Pedagogical Outcomes of the Transnational Pilot Training BUILD2050

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2025 6th International Conference of the Portuguese Society for Engineering Education (CISPEE) | 979-8-3315-2189-9/25/$31.00 ©2025 IEEE | DOI: 10.1109/CISPEE64787.2025.11124019

***Abstract*—This paper presents the pedagogical outcomes of BUILD2050, a transnational pilot training composed of eight training courses addressing building decarbonization. Challenges in defining and implementing active learning in cooperation with five different academic institutions are discussed. Also, the students' performance and perceptions over the training courses, as well as the teachers' feedback on the application of active learning techniques are presented.**

Keywords—transnational training, engineering education, interdisciplinary knowledge

I. Introduction

The European Union (EU) real estate sector is the largest energy consumer in Europe, accounting for 40% of total energy usage, with approximately 75% of buildings classified as energy inefficient [1]. Given these low efficiency levels, decarbonizing the building stock is a critical long-term goal for the EU. By 2050 the EU aims to achieve a decarbonized economy, with buildings playing a key role in this transition [2]. Achieving this target requires the development of integrated technologies and holistic approaches tailored to regional climates, cultural contexts, and natural resource conditions, employing circular economy methodologies. This presents a significant challenge for stakeholders, including architects, engineers, scientists, policymakers, and citizens across all member states.

To support this transition, new courses must be developed using innovative training methods that emphasize interdisciplinary content and maintain a European perspective, enabling continuous professional updates.

At the turn of the century, various frameworks emerged to evaluate buildings, primarily focusing on sustainability. Today, the concept has expanded to integrate health and well-being, recognizing the growing importance of creating healthy built environments [3]. However, decarbonizing construction by 2050 extends additional challenges. Beyond minimizing resource consumption, it must embrace circularity and contribute to restoring the natural environment. Buildings of 2050 must be envisioned as nearly zero-carbon or even positive energy buildings, promoting health and well-being while actively regenerating or rethinking the resources' incoming and outgoing [4].

The decarbonization of the economy by 2050 is no longer an aspiration but a necessity, in particular in construction field. This shift demands a new generation of professionals equipped with interdisciplinary expertise to meet the market's evolving needs. Higher education institutions face the challenge of preparing these professionals, whose roles will span sustainability, construction health, and regeneration. These interconnected fields represent complementary objectives essential for a sustainable future [5].

Flexibility in higher education programmes is also essential to ensure that study cycles can adapt to the rapidly changing demands of decarbonization and sustainable construction. This evolution requires a forward-thinking approach to education that aligns with the realities of a decarbonized, circular, and health-focused economy. This paper presents the challenges and results of the pedagogical framework designed to be implemented in the European project Training for Sustainable and Healthy Building for 2050 (BUILD2050), coordinated by Polytechnic Institute of Setúbal, from Portugal, and promoted by the Erasmus+ Programme KA220 – Cooperation partnerships in higher education.

This paper has the following structure: in section II the research methodology is described; in section III the BUILD2050 pilot training project is presented; in section IV the pedagogical challenges faced in the development of the BUILD2050 training courses are addressed; in section V the outcomes of the training courses are given and in section VI some relevant conclusions are pointed out.

II. Research Methodology

A. Research Approach

Two research approaches were implemented: a quantitative method and a qualitative method [6]. These methods were applied either sequentially or concurrently, depending on the questions raised and the data to be examined.

The quantitative method was based on the evaluation of the students' feedback given by two different surveys and of the teacher's feedback given by one survey. All surveys were carried out anonymously to protect the participants' privacy and maintain their confidentiality.

The qualitative method employed an interpretive approach based on the teacher's observations of students' behavioral attitudes throughout the learning process. This provided valuable insights into how the course content was being interpreted and applied, offering additional context to complement the survey responses.

B. Students´ Profile

The initial survey, composed by multiple-choice questions, was designed to assess the students' profile. This survey was carried out during the enrolment of the training courses to characterize their academic and professional background. The academic profiles of the 85 transnational students – 32 from Portugal, 33 from Italy, 10 from Poland, 9 from Greece and 1 from Germany – were categorized as follows:

- PhD – 5%;
- Master – 40%;

- Post-graduation – 1%;
- Graduation – 15%;
- N/A – 39% (either no answer or a different type of qualification).

These data indicate that most participants held a master degree.

C. Data Collection

The final surveys, composed by multiple-choice questions and open-ended questions, aimed to capture the students and teachers' perspectives over the training courses. Some of the questions were focused on the synchronous and asynchronous classes and students were also invited to highlight the most positive and negative aspects of each training course.

III. BUILD2050 Pilot Training

BUILD2050 was a three-year pilot training project (from February 2022 to January 2025) involving six European academic institutions: Polytechnic Institute of Setúbal (Portugal), University of Bologna (Italy), Warsaw University of Life Sciences (Poland), National and Kapodistrian University of Athens (Greece), Polytechnic University of Milan (Italy), and University of Bochum (Germany). This project was split into three phases, around one year each. The first phase aimed to design eight training courses handling the input of the associated partners [7]. In the second phase the eight training courses were sequentially conducted for trainees from consortium countries, including both students and professionals [8]. The third phase was dedicated to analysing the feedback of the courses' participants and to develop the BUILD2050 eBook, which will be available online as a key outcome of the project.

The eight training courses used a blended-learning approach, each focusing on a distinct topic and led by five of the six academic institutions. University of Bochum didn't lead any training course, only provided didactic support to some of them and developed the eBook. Each course was taught in 25 hours (5 hours per week), covering key aspects of sustainable construction and innovative practices areas as follows:

- Course 1 - introduced participants to regulatory requirements for zero-emission buildings, comparing today's buildings with those of 2050, and explored challenges in construction standards and certification processes.
- Course 2 - focused on achieving Zero Energy and Positive Energy Buildings, covered the necessary technologies and design strategies to fully decarbonize buildings.
- Course 3 - examined circular water management, discussing its implementation in modern buildings while drawing lessons from historical water-use practices.
- Course 4 - explored innovative construction materials, highlighting their applications across different European contexts.
- Course 5 - centered on the digitization of buildings, teaching participants how to collect and use building data effectively.
- Course 6 - emphasized sustainable construction techniques, showcasing insights from European projects and collaborations with energy companies.
- Course 7 - addressed circular economy principles in construction, focusing on Life Cycle Assessment (LCA) methodologies and their application to building materials and recycling processes.
- Course 8 - explored innovative business models rooted in circular economy practices, preparing participants for future challenges in the construction industry.

This comprehensive programme provided the participants with cutting-edge knowledge and skills for advancing sustainable and zero-emission construction practices.

The students that participated in each training course were from several enterprises, institutions or academic institutions, with various knowledge backgrounds, such as architecture, physics, environmental, civil, mechanical, and power engineering. These individuals, whether graduates or professionals, brought diverse expertise, skills, and technical language. Despite their varied backgrounds, all participants engaged in the same learning activities to achieve the course's educational goals.

IV. Pedagogical Implementation - Challenges

The development of the eight BUILD2050 training courses raised several significant challenges, requiring meticulous planning and cooperation between the five academic institutions of Portugal, Italy, Greece and Poland that led them.

One key challenge during the first phase was developing a unified, innovative pedagogical methodology to promote active learning through research, collaboration, task-based learning, discussion and simulation for the transnational course leaders. This approach required standardizing knowledge transmission and to ensure the courses' complementarity, preventing the overlapping of content.

Over seven months, from July 2022 to January 2023, the BUILD2050 pedagogical framework was designed to address teaching challenges aligned with the references of the European Working Group on Learning and Teaching [9]. The pedagogical course development process began by defining learning objectives, aligning them with the available timeframe and desired knowledge levels of the content. These objectives guided the courses' design, linking student outcomes, teaching methods, and assessment timelines. Content and assessment were then selected to support these goals effectively. The framework emphasized a student-centered approach, encouraging the transnational students [10] to take responsibility for their learning and actively engage in applying knowledge to meet courses' objectives. Its flexibility allowed transnational teachers to adjust strategies, refine techniques, and align activities with course content and student needs [11]. To achieve this, an expanded pedagogical alignment model was implemented, integrating various elements such as learning outcomes, teaching and learning activities, complementary techniques, content, resources, and assessment.

Teaching and learning activities incorporated active learning techniques [12] tailored to each training course, supported entirely by digital resources to accommodate the

project's transnational and blended format. This pedagogical framework also addressed the continuity between synchronous and asynchronous teaching modes, ensuring a seamless and cohesive learning experience for all students. Synchronous sessions used MS-Teams or Zoom platforms, while asynchronous activities were hosted on Moodle.

To enhance engagement and skills development, approximately ten active learning techniques were integrated, including challenge-based learning, case studies, cooperative group work, problem-based learning, interviews, role-playing, video presentations, content-focused reflection, round-table discussions and self-assessment. These pedagogical strategies not only strengthened technical and scientific knowledge but also reinforced soft skills essential to prepare future professionals to apply the concept of sustainability with health and well-being in buildings.

Engineering educators, with diverse pedagogical backgrounds and experiences, collaborated to align their approaches and guide students from various countries and fields of knowledge—such as architecture, physics, and several engineering fields—towards achieving shared learning objectives based on the BUILD2050 pedagogical framework developed.

Each training course was held in 25 hours over five weeks, with a weekly structure of 3-hour synchronous classes and 2-hour asynchronous activities [13]. This dual-mode approach needed adaptable teaching methods and resources, which were carefully designed to provide a unified and engaging educational experience, while also addressing challenges such as coordinating different time zones, languages, and academic calendars.

V. Outcomes

During the third phase of BUILD2050 project, a report on the outcomes obtained by the eight training courses, based on the anonymous survey responses of the students and teachers who participated in each course, was produced. Afterwards, each course leader and its team teachers were encouraged to reflect on the aspects highlighted in this report to address any weaknesses and improve the relevant areas of their training. The most relevant data given in the report are now presented.

A. Courses' Attendance

In the Moodle learning platform, there were 379 enrolled transnational students registered in all training courses. In Fig. 1 the distribution of the students by training course is presented.

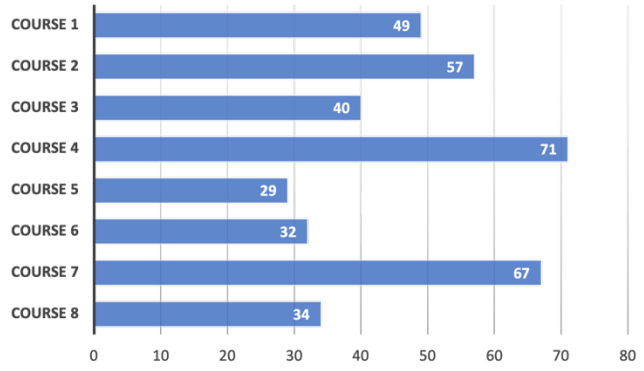

Fig. 1. Number of students enrolled in each course.

It can be noted courses 4 and 7 at the top of enrollments, while course 5 was the training course with less enrollments.

The distribution of the 85 transnational students attending the training courses was as follows:

- 34 students attended only one course;
- 23 students attended two courses;
- 12 students attended three courses;
- 8 students attended four courses;
- 1 student attended five courses;
- 3 students attended six courses;
- 1 student attended seven courses;
- 3 students attended all the eight courses.

This analysis highlights the varied levels of engagement across the training programme, with less than 20% of the students participating in more than three courses.

Among the 47 transnational teachers that taught in the eight training courses, their distribution by country was as following: 9 from Portugal, 25 from Italy, 5 from Poland, 4 from Greece and 4 from Germany.

B. Students' Performance

Overall, from the 379 enrolled students, represented by the global area of the circle in Fig. 2, 202 students were evaluated, of which 132 passed, representing a success rate of 35%, and 70 students failed, representing a failure rate of 18%. Moreover, 177 enrolled students never attended the training courses, representing a dropout rate of 47%.

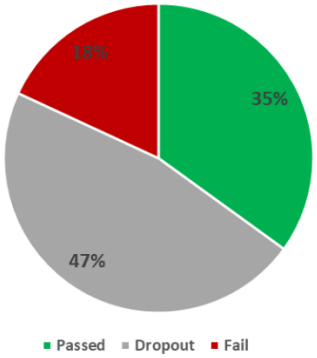

Fig. 2. Global percentage of passed, dropout and failure rates.

The success rate of 35% over the total enrolled students can be divided in A, B, C and D grades, as shown in Fig. 3.

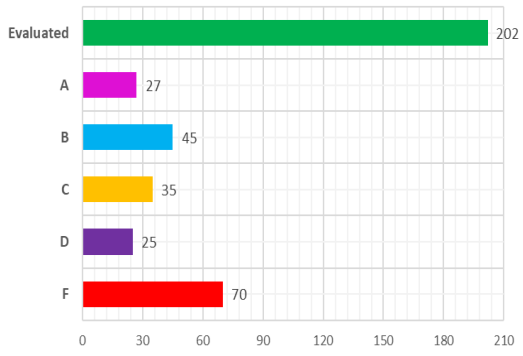

Fig. 3. Grades of the evaluated students.

Regarding the 202 evaluated students, grade A, corresponding to the highest rating between 90% and 100% of the course's learning objectives, was achieved by 13% of students; grade B, corresponding to the second better rating between 80% and 89% of the course's learning objectives, was achieved by 22% of students; grade C, corresponding to the third rating between 70% and 79% of the course's learning objectives, was achieved by 17% of students; grade D, corresponding to the last passed rating between 60% and 69% of the course's learning objectives, was achieved by 12% of students. Grade F, for students that fail assessment, was assigned to 35% of the evaluated students, while the success rate of the evaluated students was around 65%.

C. *Students' Feedback*

Regarding the students who attended the eight training courses, an average of 66% replied to the anonymous survey carried out at the end of each course to evaluate the implementation of the pedagogical approach [8].

Concerning the team teachers of each training course, most students classified them as good or excellent, as shown in Fig. 4.

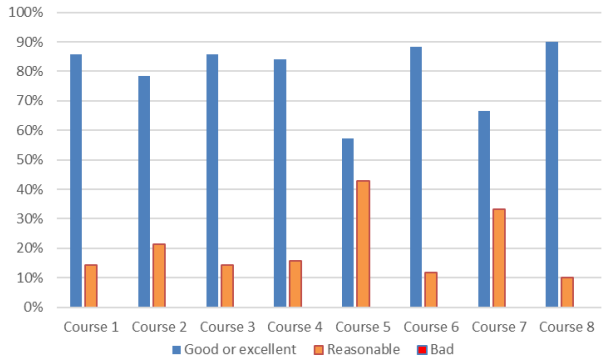

Fig. 4. Students' reply to the question *"How would you classify the teachers' team of this training course?"*.

The positive and negative aspects about the training courses pointed out by students in the final open question of the surveys are now presented. Regarding the positive aspects, students highlighted the following aspects:

- Topics covering multiple points of view.
- Diversity of practical and theoretical information;
- Innovative and relevant courses;
- Moodle's dynamic learning;
- Teachers with different background knowledge;
- Cultural exchange and information;
- Great case studies on renovation of buildings;
- Large number of new subjects learned;
- Good interaction with the fellow colleagues;
- Creative presentations.

Regarding the negative aspects, students highlighted the following aspects:

- Difficulty in scheduling work group outside classes;
- Too theoretical approach;
- Too detailed and complex approach for architects;
- Difficult development of asynchronous work;
- Short number of group activities;
- Quiz activities carried out by the end of the course;
- Same topics repeated by different teachers;
- Unclear purpose of some learning activities.

D. *Teachers' Feedback*

Regarding teachers who taught in the eight training courses, an average of 79% of these teachers replied to the anonymous survey carried out at the end of each course to report their perception of the application of the student-centered approach and the use of lectures [8].

Concerning the teaching and learning activities applied during classes, most teachers pointed out that discussions between students on new content were vital for deep understanding, they believed that most learning activities applied were student-centered and that there was a lack of time to actively involve students in their classroom teaching, as shown in Fig. 5.

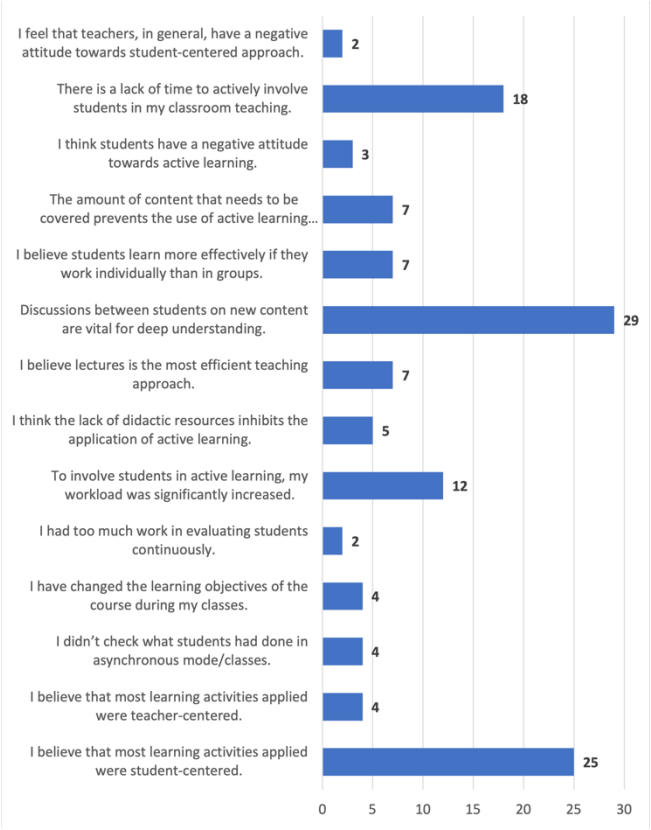

Fig. 5. Number of teachers' replies in the survey.

Also, a significant number of teachers referred that to involve students in active learning, their workload was significantly increased.

VI. Conclusions

As an overall reflection over the BUILD2050 training courses, the following aspects must be pointed out:

- The diversity of habits and cultural backgrounds among students and teachers.

- The varied academic profiles and technical skills of the participants.
- The logistical challenges posed by different time zones of the transnational participants that attended remotely to the courses.

These factors presented significant challenges for both the teaching team and students. Nevertheless, based on the participants' feedback, the overall assessment of the training courses was excellent. Their feedback also indicated small improvements that can be made to enhance future learning experiences and better address training needs.

As an overall reflection addressing global sustainable learning goals, the following success factors of project BUILD2050 must be pointed out:

- Educational Programmes – the integration of theoretical knowledge with real-world experiences, interviews, and group work, strengthened students' communication skills and autonomy.
- Global Collaboration, by promoting intercultural interaction in transnational e-learning courses, encouraging connections between students from different countries, cultures, and academic backgrounds, guided by a diverse team of specialized international educators.
- Personalized Learning Strategies, by customizing learning experiences to account for students' preferences, prior knowledge, and individual needs, ensuring a more tailored and effective approach.

In addition, overcoming linguistic and cultural barriers, ensuring respectful and effective communication among participants, and fostering a genuine appreciation for cultural diversity on the collaborative group work was required. So, challenges such as students' different time zones may have led to some instances of withdrawal, or to irregular participation, affecting the group dynamics in some learning tasks throughout the courses. Also, the fact that the training courses were offered entirely free of charge may have contributed to the enrolment of students who had limited affinity with the courses' content and its objectives. These factors highlight areas for observation and potential improvement to enhance engagement in future iterations.

In short, this educational programme enriched learning through the exchange of perspectives, enhanced teamwork and global collaboration skills, and prepared students for a highly interconnected world. This pedagogical approach not only supported the technical and professional development of participants but also aligned with broader goals of fostering global understanding and sustainable learning practices.

ACKNOWLEDGMENT

This paper is financed by Instituto Politécnico de Setúbal. BUILD2050 - Training for Sustainable and Healthy Building for 2050 is an Erasmus+ project with the reference number 2021-1-PT01-KA220-HED-000032138.

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