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TEACHING TRANSVERSAL COMPETENCES IN CIVIL ENGINEERING EDUCATION

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Abstract. In today's construction industry workflows, which require cross-disciplinary collaboration, transversal skills have become more important and the employee with such skills is more valuable in the labour market.

The master's program in Construction Information Technology Engineering aims to train construction industry professionals with IT skills. Students will learn programming skills, IoT systems and databases for monitoring buildings and structures, artificial intelligence solutions and their use, building information modelling and energy efficiency, building constructions, -services and -electrics, and engineering numerical modelling. In addition to classroom teaching, students work in teams to complete project tasks, including a week-long exercise in Semester 2 where they equip an actual building with sensors, collect large amounts of data in a variety of formats over a long period of time, and spend the rest of the semester analyzing, processing and visualizing the data.

The BME is a member of the EELISA university alliance whose main objective is to promote the education of European engineers. The masterprogram includes a 5 ECTS European Engineering Projectwork course where students spend a semester learning transversal skills, working in teams, project management tools, presentation techniques, business presentation, sales and investment skills. These skills are developed alongside the technical subjects and are applied in the context of them. The training includes an international hackathon where they participate in training and a competition with their international classmates at an EELISA partner institution. The masterprogram in this format is running with the 3rd cohort and the results are very positive; students have been able to find jobs in positions where they can apply what they have learnt in the training and several graduates have gone on to doctoral studies.

1 INTRODUCTION

One of the biggest challenges facing the construction industry is increasing efficiency,

improving productivity, and enforcing sustainability considerations in design, construction, and operation. Industry 4.0 technologies on the construction value chain, such as digitalisation, process automation and robotisation, are key enablers of these efforts [1]. International analyses show that enhancing productivity is no longer optional if the sector is to remain competitive, but a strategic imperative [2]. Despite this, productivity in construction has stagnated compared to other industries, and in many countries, including Hungary, the sector continues to lag behind European averages [3]. Human capital, i.e. skills, education, and training, has also been identified as a key factor explaining variations in productivity within the construction sector [4].

At the EU level, a comprehensive report highlighted that the construction sector is among the least digitalised industries, facing structural barriers such as high costs of digital tools, lack of awareness, and critically, a shortage of skilled labour [5]. This trend is echoed in other international surveys, respectively. Nearly half of the respondents of a survey on digitisation in construction identified the lack of skilled professionals as a major barrier to digital adoption [6]. Recent academic reviews also emphasise that the digital transformation of construction requires not only digital adoption but the systematic development of new digital skills and technical knowledge across the workforce [7].

However, technical expertise alone is insufficient. Increasing attention has been paid to transversal competencies and soft skills, which are essential for collaboration, leadership, and adaptability in a digitalised construction environment [8]. Traditionally, such skills were taught outside the core curriculum, which has reinforced the perception that they are secondary to technical knowledge [9]. Yet, soft skills, including communication, problem-solving, and leadership, are increasingly valued in the labour market, particularly in digitalisation-related managerial roles [10]. Therefore, both personal/interpersonal skills and technical skills related to emerging digitisation technologies are deemed equally important [11].

In response to these converging challenges, the Faculty of Civil Engineering at the Budapest University of Technology and Economics launched a new master's program called Construction Information Technology Engineering in 2022. This paper presents the program's structure, explaining how it trains construction professionals from various fields to become proficient in digitalisation and sustainability. It also introduces the subjects taught and the innovative teaching methodology employed, and we also demonstrate how soft skills can be developed in a targeted manner alongside professional expertise, in an international environment.

2 MASTERPROGRAM CONSTRUCTION INFORMATION TECHNOLOGY ENGINEERING

The low level of digitization and low efficiency in the construction industry highlight the need for development [12]. Innovative construction companies are increasingly employing IT professionals to solve specific problems and introduce technological innovations. However, there is a shortage of professionals with a background in construction and a degree in civil or architectural engineering who also have sufficient IT, information and communication, and data analysis skills. Traditional civil and architectural engineering courses tend to be design-oriented, with limited coverage of IT subjects.

In response to demands from the industry, the Faculty of Civil Engineering at BME launched its Construction Information Technology Engineering masterprogram in 2022, following

several years of preparation. This three-semester (90 ECTS) program is taught exclusively in English, with Hungarian and international students studying together. Typically, there are 15–20 students per year, around half of whom are Hungarian. The subjects taught during the three semesters of the program clearly demonstrate the progression of learning outcomes. In the first semester, students from a civil or architectural engineering background learn the basics of programming (Python, six hours per week) and database systems. Meanwhile, those from an electrical, computer science or mechanical engineering background learn about building structures and finite element modelling. Additionally, all students study numerical methods, BIM fundamentals and IoT fundamentals (data collection, processing and visualization) as part of a project assignment in the first semester (Fig 1).

Figure 1: Construction Information Technology Engineering master's program exercises

Throughout the project, students learn to solve tasks independently and in groups, as well as taking measurements in real-world environments. One sample task involves building a smart home, where students learn to install various sensors (temperature, humidity, light, infrared, magnetic, inclinometer and CO_2), collect data with them, process the big data and display it. Each student group receives an Arduino microcontroller-based sensor kit and learns how to install, network and collect data with it through a cloud service. They also learn how to analyze the data. Throughout the semester, teams complete challenges in which they collaborate to solve smaller tasks. The semester also includes a group project, for which the team devises a solution to a problem with the help of their development. They develop this system week by week in consultation with their instructors and present their results to each other and their mentors in lectures at the end of the semester. The mentors assisting the students in the current semester are former graduates.

In the second (spring) semester, programming education will continue with construction tasks. Students will learn about construction automation and digitization in a separate subject and will also learn BIM modelling through laboratory exercises. The project task will also continue. Alongside the usual classroom lessons, consultations and homework assignments from the fall semester, students will participate in a one-week field trip in the spring as part of the course. This will take place at the BME knowledge centre in Balatonfüred, an hour and a half drive from Budapest. During this time, students will be accommodated in a guesthouse.

This will enable them to break free from their usual environment in Budapest and focus solely on the task at hand. The trip will provide an excellent opportunity for community building, intercultural awareness and developing communication skills. Students will learn to apply what they have learnt in class to real-life situations, solving problems and overcoming challenges that they would not encounter in a university laboratory exercise (Fig 2).

Figure 2: Students' field practice during BTC week

During the exercise, they will work in mixed Hungarian and foreign student teams, communicating in English, and present their results in lectures. During the multi-day exercise, they will collect a large amount of data, which they will also use in the programming course for the remainder of the semester. There, they will document their analyses and present their results.

The training does not aim to produce professional programmers or data analysts, but rather construction professionals who possess the fundamental skills to comprehend IT activities and communicate effectively and professionally with IT experts. Extensive teamwork, field practice and group consultations bring students closer to each other and their instructors. The program is very popular, with the first cohort graduating in January 2024. It is a great achievement that the Faculty has already admitted a fourth student from the masterprogram to its doctoral school.

3 DEVELOPMENT OF TRANSVERSAL COMPETENCIES

BME is a member of the EELISA University Alliance, alongside nine other European universities (Fig 3). EELISA offers numerous opportunities for university cooperation, including joint student programs, conferences, R&D collaborations, joint degree program development and research into innovative teaching methodologies.

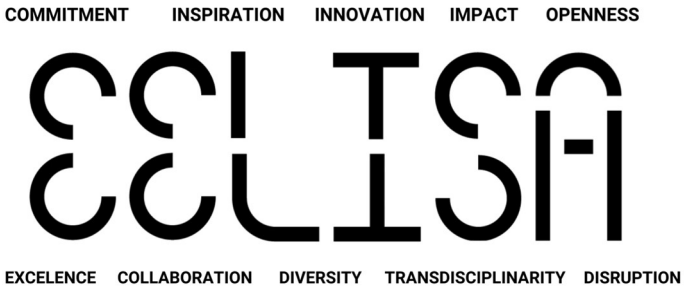

Figure 3: The building blocks of EELISA [13].

One of EELISA's objectives is to define the competencies required for the European engineer of the future. Educational research clearly shows that non-technical competencies will become increasingly important for engineers in the future [14]. University education cannot ignore the development of these transversal competencies, which can be effectively taught through interactive tasks and activities [15,16].

The Construction Information Technology Engineering masterprogram develops a number of transversal competencies and soft skills through independent tasks, teamwork, consultations and lectures. To place greater emphasis on developing these competencies, we have launched a 5 ECTS course called 'European Engineering Projectwork' for master students. Students can take this course during the second semester of the three-semester program. It is a popular course, and so far, almost all students on the program have taken and completed it. Students organize themselves into teams of three to four and work on developing a virtual product or service during the semester. They then participate in an EELISA international hackathon at the end of the semester (Fig 4). European Engineering Projectwork was created in accordance with the SEFI (European Society for Engineering Education) and ENAEE (European Network for Accreditation of Engineering Education) guidelines, with explicit goals of fostering entrepreneurial thinking, critical reasoning and collaboration with peers [17, 18]. The education program design applies Bloom's taxonomy to support skill development from knowledge to application and evaluation.

Figure 4: Teamwork and presentation at the hackathon

During the assignment, they use online project management tools, attend lectures on business development, business model creation, and presentation techniques, complete a pitching exercise, and develop their argumentation and debate skills. A mentor will monitor each team's work, and they will also prepare written documentation and give oral presentations on their results. One of the fundamental elements of the EELISA alliance is communities of teachers and students carrying out activities beyond university education in a given focus area. Within the framework of the European Engineering Projectwork, students typically work on topics related to construction efficiency, digitalization and sustainability. These topics overlap significantly with the activities of the EELISA Sustainable Buildings, Cities and Communities (SusBCC) community, with whom we collaborate. Some of the lecturers on the masterprogram are members of the SusBCC community and organize a hackathon at the end of each semester in collaboration with them. During the four-day hackathon, students attend lectures and visit facilities, digitisation labs and innovative companies. They then work in teams with students from other EELISA institutions to complete tasks similar to their semester assignments within a short timeframe. At the end of the hackathon, the students present their results to virtual investors, who evaluate their work. They also produce social media content about their work processes to present alongside their results. So far, students from the BME masterprogram have

participated in all three hackathons: Universidad Politécnica de Madrid; 2024: Istanbul Technical University; 2025: Universidad Politécnica de Madrid).

4 SUMMARY

Future higher education programs must respond quickly to current industrial and social demands. This is why the Construction Information Technology Engineering masterprogram was created at the Faculty of Civil Engineering at BME. The construction industry is in great need of new technologies and the automation of work processes due to its low level of digitization and low efficiency, which requires professionals with special skills. Transversal competencies are just as important as technical competencies. Professionals who can work in teams within construction workflows, who have economic knowledge and who are good presenters can work effectively.

On the European Engineering Projectwork course at BME, students develop these skills over the course of a semester, before testing their knowledge against international students in an international hackathon at the end of the semester. The first three years of the course have been very successful, with students greatly improving their communication, presentation and teamwork skills, which they have already put to good use when writing their theses.

As an added benefit, these training elements have increased the popularity of the entire program, boosted student commitment (all students have graduated to date, with no dropouts) and enhanced trust in the educational institution (four graduates from the third year have been accepted onto PhD programs to date). Another benefit is that it sets an example for instructors in other programs, as the results confirm the importance of developing these competencies. During the development of the program, other disciplines have also placed increasing emphasis on developing these competencies. It is in our mutual interest to produce professionals who can operate effectively in an international environment and understand complex work processes.

Integrating transversal competence development into engineering curricula is not only desirable, but necessary. We recommend that similar masterprograms incorporate project-based learning, international cooperation and the development of transversal competencies, to ensure that future engineers are prepared not only in technical areas, but also in terms of their ability to work in teams and innovate.

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