advanced courses throughout the degree.

1. INTRODUCTION

The Architecture, Engineering and Construction sector (AEC) includes a variety of professions shaped by evolving challenges and emergent opportunities. Professionals from the sector need a broad skillset to address global endeavours included in the SDG such as climate action, decent work and growth, clean water and sanitation, affordable and clean energy. These endeavours must shape altogether all technological advancements that are driving the industry. Inclusive and sustainable industrialization, together with innovation and infrastructure, are meant to unleash dynamic and competitive economic forces that generate employment and income. Technological advances in the Architecture, Engineering and Construction sector (AEC) are evolving at a fast pace. The built environment sector is reaching maturity for leapfrogging to more efficient production, business models and overall, value chains. Educationally, this has profound consequences for new generations of the sector and as a result, both teaching and research players at universities and industry require adaptation to those changes. For instance, civil engineering curricula have seldom been infused with up-to-date ICT technologies.

With the aim of contributing to this gradual adaptation, a recently finished educational project has been developed at the School of Civil Engineering in Barcelona, Spain. The name of the project is MATES to STEAM, which is a playful turnaround of the Spanish acronym MATES (an informal way of referring to Mathematics) to the well-known acronym STEAM (Science, Technology, Engineering, Arts and Mathematics). The activities on Calculus courses that are presented in this paper belong to this vaster project, whose methodology is based on the creation of STEAM-rich activities for a new degree of Technologies in Civil Engineering which is being implemented at the School.

The paper is organized as follows. First, we summarize the new degree on Civil Engineering Technologies, which represents the inspirational arena for the development of the project. Next, we present the overall learning path that is proposed for this new degree. It is worth pointing out that this represents a set of activities conceived from 1st to 4th year with a STEAM perspective. Then, the paper shows a description of the interactive programming activities that have already been implemented with 1st year students of Civil Engineering Technologies.

2. CIVIL ENGINEERING TECHNOLOGIES

The field of civil engineering is expanding beyond the traditional design and decision-making process. As global challenges continue, civil engineering requires innovation to maintain competitiveness. New social, environmental and economic models and scenarios pose significant challenges for the adaptation of current structures and systems, mobility management, transport and logistics, large infrastructure management, water supply, energy sources, waste reduction and environmental protection. Civil Engineering plays a key role on the improvement of people's quality of life, environmental protection and economic growth, which is nowadays and historically aligned with the SDG. In order to contribute to this adaptation, a new degree on Civil Engineering Technologies has been recently implemented at the Technical University of Catalonia, in Barcelona, Spain. On a nutshell, the degree can be described as a journey from solid theoretical background in mathematics and sciences in first years to state-of-the-art technologies at the end of the degree.
In order to explore up-to-date technologies and to eventually contribute to the new degree curriculum, the project MATES-to-STEAM has been developed. The outcome of this project is a comprehensive Construction 4.0-related complementary learning path for students of the new degree. Content, activities, workshops, cornerstone and capstone projects erect the frame of this learner-centred pathway. The whole set of activities is referred to within the project as demonstrators. The objective of the proposal is to aggregate Construction 4.0 content coherently and subsequently, to propose this content to students at the School of Civil Engineering in Barcelona. Several features of these demonstrators are pointed out:

- In the 1st academic year, demonstrators consist of cornerstone projects related to coding. These projects are aligned with the actual curriculum and the particular goal of such projects is to infuse coding and programming topics that are simultaneously taught in courses of Calculus, Algebra and Geometry.
- In 2nd and 3rd year, demonstrators consist of a set of workshops. Different themes of Construction 4.0 such as Automation and Robotics, Digital Fabrication, BIM or IoT represent fertile topics for the generation of workshops that can be updated year by year.

- In 4th year, a capstone project allows closing the loop by integrating all (S) (T) (E) (A) (M) components in a single demonstrator. The demonstrator is related but not limited to the course "Digital Twins and Augmented Realities in Construction", included in the new degree.

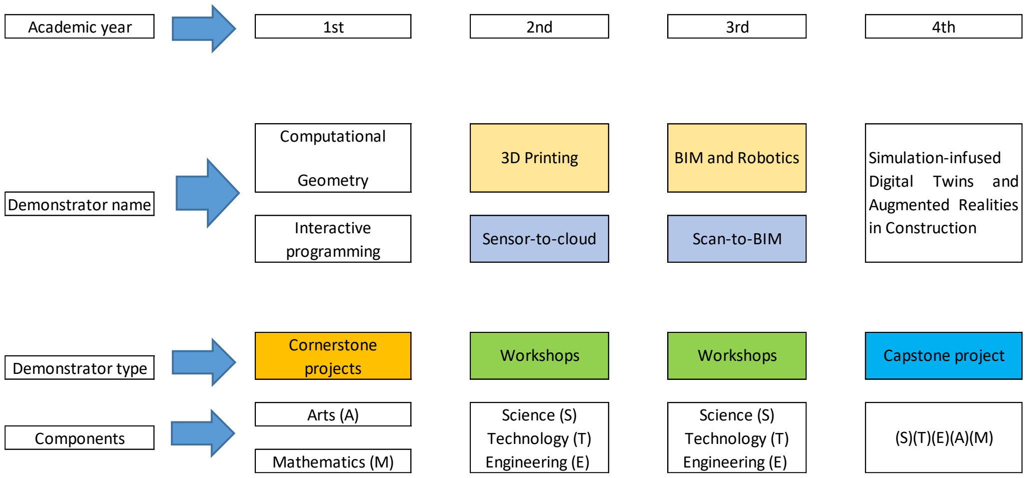


Fig.1: Overall design of the Construction 4.0 learning path

3. INTERACTIVE PROGRAMMING IN CALCULUS

The MATES to STEAM project aims to bring Science, Technology, Engineering, Art and Maths together not only for the development of Construction 4.0 activities but also, for encouraging a more interdisciplinary view of the curriculum in regular subjects. Following this idea, one of the subjects that nourished from the project was Calculus course on the first year of Civil Engineering together with Civil Engineering Technologies of the nre degree. Both cover basic knowledge about differential and integral calculus of one and more variables as well as ODEs. Even though the overall project has been conceived for the new degree on Technologies, students from the classical Civil Engineering degree have also developed the activity.

The main goal of this integration was to teach interactive programming skills to 1st year students while strengthening mathematic concepts such as functions, differentiation and coordinate transformation.

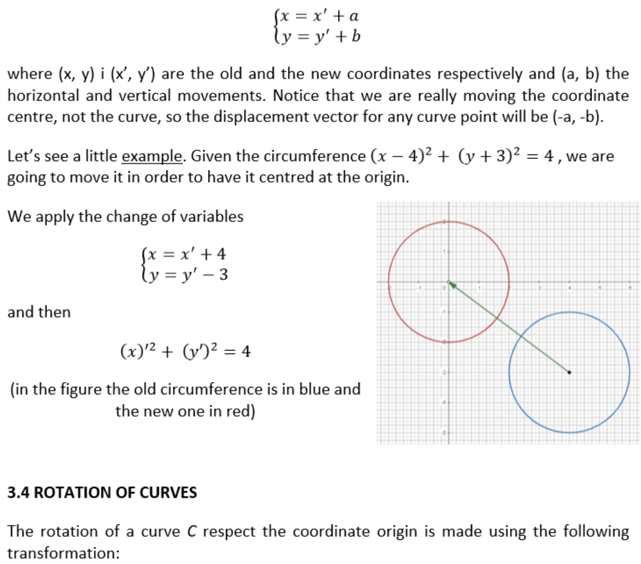
To do so, an optional and mainly autonomous assignment was prepared and implemented during 2019-2021 (the duration of the project). The activity consisted of plotting an implicit curve on a virtual canvas and then introducing a basic interaction feature that showed the tangent line to the curve when the mouse cursor was when the mouse was on it. To be able to construct this plot, an analytical view of implicit differentiation is first conducted. Subsequently, interactive programming is carried out using Processing [1], which is a flexible software sketchbook and a language for learning how to code within the context of the visual arts language. It is found suitable due to its simplicity and native plotting structure. This coding language is broadly used at the School for the

development of interactive applications using sensors, microcontrollers and different user interfaces in courses of civil engineering such as structural analysis [2] or structural dynamics [3].
The first set of projects is defined as cornerstone due to the need of basic understanding of coding. The demonstrators have been already implemented twice. In the first two editions, the demonstrators have been conceived as a challenge proposed to students which deals with mathematics. Applied introductory programming are always useful for civil engineering students due to their uneven prior acquaintance with coding skills. The first (2020) and second edition (2021) of the demonstrator were aimed at reinforcing concepts of differentiation throughout a hands-on coding activity. More details about other workshops and capstone of the project can be found in [4].

4. METHODOLOGY

The formal Calculus syllabus (M) including derivatives is illustrated by students by designing a beautiful visual application (A). Students enrolled in the Calculus course were given an optional yet graded task. The challenge of the activity was: For a given implicit function, an interactive visual application ought to be developed. This application requirements were: i) drawing the curve using points, lines, colors, axes and a Canvas and ii) drawing a tangent line to the curve as the mouse pointer is placed on any of its points (x,y). The first requirement is a straightforward static code in which points of coordinates (x,y) are plotted in a Canvas. The Canvas represents the design space of given coordinates in pixels. Most students in Civil Engineering are not acquainted with computer graphics and thus, pixels must be presented as a length unit for the first time for them. The second requirement is more advanced dynamic interactive code that presumes an adequate use of Time within the design space. Similarly, units are related to frames per second, milliseconds and thus, Time and Space are intertwined within the application. Students are entitled to use creativity and beauty in the development of such applications by plotting moving primitives (points, lines, rectangles, circles, triangles) in a 2D space with a creative formatting. The provided didactic material that is provided for the assignment is:

- Main guide/manual: a 20-page manual written specifically for this activity that covers all the needed knowledge about Processing (from installation to main structure and basic commands) as well as a brief reminder of the mathematical concepts required for the assignment. It is important to note that the guide does not explain how to do the assignment step by step, but presents all the required tools/commands so the student can deduce their own solution to the problem. Definition of points, lines, curves, movement, rotation, translation, colors and other visual aspects are treated in this document. Time and Space in Computer Graphics represent fundamental concepts that are explained in this document.



$$\begin{cases} x = x' + a \\ y = y' + b \end{cases}$$

where (x, y) i (x', y') are the old and the new coordinates respectively and (a, b) the horizontal and vertical movements. Notice that we are really moving the coordinate centre, not the curve, so the displacement vector for any curve point will be (-a, -b).

Let's see a little example. Given the circumference $(x-4)^2 + (y+3)^2 = 4$, we are going to move it in order to have it centred at the origin.

We apply the change of variables

$$\begin{cases} x = x' + 4 \\ y = y' - 3 \end{cases}$$

and then

$$(x)'^2 + (y')^2 = 4$$

(in the figure the old circumference is in blue and the new one in red)

3.4 ROTATION OF CURVES

The rotation of a curve *C* respect the coordinate origin is made using the following transformation:

Fig.2: Documentation provided to students. Points, curves, movement, rotation, translation, Time and Space.

- 20 minutes long video tutorial with general information. A pre-recorded tutorial was provided to students. It is worth pointing out that the first edition of the video was delivered in the middle of the lock-down due to the Pandemics. It proved satisfactory for students who were most of the time online during those days. A Q&A sessions was also offered.

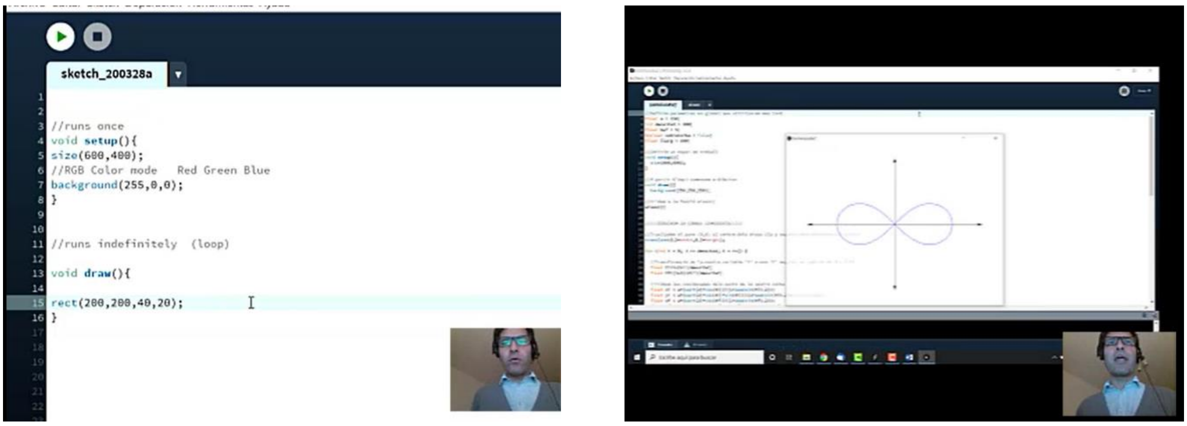


Fig.3: Video tutorial with generic interactive programming

- Customized implicit curve: there is a list of 25 "famous" curves of similar difficulty with its implicit form. Every group of students was given curve of the pool.

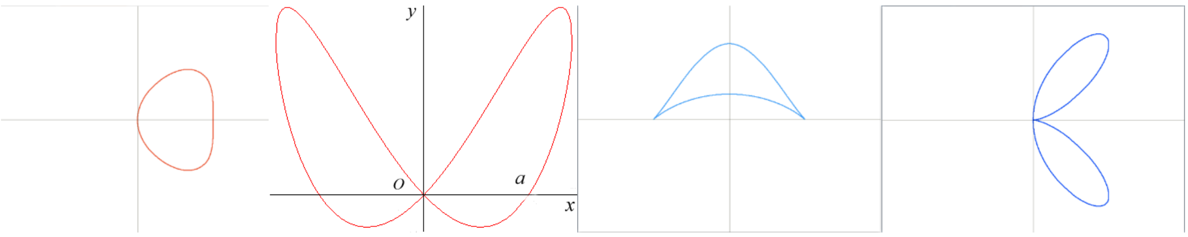


Fig.4: Illustrative examples of implicit curves that belong to the pool of functions

The activity was conducted entirely online following the following workflow:

- First, the assignment is presented in a regular theory class and the students are asked to group themselves in groups of 2 or 3 people.
- Then the group are able to contact the facilitators in charge of the activity via email and they are given a personalized curve, its implicit expression and a guide/manual about the theory and Processing.
- For about 10 days, the students work independently trying to solve the assignment with the information given. In the case they are stuck at some point, they can get help via email from the facilitators.
- Then, a Q&A session is conducted, in where facilitators have processed the previously asked questions. General questions and hints on how some parts of the assignment can be fulfilled are discussed. At the end of the main session students can also ask for specific help.
- Finally the students are given about 5 days until the final submission of the assignment.

5. RESULTS

The results of the activity were mostly satisfying, with high participation and performance. The participation is much higher during 2020, probably due to the lock-down in where the students spent longer periods online. It was noted that students were more enthusiastic about novel dynamic and different activities than plane online lectures. In Table, some results are pointed out.

Table 1. Quantitative results in 2020-2021 editions

	Students	Av. mark	Groups
2020	108	7.93	44
2021	61	7.12	21

In order to monitor more specific performance of the students, facilitators focused on some of the specific tasks:

- Report on Maths: written mathematical study.
- Adequacy of the curve construction: plotting the curve in the canvas.
- Playful Interactivity: adding the interactive part that shows the tangent line.

In table 2, the number of groups that succeeded in every performance indicator are showed. Succeeding means receiving more than 50% of the grade of each task.

Table 2. Performance indicators in 2020-2021 editions

	Groups	Maths	Construction	Interaction
2020	44	34	41	27
2021	21	14	18	12

During the development of the activity the students i) plotted the curve in the canvas, ii) found the differentiation of an implicit curve (using chain rule and other concepts) and iii) used the derivative function for drawing a tangent line whose angle of rotation must be in accordance to the coordinates generated by the mouse pointer (x,y)=(mouseX, mouseY). Figure 5 shows an example of a curve and its tangent developed by one of the participants. A simple plot of the function in a 2D space is presented. Axes are drawn using lines and triangles and the function is plotted using points. The tangent line appears only when the mouse pointer is set on the curve at any point. A text indicating the slope is added for verification purposes.

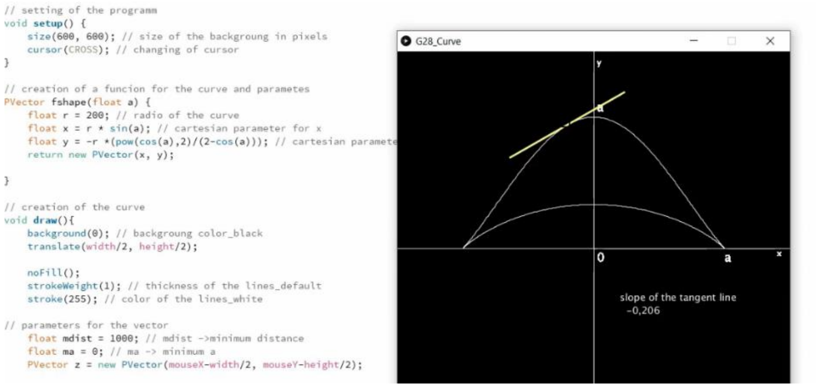
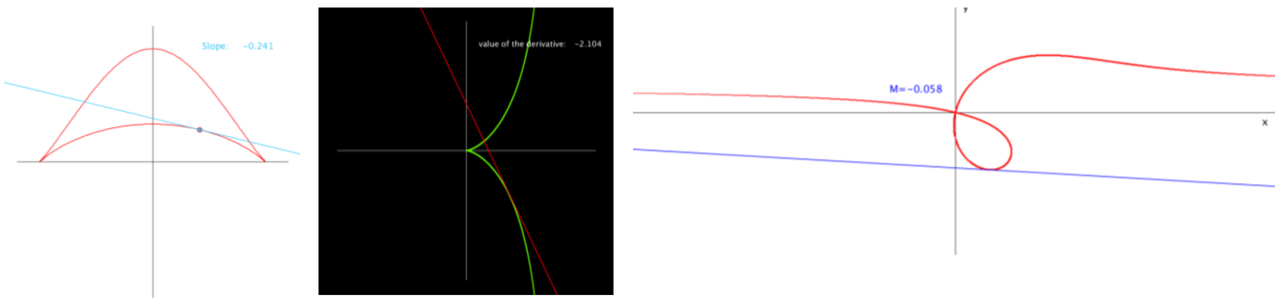


Fig.5: Typical results obtained with a curve and its tangent line

Other examples of the developed curves are shown in Figure 6.



Bicorn Cissoid Strophoid

Fig. 6: Developed curves

6. DISCUSSION

For the first edition, a total amount of 158 students were enrolled. 50 curves of implicit functions were identified (cardioid, nephroid, lemniscata, cissoids, etc). The activity was developed by groups of up to 3 students, which represented nearly 99% of participation. Each group was given a curve from the pool randomly. Students were provided with a bonus point (1 out of 10) as a reward in case of adequate submission. The activity was set when the course had reached 75% of its regular path and represents an optional marking grade of 10% of the total. For the second edition, the reward system changed. The submission allowed substituting the lower grade obtained during the course. 20 groups (58 students) submitted adequate projects, which represents 50% of participation. The activity was set when the course had reached 75% of its regular path and represents a maximum yet optional marking grade of 10% of the total as well. It is interesting to point out that in the second edition, students were not locked down and lectures were held in Campus whereas for the former, students were locked down and lectures were fully remote. Moreover, it is important to pinpoint that the Calculus course of first year has 6 European Credit Transfer System (ECTS) with an approximate amount of 4 hours of lectures per week during the whole academic year.

7. CONCLUSIVE REMARKS

In this paper, some experiences and learning outcomes from the implementation of interactive programming at 1st year of Calculus are presented. With the aim of contributing to a new curriculum design on a degree on Civil Engineering Technologies, a recently finished educational project has been developed at the School of Civil Engineering in Barcelona, Spain. The activities on Calculus courses that are presented in this paper belong to this vaster project, whose methodology is based on the creation of STEAM-rich activities for a new degree of Technologies in Civil Engineering which is being implemented at the School. For the first edition, a total amount of 158 students were enrolled. 5. The activity was developed by groups of up to 3 students and as optional it proved successful (99% participation). Students were locked down during this edition and the activity represented a motivational exercise of Maths. For the second edition, changes in the reward system as well as in the lockdown generated that the participation halved. In either case, participants provided successful exercises in which interactive curves with adequate use of Time and Space were implemented. In future editions, similar projects including other computational geometry tools will be prepared in a similar way.

8. ACKNOWLEDGEMENTS

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"The role of education for Civil Engineers in the implementation of the SDGs"
1st Joint Conference of EUCEET and AECEF

Thessaloniki, Greece, November 12th, 2021

THE SUSTAINABLE DEVELOPMENT GOALS IN THE EUROPEAN UNIVERSITIES PROJECTS: THE CASE OF ENGINEERING EDUCATION

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Key words: European universities, engineering, SDGs

ABSTRACT

Many studies predict that more than a third of today's jobs will be gone within 20 years, as global challenges such as the fight against global warming, the preservation of natural resources, and democratic, economic and social crises multiply. The 17 Sustainable Development Goals (SDGs) are the roadmap defined by the 193 member countries of the UN in 2015 to build a more just and sustainable world by 2030.
In this context, higher education has an important role to play in preparing and training young people and local stakeholders for the upcoming transitions and new professional realities.

The "European Universities" have an ambitious mandate to trigger unprecedented levels of institutionalized cooperation, making it systemic, structural and sustainable. As such, the European Universities aim to achieve the following two objectives:

- To promote common European values
- Achieve significant progress in the quality, performance, attractiveness and international competitiveness of higher education institutions

The aim of this initiative is to bring together a new generation of creative Europeans able to cooperate across languages, borders and disciplines to address societal challenges and skills shortages faced in Europe.

41 alliances have been selected by the European Commission as part of this flagship initiative to strengthen the European Higher Education Area. Many of these 41 alliances aim to address SDGs. This paper will present some initiatives to address SDGs in engineering education within European university alliances. We will present an illustration through objectives and actions planned by the European Engineering Learning Innovation & Science Alliance (EELISA).

1. THE EUROPEAN UNIVERSITIES

Echoing the Sorbonne speech delivered by the President of the French Republic, Emmanuel Macron, on 26 September 2017, the European Commission has launched two calls for pilot projects in 2018 and 2019 to test different models of European Universities. 41 three-year projects are the result. 32 French institutions are involved in 28 of these alliances.

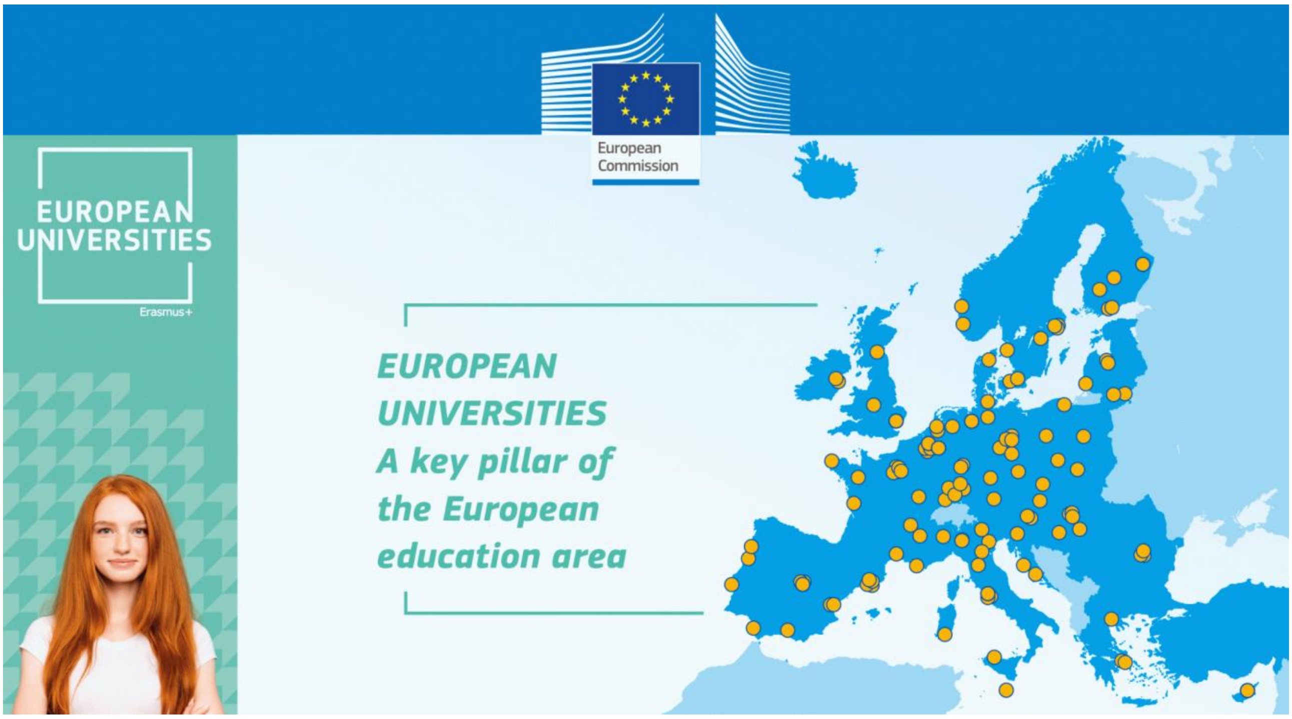

Fig. 1: Geographical distribution of European universities (https://www.arqus-alliance.eu/)

European University projects focus on different themes. Most alliances have a transdisciplinary approach. These alliances do not have a dominant theme and focus on cross-cutting topics for joint work, for example on themes such as education and citizenship, digital, environment, societal transformations or health. Other alliances, on the other hand, focus on a specialisation. Two specialities stand out among the 41 selected projects: the environment and science and technology. [1]

The United Nations' sustainable development goals, with their emphasis on multidisciplinary approaches and their ambition to educate future European citizens to address societal challenges, are echoed in many of the alliances selected by the European Commission.

2. THE SUSTAINABLE DEVELOPMENT GOALS

The Sustainable Development Goals are a call to action for all countries - poor, rich and middle-income - to promote prosperity while protecting the planet. They recognise that ending poverty must go hand in hand with strategies that expand economic growth and address a range of social needs, including education, health, social protection and employment opportunities, while tackling climate change and protecting the environment.[2]

The 17 Sustainable Development Goals and their 169 targets form the core of the 2030 Agenda. They cover all sustainable development issues such as climate, biodiversity, energy, water, but also poverty, gender equality, economic prosperity, peace, agriculture, education...

The 2030 Agenda is also characterised by the recognition of the intrinsic links between the different themes and the necessary mobilisation of all actors, both institutional and civil society.

The ambitious and cross-cutting nature of the sustainable development goals raises a number of issues for the coming years:

- Ensuring a realistic assessment of the situation, then implementing rigorous monitoring of the progress made and identifying possible areas for improvement.
- Create a dynamic for the appropriation of sustainable development objectives by the territories, civil society, the private sector and citizens.
- Foster a context of cooperation: disseminate good practices and build a framework for cooperation between actors to carry out joint actions.

All countries must implement the entire agenda, with the same degree of ambition, while taking into account the variety of situations. They are invited to report annually on their progress to the UN High Level Political Forum. [3]

Fig. 2: List of Sustainable Development Goals (https://www.geneve-int.ch/)

Universities, higher education and research institutions have the potential to be key players in achieving the goals of sustainable development. Of course under Goal 4 (quality education). But also in the sense that universities play an important role in assessment, ownership and cooperation between actors in our societies.

3. A WAY OF LOOKING AT HOW EUROPEAN UNIVERSITIES PLAN TO ADDRESS THE OBJECTIVES OF SUSTAINABLE DEVELOPMENT

One way of looking at the consideration of sustainable development goals by the 41 winning alliances of the call for European university projects is to cross-reference the keywords with the communication and dissemination elements of these alliances (websites, fact sheets, press releases).

Thus we looked in particular at two aspects of the fact sheets:

- the occurrence of certain terms in the sustainable development objectives;

- the inclusion of sustainable development objectives in the "key deliverables/activities" section.

While the fact sheets only partly reflect the range of European university projects, the unit format allows a comparative approach.

Furthermore, the bias of a restrictive keyword approach may occasionally lead to the under- or over-estimation of the consideration of a particular sustainable development goal. Thus, if we take the example of SDG16 "peace, justice, strong, institutions", the use of the term "institutions" to sometimes refer to alliance partners leads to an artificially strong presence of this SDG in Figure 3. The same is true, at least to some extent, of SDG9 "industry, innovation & infrastructure", where the terms "innovation" and "infrastructure" sometimes refer, in the fact sheets, to pedagogical innovation or research infrastructures, for example.

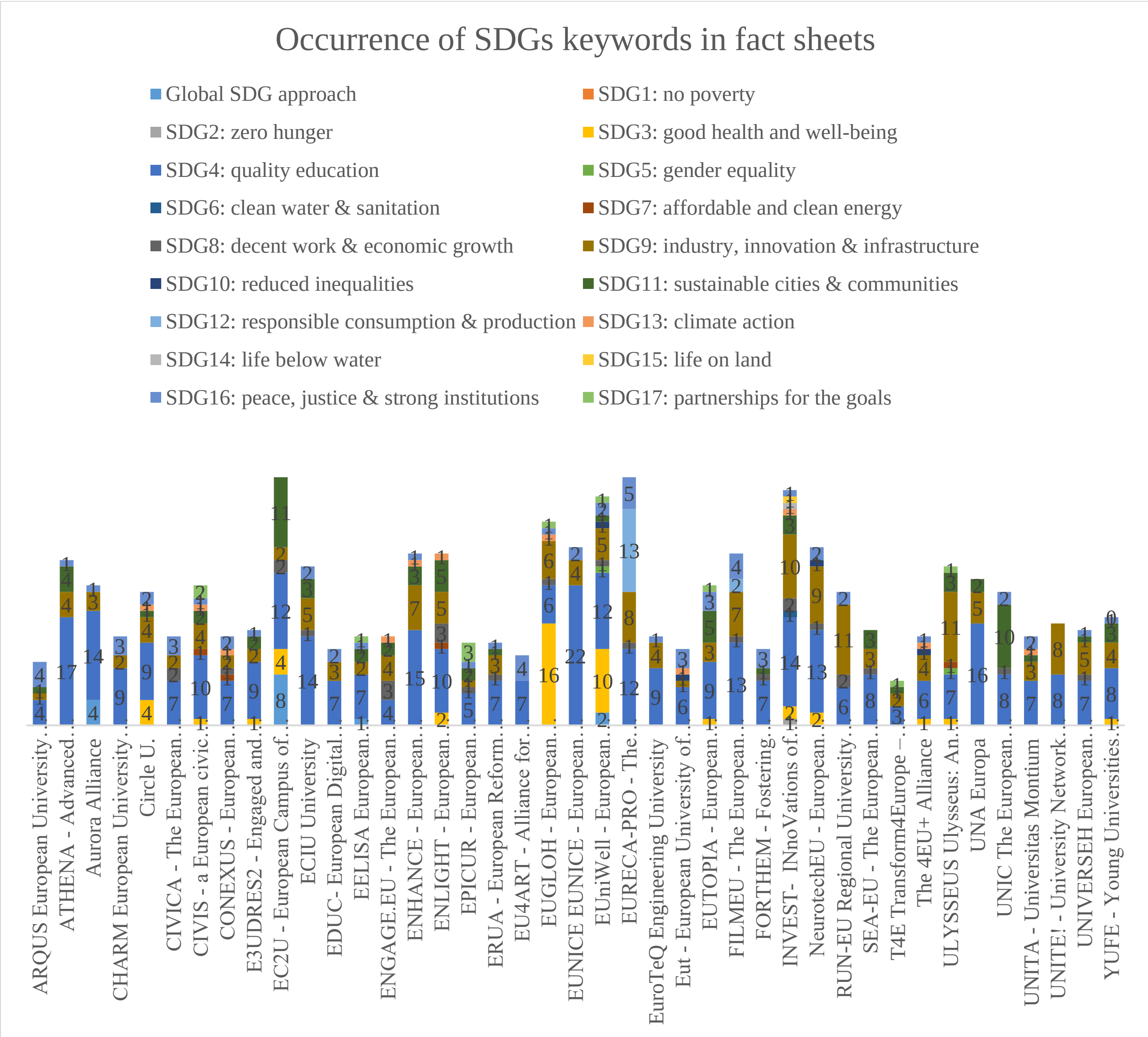

Fig. 3: Occurrence of key SDG terms in European university fact sheets

4. COMMONALITIES

It is clear that no alliance "skips" the SDGs: we find from 10 to 39 occurrences depending on the alliance. We also clearly see that SDG4 "quality education" is logically very well represented in all alliances.

The analysis of the key deliverables and activities proposed by the alliances reveals certain recurrences in addressing certain SD The analysis of the key deliverables and activities proposed by the alliances reveals certain recurrences in addressing certain SDGs:

- SDG4 "quality education" is addressed by several alliances by putting forward a common approach to competences (Aurora, 4EU+, ENHANCE) or by proposing open platforms of shared educational content (EuroTeQ, EUNICE, ATHENA).

- SDG9 "industry, innovation & infrastructure" is addressed several times through the creation of a network or hub bringing together education and research actors, services for the development and support of entrepreneurship and regional socio-economic actors (UNITE!, Ulysseus, RUN-EU, ENHANCE). A parallel can also be drawn between the way several alliances address this SDG9 and the proposals to address SDG17 "partnerships for the goals".

5. ENGAGING BIASES

What emerges from an analysis of the key deliverables and activities put forward by some alliances is that a few have clearly chosen to address an SDG.

This is notably the case for the following alliances:

- EUGLOH et EUniWell are positioned on the SDG3 (good health and well-being). EUGLOH will settle a pilot cross-disciplinary and/or multiple degree European curricula to address global health areas. EUniWell targets the establishment of four research areas which would be a key tool for reforming this alliance approach towards research on well-being, the articulation between research and teaching and the role of external stakeholders.

- CONEXUS and ECIU University alliances are positioned on the SDG11 (sustainable cities and communities). CONEXUS is focused on smart urban coastal sustainability and will launch a dedicated master. ECIU University will focus on topics related to the United Nations Sustainable Development Goal 11 – Sustainable cities and communities – with the ambition of creating a model adaptable to any future societal development objective.

6. THE SUSTAINABLE DEVELOPMENT GOALS WITHIN THE EELISA ALLIANCE

European Engineering Learning Innovation and Science Alliance (EELISA) is the first alliance of Higher Education Institutions (graduate engineering schools, technology universities and full-spectrum universities) from different countries in Europe meant to define and implement a common model of European engineer rooted in society.

EELISA aims to transform European higher education while strengthening links between engineering and society by:

- Re-inventing the “European engineer”.
- Democratizing engineering education.

- Evolving interdisciplinary engineering learning.
- Encouraging knowledge, skills and technology transfer.
- Fostering inclusiveness and diversity.
- Making a real impact on society following the 2030 Agenda for Sustainable Development and the SDGs.

The tool that the EELISA alliance wishes to use to better connect students and beyond higher education institutions with societal issues related to the Sustainable Development Goals are called communities. Unlike departments or faculties (which have a disciplinary approach) or degrees (which have a professional approach), communities are intended to be spaces for exchange, teaching and co-construction of reflections and solutions with a multidisciplinary approach focused on the objectives of sustainable development.

Fig. 4: EELISA communities definition (https://psl.eu/)

In order to measure and reward students' involvement in these communities, the EELISA alliance is working on developing EELISA credentials. These credentials will be tools for students to collect demonstrable learning outcomes gained through participation in community-based educational activities. The chosen repository for measuring educational outcomes is the educational objectives related to the Sustainable Development Goals from Education for Sustainable Development Goals: learning objectives (UNESCO, 2017). This framework provides 255 items (15 per objective) divided into 3 categories:

- The cognitive domain comprises knowledge and thinking skills necessary to better understand the SDG and the challenges in achieving it.

- The socio-emotional domain includes social skills that enable learners to collaborate, negotiate and communicate to promote the SDGs as well as self-reflection skills, values, attitudes and motivations that enable learners to develop themselves.

- The behavioural domain describes action competencies.

Table 1.2.4. Learning objectives for SDG 4 "Quality Education"

Cognitive learning objectives	1. The learner understands the important role of education and lifelong learning opportunities for all (formal, non-formal and informal learning) as main drivers of sustainable development, for improving people's lives and in achieving the SDGs. 2. The learner understands education as a public good, a global common good, a fundamental human right and a basis for guaranteeing the realization of other rights. 3. The learner knows about inequality in access to and attainment of education, particularly between girls and boys and in rural areas, and about reasons for a lack of equitable access to quality education and lifelong learning opportunities. 4. The learner understands the important role of culture in achieving sustainability. 5. The learner understands that education can help create a more sustainable, equitable and peaceful world.
Socio-emotional learning objectives	1. The learner is able to raise awareness of the importance of quality education for all, a humanistic and holistic approach to education, ESD and related approaches. 2. The learner is able through participatory methods to motivate and empower others to demand and use educational opportunities. 3. The learner is able to recognize the intrinsic value of education and to analyse and identify their own learning needs in their personal development. 4. The learner is able to recognize the importance of their own skills for improving their life, in particular for employment and entrepreneurship. 5. The learner is able to engage personally with ESD.
Behavioural learning objectives	1. The learner is able to contribute to facilitating and implementing quality education for all, ESD and related approaches at different levels. 2. The learner is able to promote gender equality in education. 3. The learner is able to publicly demand and support the development of policies promoting free, equitable and quality education for all, ESD and related approaches as well as aiming at safe, accessible and inclusive educational facilities. 4. The learner is able to promote the empowerment of young people. 5. The learner is able to use all opportunities for their own education throughout their life, and to apply the acquired knowledge in everyday situations to promote sustainable development.

Table 1: example of learning objectives for SDG #4 (https://www.unsdgproject.com/)

Having a reference scale for qualifying learning outcomes is a definite asset for broad and reasonably rapid adoption by teachers at the various alliance institutions. However, there is still work to be done in order to have a homogeneous approach to the modes of assessment of the acquisition of this learning outcomes. Indeed, if for the learning objectives which are related to the cognitive domain, a convergence of the assessment methods seems easily achievable, it is much more questionable in the case of the socio-emotional and behavioral domains.

Within the EELISA alliance, we envision the list of educational outcomes related to the SDGs as a menu, from which the designer of an educational activity will be able to select those that a student participating in that activity is likely to complete/improve. Thus, an EELISA credential would be a collection of tips for acquiring SDGs educational outcomes acquired through participation in a series of activities.

7. CONCLUSION

Our study on the key terms related to the sustainable development goals in the fact sheets of European universities allows us to show that:

- all alliances directly or indirectly address the Sustainable Development Goals.

- some objectives are very clearly mentioned in many alliances: SDGs 4 and 9. Most probably because improving educational processes and fostering innovation is part of the general missions of universities, and of the European Universities Initiative in particular.

- Some alliances have made the interesting and assumed choice of positioning themselves thematically on a particular SDGs: SDG 3 for health, SDG 11 for cities.

The EELISA alliance, in order to address the sustainable development goals, will use "communities" which will be multidisciplinary groupings of several educational activities dealing with societal challenges. The 255 educational outcomes linked to the SDGs, published by UNESCO, will serve as a scale for measuring the acquisition of skills. These acquired educational outcomes will be collectable and valorizable in the form of a credential.

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UNIVERSITY EDUCATION ON PERFORMANCE BASED DESIGN AND LIFE CYCLE ENGINEERING IN THE PERSPECTIVE OF PANDEMICS AND DIGITISATION

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Key words: sustainability, performance, risk, infrastructure, digital learning, pandemics

ABSTRACT

The paper focuses on the digital interaction and possibilities to activate the students with distant learning, and without having the possibility to know each other in person previously. The case study focuses on the newly introduced course "Performance Based Design and Life Cycle Engineering". It is an online course that was only recently introduced and took place in the first semester under pandemic conditions. One of the aspects of the study is that the course is quite current and it had to be promptly included to the curriculum. This is due to the fact that the course it addresses an entirely new field for civil engineering, while the content is aligned with new pressing global modern demands for civil engineering, as for example reflected in the 17 Sustainable Development Goals (SDGs) of the latest United Nations Resolution called the 2030 Agenda, but also the New European Bauhaus initiative. Furthermore, the course deals broadly with the conception and management of risk in civil engineering. As such the pandemic situation is often referred to in order to exemplify significant risks, as well as risk reduction measures, such as precautions, consequence mitigations, risk perception and communication, and extreme unforeseen natural events. The lecture is delivered with pre-recorded slides and weekly live Q&A sessions in Zoom. The guest lectures are also taking place in live sessions. Experiences and concerns regarding the specific course flow under the current situation are presented, and the conclusions aim to provide paradigms for similar educational situations in relation to civil engineering sustainability.

1. INTRODUCTION

The built environment has virtually replaced the natural environment as humanity's habitat. We spent most – if not all – of our lifetime in residential, commercial or office buildings and generally built space, such as cities, and transport networks. Besides, our day life strongly depends on technical infrastructure, which is also hosted in civil-engineering works.

In recent years, performance management, durability assessment and ongoing maintenance of built infrastructure in general confronts unprecedented demands. Increase in population, densification of cities, globalisation of markets, extreme natural phenomena, and an urgency toward more sustainable development pose great challenges that existing and future infrastructure systems have to confront. Although reinstating or improving interventions on infrastructure components are unavoidable at some point in time, recent research has recognised and promoted predictive/preventive – as opposed to reactive – maintenance which does not only cater for higher levels of safety, but also for lower overall whole life costs, waste and material resources [6][8]. On the polar opposite of the tremendous technical challenges faced by the civil engineering systems and components come the constantly expanding modern technologies and scientific leaps toward more accurate, realistic, and generally efficient engineering. This combined technological and scientific knowledge is understood in the context of this paper as Performance-Based and Life-Cycle Engineering.

The importance of the response of our societies, where the civil engineering profession holds an instrumental role in many aspects, is clearly reflected among most of the 17 interlinked UN's Sustainable Development Goals (SDGs) [15]. Responding to the acute need for education in this field, the Architecture and Civil Engineering Faculty of the TU Dortmund University offers a special course under the title "Performance Based Design and Life Cycle Engineering" [4]. The course is well-integrated in the overall teaching and research approach of the faculty. Through this approach architecture, spatial and building and planning, structural engineering, construction, and management converge, under the umbrella of the Dortmund Model of Building Engineering / Dortmunder Modell Bauwesen [3][10][12]. In the broader character of the Dortmund Model, several interwoven issues need to be accounted and resolved. These include the durability and degradation of building materials, the assessment of loads and structural effects, the reliable modelling of structures in static and time-dependent situations. It also extends to advanced asset management techniques and practices, co-evaluation of capital and operational expenditures in the investment, suitable integration of various technical equipment, and prediction of the building functionality and attractiveness along its entire service life. Finally, the building is understood as an entity within its surrounding environment and associated communities [11]. Alignment of this course's content with the SDGs can be located, not only with respect to more efficient use of built infrastructure (hence more sustainable use of land and life in cities), as well as resource oriented solutions, but also to the social aspects of safety and corporate or professional responsibility as discussed in [5] [9] [14] [16]. Furthermore, in agreement with [2] and [17] a collaborative and hands-on project learning approach is used throughout the learning process as well as the final examination/assessment process.

Moreover, a special characteristic of this course is that it was introduced amidst the breakout of the Covid-19 pandemic and hence designed in digital form from its inception. In addition, the lecture deals extensively with the conceptualization and management of risks in civil engineering. To the benefit of student discussions, frequent reference is made to the pandemic situation to illustrate significant risks as well as risk mitigation measures such as preparedness, consequence mitigation, risk perception and communication, and extreme unforeseen natural events.

This paper presents the teaching concept of the course, together with indicative contents. In the framework of the Constructive Alignment concept [13], it also introduces the competences, and teaching procedure as well as the examination format and requirements. Finally, some evaluations of the course based on third-party assessments, structured and unstructured student feedback is demonstrated, which allows for useful conclusions on the possible further educational work on this topic.

2. TEACHING CONCEPT

2.1. Teaching process and content

The target audience is civil engineering students in the master's curriculum who have a basic understanding of statistics, engineering design and construction practice. The course was introduced

during the Covid-19 pandemic in the summer semester of 2020 and delivered in a digital format, so it was methodologically designed with this central consideration. The teaching was done through pre-recorded slidecasts, with a technically appropriate equipment, and after each session there was a Q&A session with all students in an online meeting via the Zoom platform. Matlab-based software was created by the tutors with an interface for students that allowed for a "digital lab" where students could experiment with various statistical models and gain a hands-on understanding of the course content. As a result of the small number of students, the exam could be oral with an additional customized exercise presented. The exercise required the application of all the important content of the lecture including calculations and reasoning about the assumptions made in the elaborations. This exercise also accounted an actual example from familiar engineering problems for the University’s wider cross-border region, i.e. the conversion of an old industrial building into a cultural establishment with high life cycle and safety requirements.
The course contents included insights to the backgrounds of the design standard Eurocode 0 [1], the fundamental and most current standardization document for performance-based structural design, the risk and probability theory in the practice of civil engineering, the assessment of safety and reliability of engineering structures and finally an extension to principles and practice of life cycle design. The qualifications and competencies included advanced knowledge in the application of Eurocode 0 and dimensioning under exceptional life-cycle and safety requirements, based on probability theory. In addition, the lecture was given in English to promote the students' language and internationalization skills. Some indicative learning materials are provided in Figure 1.
In more detail, the 12 units comprising the course cover the following sub-topics:

1. Introduction/Course organisation
2. Status and necessities of sustainability oriented civil engineering in a socioeconomical context
3. Introduction to risk science, technical and comprehensive risk management
4. Probability theory, statistics and reliability engineering
5. Structural robustness
6. Seismic robustness (guest lecture – engineering consultancy)
7. Construction/Property insurance (guest lecture – broker and insurance company)
8. Numerical methods in probabilistic and reliability analysis
9. Advanced computing techniques in reliability-based design (guest lecture – academic expert)
10. Existing structures assessment & life-cycle design
11. Data-driven engineering (guest lecture – internet technology firm)
12. Closure

2.2. Examination process

The exams were mainly conducted by the lead lecturer (Prof. Dr. P. Spyridis), accompanied by one of the teaching assistants / tutors for the course. In the examiner’s role a fair assessment based on the preparation of the students in accordance with the course content must be ensured. At the same time, the examination approach was used to provide a final opportunity to clarify some points to students and also to help them understand their levels of competence as part of a self-evaluation process, which was also another main goal of the exam, besides assessment. Otherwise, the examination procedures were based on the Faculty’s Examination Regulations, expanded to include the University's interim and adaptive guidelines for conducting examinations during the pandemic period online. The exams were carried out using a question template and the previously submitted assignment. To achieve this, the assignment was developed in a homogeneous and structured way in accordance with the different teaching objectives of the course. In this, students had to submit an exercise that combines many sub-chapters of the course (risk, robustness calculation, economic-technical risk assessment, reliability assessment, Bayesian updating) in a coherent working example. Finally, they are orally examined based on this homework and the entire theoretical content of the course.

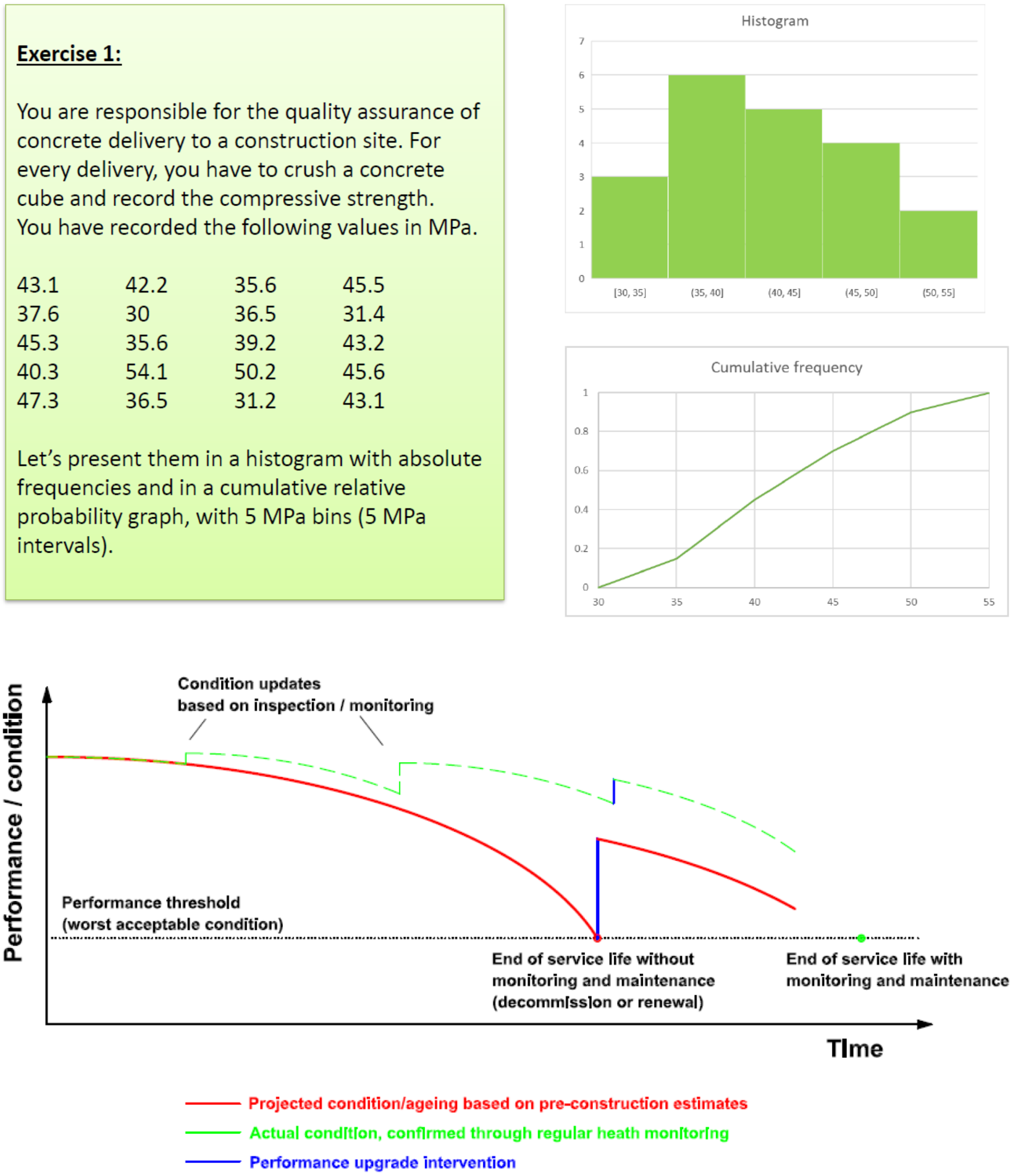

Fig. 1: Indicative course material: risk/reliability simulations (top) and life cycle engineering concepts (bottom)

2.3. Innovative aspects

Innovations of the course can be seen in both the content and structure of the course.
As regards the content, this is a first-of-its-kind lecture to the authors' best knowledge integrating theoretical and practical aspects of risk-based and life-cycle engineering and connecting the societal needs across the basic risk and management theoretical background to a broad spectrum of modern civil engineering practical work under very high uncertainty. Of particular interest is the combined teaching of structural and seismic robustness, recognising that these need to be seen as a single topic developed with somewhat different and historically separated engineering mentalities. Also, delivery of the lecture in English, supporting the academic internationalisation is also not commonplace in German civil engineering academia. The main core of the course was also combined with targeted guest lectures from adjacent technical areas representing scientific niches but also non-traditional practical experiences (e.g. how does the insurance industry, or a unicorn technological company deal with sustainable construction).
The digital hybrid format with pre-recorded slidecasts seamlessly bridged with the Q&A and motivational sessions is basically developed on a "Flipped Classroom" methodology [7], as traditionally taught content is developed with the help of learning recordings as preparatory homework and the live sessions are used for student-centered activities. The video learning phase is instructionally oriented, while the learning activities in the classroom phase follow a constructivistic educational approach. In general, flipped classroom is an established concept, but it has rarely been implemented at technical universities, moreover with implementation of organised synchronous sessions with expert guest lectures.

3. INTERACTION AND ACTIVATION IN THE TEACHING PROCEDURE – EDUCATIONAL CHALLENGES AND RESPONSE

A significant didactical challenge in the framework of the newly introduced course can be summarised in the following questions:

- How can we activate students during live online meetings?
- How can we design and encourage collaboration/engagement among students?

In order to understand and response to the above challenges, the course was developed on the basis of Constructive Alignment. At this stage the specific teaching outcomes were brought to focus. As regards solely technical skills and dexterities, the course focused on competent application of the related construction standard and profound understanding of risk theory in construction practice, which could also be tested by traditional problem solving in form of calculations. As regards transitional skills, an aim of the course was set to the independent assessment of service life and reliability of structures, which was extended to peer evaluation of results. In terms of social abilities, the main pillar was dealing with engineering topics in English language. Toward the optimisation of the course, some additional considerations were carried out early on in the teaching period and an "educational toolkit" based on [13] was put in action.

In order to strengthen technical skills, the problem-oriented learning by use of homework and assignments appeared to be a suitable measure. Also, a clear description of the sequence of sessions and how they relate to each other was provided, to allow coherence in the knowledge build-up. In this case a mind map (cognitive orientation) was included at the beginning of each slidecast session as a recapitulation. Furthermore, weekly exercises were introduced and a discussion on their possible solutions was motivated during the online Q&A Sessions, either with the own interest of the students or by initiation (chat ignition) form the tutor's side. In this case, also a role play from the tutor between the adviser, the coordinator, and the inquirer has been implemented, and a creative solution to various real-life problems was requested by the participants (e.g. imagine yourself in the situation of a construction project manager – what would you do if …?). At the same level, brainstorming sessions were allowed, providing further different roles to the students (client, contractor, planer, building authorities) and breakout rooms to discuss the problem at hand aiming to creative solutions, which were in turn assessed mutually in the main session. The online room was kept open and accessible to all students at all times, to allow interactions of the students outside of the Q&A and guest lectures, which was also verbally encouraged by the tutor. One clearly stated objective of the online coworking space was to meet and exchange thoughts and solutions to questions and homework assignments. The incorporation of live guest lectures was introduced in the second semester of teaching (summer semester 2021) and it acted positively in the attendance of registered students. At the same time external audience was invited which also strengthened participation and discussion, although care had to be taken to keep the learning process and the students at the center of these live online interactions. This process simulated a blended learning, although still in a digital environment.

4. ASSESSMENT RESULTS AND DISCUSSION

Since the students became aware of the novelty and overall significance of the course, they were in principle motivated to be present and provide feedback regularly. Furthermore, an evaluation of the course was done by the anonymous online questionnaires of the university. The course was also appraised by an academic evaluation committee with a mixed participation by internal and external faculty members, students and academic assistants, which included review of the teaching material and evaluations as well as a probe lecture. The anonymous and committee assessed the quality and content of the lecture as excellent and outstanding respectively.

The internal evaluation measures within the teaching team used as evaluation measures: (a) the number of participants in the live sessions and collaboration room, and (b) the direct feedback on the structure of the course by the students.

Regarding the number of attendances, it was observed that in the online Q&A sessions this became higher after the implementation of the toolkit, but at the same time there were altering participants, which revealed a proportion of higher interest and to some extent a higher frequency of recurring participants. At the same time the attendance was very high for the live guest lectures. During these live lectures, there were always at least 1-2 contributions and interaction events (questions, comments, etc) from each student. With respect to use of the constantly online coworking space, there were only a few (1-2) reported instances of students meeting. It was however reported that some of the students nevertheless stayed in contact via other common telecommunication means such as

chatting apps and emailing, which may explain the low participation rate in the online coworking space.
The feedback by the students included a very good rating of the digital structure of the lecture, particularly because it allowed mastering the material at everyone's own learning pace. However, only small deviations were noted between the times needed by each student to assimilate the material. The quality of the recordings was marked as excellent, and it was noted as a highly important role in the content assimilation. One of the sessions (reliability theory session / sub-topic 4) was noted to be of very high workload, and it was recommended to be split in two parts. The guest lectures were assessed as a very positive addition, especially because of the engagement of the lecturers and the exchange of opinions and perspectives from different professions on the topics of overall sustainability. Attendance at the live Q&A sessions was stated to occur, either for response to theoretical and organisational queries, or for the attendance of guest lectures, while the students did not substantially engage in the weekly homework and discussion thereof online. However, especially due to the pandemic situation, there was also a lot of motivation to join the live sessions as a means of socialisation and encountering with colleagues and maintaining acquaintances. The digital sessions have been suggested to increase participation, since otherwise some students had to undertake very long commutes for very short timeframes, even in the pre- and post-Covid-19 era. The examination success rate is reflected with all participants earning a pass note in the top 20% range.

5. OUTLOOK

A specially designed course under the title "Performance Based Design and Life Cycle Engineering" has been designed and introduced to the Masters Curriculum of Civil Engineering at the Faculty of Architecture and Civil Engineering of the TU Dortmund University in Germany. The course forms part of teaching under the umbrella concept "Dortmund Model for Building Engineering" which promotes a comprehensive thinking towards architecture and civil engineering strongly based on sustainability concepts and extending considerations in the entire spectrum of societal demands, integration with cities and communities, environment friendly and resource-oriented construction and building management, and of course safety of the users from the perspective of structural engineering. As such, it is proposed that this course – as well as the wider concept of the engineering education at the TU Dortmund – aligns also well with the UN's SDGs. The course contents cover a significant spectrum of socioeconomic backgrounds, fundamental and applied theory, as well as engineering practice, and hence it is deemed to provide a solid foundation for civil engineering students to respond to sustainability challenges of the current and future generations. Hence, it is believed that the course content lends itself to a paradigm for civil engineering education under consideration of the UN's SDGs.
A more precise assessment of the course, which was moreover designed and delivered in digital form within the Covid-19 pandemic induced lockdowns, reveals possible strengths and weaknesses mainly in terms of its delivery, and less so on its objectives and examination. Room for improvement is seen as regards the activation and interactions of the students. At the inception of this paper, some current pandemic mitigation measures in the higher education functions are laxed in Germany and elsewhere and it is deeply hoped that the pandemic will soon be eliminated. Further improvements of the course

may be allowed by a hybrid digital and presence delivery of the course, which is thought to be optimal for such a multifaceted educational endeavour.

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