ET4Digital – Empowering Trainers for Digital Innovation in Construction Ecosystem

Deliverable 2.1

Analysis of Digital Ecosystem in construction sector

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PP	

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Summary.

ET4Digital – Empowering Trainers for Digital Innovation in construction Ecosystem is dedicated to advancing the quality, effectiveness, and innovation in training trainers and teachers within the construction sector for the seamless integration of digital technologies. The initiative involves creating innovative tools and a comprehensive capacity-building program. Trainers will engage with a specially designed digital technologies demonstrator, fostering hands-on experience. The project aims to overcome barriers hindering SMEs from adopting digital technologies by co-designing, testing, and validating training programs. The ultimate goal is to empower trainers to lead the digital transition in the construction industry, tapping into its significant but underexplored potential.
Although digital innovation has grown significantly in recent years, companies are finding it difficult to effectively exploit this enormous potential. Instead, digitization in the construction sector can offer significant opportunities for the entire value chain by not only improving existing practices, but also integrating disruptive technologies and tools that can lead to new processes, business models, materials and solutions. It is important to underline that the combination of digital technologies makes it possible to maximize the benefits associated with digital transformation. For example, BIM, IoT, Augmented Reality and Digital Twins are deeply interconnected, as they refer to technologies that leverage each other and can be seen as different phases or elements of the same digital transformation.

As demonstrated by several European and national researches, the construction sector is positioned far behind the other industrial fields when it comes to digitalisation.
To date, the European construction sector is facing challenges which are hampering its competitiveness. Among these:

- Labour shortage
- Lack of digital skills in some countries
- Lack of interest among entrepreneurs and workers on the digitalisation of processes
- Lack of motivation on the part of young people to work in the sector
- Need to increase productivity while improving quality, cost efficiency and project delivery
- High costs related to technologies and digital tools

Therefore, the specific objective of the project is to deliver customized programs to professional trainers, aiming to equip them with new digital strategies, tools and skills. As intermediaries, these trainers play a crucial role in demonstrating to enterprises and workers the benefits of digitalization and the positive outcomes it can yield. This approach facilitates the upgrading of workers' skills in digitalization, emphasizing that traditional materials and techniques can be innovatively supported by digital technologies, leading to reduced costs and time wastage.

Furthermore, the job market continually evolves, shaping the required profiles and skills that workers need to possess in response to the demands of companies and employers. By updating the professional profiles required in the construction sector and digitalizing its processes, we can attract young, educated workers to a field of work still considered "traditional".

1 Introduction.

1.1 Objectives and key results of WP2.

Work Package 2 (WP2) of the ET4Digital project aims to analyse the current state of digitalisation in the construction sector and to identify, using a data- and evidence-based approach, the digital skills trainers need to guide the digital transition in SMEs. WP2 represents the exploratory and foundational phase of the entire project, as it provides the knowledge and operational basis for designing the training framework (WP3) and the educational content (WP4).

The first objective of WP2 is the development of a framework of digital technologies applicable to the AECO sector (Architecture, Engineering, Construction and Operation). This technological framework was developed based on an analysis of technologies already available on the European market and in partner countries, assessing their actual diffusion, intended uses, perceived benefits, and barriers to adoption. Particular attention was paid to the relevance of these technologies for construction SMEs. The framework enabled the identification of the most promising emerging technologies and the mapping of perceived priorities among sector stakeholders.

The second objective is the development of a digital skills map for trainers, aimed at identifying the digital abilities currently held by teachers, trainers, and VET professionals, as well as the main gaps that need to be addressed in order to make upskilling paths more effective and aligned with market needs. This mapping was based on a dedicated questionnaire and validated through qualitative discussions.

To achieve these objectives, WP2 adopted a multi-method and integrated methodology based on several data collection tools:

1. a literature review and analysis of key European frameworks on digitalisation, competences, and training (DigComp, DigCompEdu, ECSO, CEDEFOP...);
2. two online surveys:
   - Survey 1, addressed to technicians, entrepreneurs, designers, and construction professionals, gathered data on the adoption and perception of digital technologies;
   - Survey 2, aimed at VET trainers and teachers, explored their level of digital competence and training needs;
3. 14 national focus groups (two in each partner country), which enriched and validated the survey data, highlighting cultural, operational, and systemic differences among countries;
4. the creation of a stakeholder panel to share emerging results and promote dialogue among businesses, training institutions, policy makers, and other actors in the system.

From the comparison of the collected evidence, some key results emerged. On the technological side, the most widely adopted tools include BIM, 3D design software, IoT sensors, collaboration platforms, and site monitoring technologies. More innovative technologies such as AI, Digital Twins, AR/VR, and 3D printing are still underused but seen as highly strategic for the future, according to respondents and focus group participants. The main barriers to adoption are the high initial costs, lack of internal skills, cultural resistance to change, and insufficient specific training.

Regarding skills, trainers report good familiarity with basic digital tools, but show difficulties with more specialised tools (BIM, virtual reality, data management). There is a high demand for training, particularly in applied AI, IoT, and digital simulation. Cross-cutting needs also emerge, such as the ability to design digital learning modules, manage hybrid training environments, and assess the impact of technologies on learning outcomes.

This evidence provides a solid foundation for designing, in the following WPs, realistic and modular training content, based on real cases and aligned with the needs of trainers and construction SMEs.

1.2 Preview of Key Evidence from WP2.

This section offers a preview of the main insights that emerged during the implementation of Work Package 2 (WP2), which investigated the current state of digital transformation in the construction sector and the role of vocational education and training (VET) in supporting this transition. While detailed findings are provided in Chapters 4, 5, and 6, this brief overview aims to contextualise the strategic relevance of the project and frame the need for action.

The combined results from two European surveys and fourteen national focus groups confirm a widespread interest in digital technologies across the AECO (Architecture, Engineering, Construction, and Operation) sector. However, the level of adoption and integration remains highly variable. Most professionals report being familiar with basic digital tools—such as CAD software, laser scanning, and GPS-based monitoring—but less so with more advanced or integrated systems like Digital Twins, AI applications, or IoT-driven predictive analytics.

Among the most cited technologies are Building Information Modelling (BIM), which emerges as both widely recognised and underutilised, and IoT systems for safety and energy monitoring. Digital Twins and immersive technologies such as Augmented and Virtual Reality (AR/VR) are viewed with increasing interest but are still perceived as complex, costly, or lacking in practical application examples. These patterns are echoed by both professionals and trainers, suggesting a convergence in perception but a divergence in capacity and readiness.

On the training side, VET trainers show a clear willingness to innovate but face tangible barriers—including limited access to updated equipment, a lack of structured training paths, and difficulty in aligning educational content with rapidly evolving industry needs. Trainers express the need for flexible, modular, and practice-oriented learning resources that can be easily integrated into existing curricula.

The focus groups further enriched these findings by revealing national and institutional differences, as well as cross-cutting challenges such as cultural resistance to change, fragmentation of initiatives, and insufficient collaboration between companies and training providers.

Taken together, these initial insights reinforce the rationale behind the ET4Digital project and its mission to empower trainers as key facilitators of digital transformation. The following chapters will explore these topics in greater detail, offering data-driven evidence and qualitative reflections that will inform the design of the training model and educational resources developed in the next Work Packages.

1.3 The ET4Digital project and the role of WP2.

The ET4Digital project – *Empowering Trainers for Digital Innovation in the Construction Ecosystem* – was launched with the objective of strengthening the digital competences of vocational education and training (VET) trainers in the construction sector, directly contributing to the digital transformation of small and medium-sized enterprises in the industry. The project aligns with European priorities related to the digital and green transitions, placing the strategic role of trainers at the core of the intervention as key enablers of innovation within educational, technical, and professional pathways.

The project involves partners from seven European countries – Austria, Estonia, Germany, Greece, Italy, North Macedonia, and Spain – and is structured into a coordinated set of work packages aimed at defining a new European model for the development of digital competences for trainers, with a strong focus on practical applicability within construction SMEs.

In this context, WP2 represents the exploratory and analytical phase of the project. Its role is twofold: on the one hand, to build an up-to-date and structured overview of digital technologies currently applicable in the construction sector, assessing their diffusion, barriers, benefits, and priorities; on the other hand, to map the digital competences that VET trainers currently possess, require, or are expected to acquire, identifying the main gaps to be filled and providing guidance for training design. WP2 thus provides the foundation on which the subsequent WP3 (training model) and WP4 (content and platforms) will be built, ensuring methodological consistency, technical relevance, and alignment with the real needs of the sector.

1.4 Purpose of this deliverable.

This deliverable aims to systematically document the activities carried out and the results achieved within Work Package 2 of the ET4Digital project. WP2 represents the analytical phase of the project, during which an in-depth reflection was conducted on the current state of digitalisation in the construction sector, the adoption of digital technologies, and the role of trainers within this process. Through a combination of literature review, the administration of two European surveys, the organisation of 14 national focus groups, and the direct involvement of stakeholders and key actors, WP2 enabled the collection of a solid and validated base of empirical evidence. This document aims to synthesise and present the acquired knowledge in a structured way, offering a realistic and up-to-date overview of the digital landscape in the construction sector. It describes the technologies deemed most relevant for SMEs, the barriers and enabling factors for their adoption, as well as the most in-demand digital competences for trainers and the main gaps identified.

The results presented in this report form the starting point for the subsequent project phases. In particular, WP2 provides essential references for the development of a European training model for digitalisation in the construction sector, to be elaborated in WP3, and for the creation of specific and modular training content, which will be implemented in WP4. This deliverable therefore serves as a bridge between the initial analysis and the action phase, ensuring continuity, coherence, and alignment with the project's intended impact.

By contributing to the upskilling of VET trainers and supporting the digital transformation of SMEs in the construction sector, this deliverable aligns with the overarching goals of the Erasmus+

programme—namely, fostering innovation in vocational education, enhancing employability, and bridging the digital skills gap across Europe.

1.5 Key Digital Technologies Explained.

To ensure a clear and shared understanding of the terminology used throughout this deliverable, this section presents a brief but structured description of the main digital technologies that emerged from the literature review, surveys, and focus groups conducted in WP2. These technologies are central to the digital transformation of the construction sector and constitute the core reference for the design of future training pathways.

Building Information Modelling (BIM). BIM is a collaborative process that relies on intelligent 3D models to generate and manage digital representations of the physical and functional characteristics of a built asset. It supports the entire lifecycle of a project—from early design to construction and facility management—by integrating geometry, data, processes, and stakeholders. BIM enhances coordination among professionals, facilitates clash detection, improves project accuracy, and enables better cost and time management. Its adoption is increasingly mandated in public procurement procedures across Europe.

Digital Twin. A Digital Twin is a dynamic, real-time digital replica of a physical asset or system, continuously fed with data from sensors and other sources. It allows advanced simulations, performance monitoring, and predictive maintenance. In construction, Digital Twins are used to anticipate building behaviour, optimise energy consumption, and enable smart maintenance. Although the concept is still emerging in the sector, it is considered a high-potential technology with applications that extend well beyond the design phase into the operational and decommissioning stages.

Internet of Things (IoT). The Internet of Things refers to a network of physical devices embedded with sensors and connectivity, capable of collecting and transmitting data. In the construction sector, IoT enables real-time monitoring of various parameters—such as temperature, structural stress, vibration, or worker movements—contributing to improved safety, energy efficiency, and predictive maintenance. IoT systems form the backbone of many smart building and site monitoring applications.

Artificial Intelligence (AI). AI encompasses a broad set of technologies that allow machines to simulate human intelligence, including learning, reasoning, and decision-making. In construction, AI is used for scheduling optimisation, risk assessment, energy forecasting, and resource allocation. More advanced applications involve machine learning algorithms capable of detecting patterns and anomalies in large datasets, supporting predictive maintenance, quality control, and project management.

Augmented Reality (AR) and Virtual Reality (VR). AR and VR technologies offer immersive and interactive environments for training, design, and communication. AR overlays digital elements onto the physical world—useful for site inspections, real-time guidance, or safety visualisation—while VR creates entirely virtual scenarios for simulation-based learning, design walkthroughs, or stakeholder engagement. These tools are increasingly integrated into training curricula to enhance engagement and comprehension.

3D Printing (Additive Manufacturing). 3D printing involves the layer-by-layer fabrication of objects directly from digital models. In construction, this technology is used to create structural elements, prototypes, or entire components using concrete or other materials. It offers advantages in terms of speed, customisation, and material efficiency, and is often explored for its potential to reduce waste and costs in construction workflows.

Cloud-Based Collaboration Platforms. These platforms enable remote access to project data, real-time communication among team members, and collaborative document management. Widely used in Building Information Modelling environments and project management, such tools are essential for coordinating complex workflows, especially when multiple stakeholders operate across different locations. Their integration promotes transparency, version control, and stakeholder engagement.

2 The literature review.

This chapter gathers and synthesises the main theoretical, regulatory, and policy references related to digitalisation in the construction sector and the development of digital competences within vocational education and training (VET) contexts. The literature review represented a preliminary and strategic phase within WP2, serving both to guide the design of the investigation tools (surveys and focus groups) and to frame the results collected within a solid reference context aligned with the main European trends.

Digitalisation in the AECO sector (Architecture, Engineering, Construction and Operation) is now a structural, though still heterogeneous, process that involves technologies, organisational models, and training practices. To understand the ongoing transformations, it was necessary to analyse recent studies, institutional reports, and European frameworks that link digital technologies, professional competences, and educational innovation.

The reviewed literature made it possible to identify the main drivers of digital transformation, the systemic barriers hindering its adoption in SMEs, and the strategic role that trainers can play in supporting this transition. In particular, four thematic areas were explored in depth: the state of digitalisation in the construction sector; the role of trainers in the digital transition; the European digital competence frameworks (such as DigComp, DigCompEdu, ECSO); and the implications for the VET system.

2.1 Digitalisation in the architecture, engineering, construction and operation (AECO) Sector.

Digitalisation is progressively transforming the construction sector, encouraging companies, designers, and institutional stakeholders to adopt new technologies capable of enhancing efficiency, quality, and sustainability throughout the entire building lifecycle. However, the AECO sector remains one of the least digitalised compared to other industrial sectors, despite increasing pressure due to the shortage of skilled labour, international competitiveness, and the European Union’s climate goals (*ECSO* 2021).

According to the *European Construction Sector Observatory*, the European construction industry is making progress in adopting digital technologies, but with significant disparities between countries and between different phases of the construction process. Some technologies, such as sensors and 3D scanning, are more mature, while others – such as the Internet of Things, Artificial Intelligence, or Digital Twins – are still emerging or limited to pilot projects. Other promising technologies include 3D printing, robotics, process automation, and Building Information Modelling (BIM), which is widely applied particularly in the design phase. *(ECSO 2021).*

A systematic review of international literature identified ten high-potential emerging technologies for the AECO sector: BIM, Artificial Intelligence, Internet of Things, blockchain, big data, virtual and augmented reality, cloud computing, RFID, 3D printing, and digital twins. *(Dou et al. 2023)* Among these, BIM emerges as the most studied and widespread technology, thanks to its ability to integrate multidisciplinary information and support all phases of the building lifecycle. AI and augmented reality are also gaining increasing attention, particularly in combination with BIM for collaborative design, predictive maintenance, and risk analysis.

An additional area of analysis is offered by studies on the metaverse and its potential for the construction sector. Although still little known and rarely adopted, the metaverse is seen as an evolution of immersive technologies, capable of offering three-dimensional collaborative experiences during the design phase, real estate marketing, site management, and training. However, strong uncertainties remain among stakeholders, related to costs, interoperability, data protection, and the lack of shared standards (*Claßen et al. 2024*).

Overall, the AECO sector stands at a strategic crossroads: on the one hand, digital technologies offer an unprecedented opportunity to increase productivity and improve the quality of construction; on the other hand, there remains a significant gap between the technologies available and the ability of companies – especially SMEs – to adopt them effectively. European public policies – such as the Green Deal, the Horizon Europe programme, and the mandatory use of BIM in public procurement – play a key role in promoting this process. Equally critical is the need to enhance the digital competence of sector professionals and VET trainers, who act as pivotal enablers of a successful and inclusive digital transition.

2.2 The role of trainers in the digital transition.

Vocational education and training (VET) trainers are a key element in the success of the digital transition in the construction sector. Their role goes beyond delivering technical content, extending to the ability to effectively integrate digital technologies into educational pathways, thus contributing to the training of workers who are equipped to face the challenges of ongoing technological transformation.

International literature highlights how the digital frameworks traditionally used in general education – such as TPACK, DigCompEdu, and the Professional Digital Competence Framework – often prove inadequate in capturing the specific nature of VET teaching *(Lahn et. al. 2023).* More recent studies propose a more contextualised approach that considers the connection between school-based learning and work, the adaptation to the characteristics of the relevant professional sector, and the adoption of a transformative pedagogy. This leads to the need to develop digital

competence models better suited to VET trainers, capable of including elements such as school/work connectivity, subject-specific content, adaptive pedagogy, and digital self-efficacy.
Empirical research also shows that trainers' digital competence directly influences how effectively students use technologies. In particular, the instructional support experienced by apprentices has a significant impact on the acceptance and use of digital tools, such as note-taking apps and video conferencing systems (*Wurges 2024)*. The perception of being supported by teachers and tutors not only increases the use of these tools but also improves their perceived effectiveness, contributing to the development of a more solid and participatory digital learning environment.
Finally, a broader institutional approach was proposed by *Zhong and Juwaheer (2024*), who suggest a systemic and competence-based model for developing digital competence in TVET systems . This model, defined as a "whole-institution approach", promotes the coordinated participation of managers, teachers, and students, and recognises the importance of aligning the institution's digital strategies with the continuous training of trainers and the evolving skill needs of the labour market. The adoption of this paradigm represents a crucial step in ensuring a digital transition that is sustainable, inclusive, and employment-oriented.

2.3 The European reference frameworks (DigComp, DigCompEdu, ECSO).

In recent years, the European Union has developed a series of reference frameworks to define and promote the digital competences of educators, with particular focus on vocational education and training (VET) contexts. The most well-known of these is DigCompEdu, the European Framework for the Digital Competence of Educators, developed by the Joint Research Centre of the European Commission.
This tool aims to provide a common basis for assessing and developing the digital competences of trainers, offering a shared language and a structure articulated into six main areas: professional engagement, use of digital resources, teaching and learning practices, assessment, learner empowerment, and the facilitation of learners' digital competence .
DigCompEdu is characterised by a pedagogical and reflective approach: it goes beyond the technical use of tools and seeks to integrate digital technologies into all phases of the educational process, from planning to inclusion and assessment. The twenty-two competences identified in the framework are described across six proficiency levels, and the model has already been adopted or adapted in several European countries as a reference for the continuing professional development of teachers and trainers.
This framework is complemented by extensions and reflections tailored to the VET context. For example, the European project *TaccleAI* proposed a critical review of DigCompEdu in light of the transformations brought about by artificial intelligence and the digitalisation of the world of work. The findings highlight the urgency of updating training content for VET trainers, introducing competences related to adaptive assessment, the use of intelligent teaching systems, and the preparation of students to work in automated and digitally complex environments (*TaccleAI*). Trainers must be able to understand how AI tools work and guide students in developing transversal competences such as critical thinking, digital collaboration, and the ethical use of technologies.

Another contribution comes from the *e-assessment in VET* project, which examines the use of digital technologies in the assessment of professional competences.
The report highlights how digital technologies – through simulations, e-portfolios, micro-credentials, and automated feedback – can enhance the effectiveness and transparency of assessment processes, encouraging personalised learning and student self-assessment *(Attwell et. al 2023).*
However, the full adoption of these tools requires that trainers be supported through integrated professional development paths that combine technical competences with pedagogical reflection.
In summary, European frameworks and the most recent research projects converge on the idea that the digital competence of VET trainers must be considered a strategic dimension for the success of the digital transition in the vocational education sector. This competence goes beyond the mastery of digital tools and includes the ability to design inclusive, flexible learning environments aligned with the evolving needs of the labour market.

2.4 Considerations for the VET context.

The context of vocational education and training (VET) is at the core of European strategies for the development of digital competences. The growing complexity of production environments, the acceleration of technological innovation, and the digital transformation of the labour market call for a revision of both the teaching models and the competences required of trainers and students.
In this scenario, the *Digital.VET* project represents a relevant example of an integrated approach to innovation in vocational education. The project highlighted the need to develop VET trainers' competences not only in the use of digital technologies but also in the ability to design immersive, inclusive, and flexible learning environments. Activities included the development of competence profiles for immersive teaching, the creation of an e-learning course for trainers, and the implementation of an interactive platform for creating and sharing educational content in augmented and virtual reality. Particularly significant was the use of the *iDid* app, designed to make the creation of immersive content accessible even to trainers with limited technical skills. The project demonstrated that, in order to be effective, the adoption of digital technologies must be supported by a clear training strategy, intuitive tools, and a shared vision of the ongoing transformation *(Maltese et. al. 2022).*
At the same time, the paper by Zhong and Juwaheer *(Zhong et al. 2024)* proposes a systemic and competence-based approach to the development of digital competence in VET contexts. This approach, defined as a whole-institution model and inspired by the Competency-Based Education (CBE) paradigm, emphasises the importance of coordinated involvement of managers, trainers, and students in defining digitalisation strategies. The authors point out that the effective digital transformation of VET institutions cannot take place without visionary leadership, well-prepared teachers, and aware students, each with their own area of digital competence. The suggested approach enables a structured response to the digital transition, enhancing interaction among stakeholders and promoting coherence between educational objectives, teaching practices, and labour market needs.

Overall, the available evidence indicates that, to make the digitalisation of VET systems effective, it is necessary to go beyond the mere introduction of technological tools. It is essential to promote a renewed pedagogical vision centred on active learning, co-design of content, peer interaction, and the use of technologies for authentic and personalised assessment. At the same time, it is strategically important to invest in the continuous professional development of trainers and in the creation of professional communities that share practices, resources, and tools to support an inclusive, effective, and sustainable digital transition.

3. Methodology.

This chapter describes the methodological approach adopted for carrying out the activities foreseen in Work Package 2. The methodology was designed with the aim of ensuring broad, comparable, and representative data collection, by combining quantitative and qualitative analysis tools.
The approach integrated four main components: a structured review of European and scientific literature, the administration of two online questionnaires aimed respectively at construction sector professionals and VET trainers, the organisation of 14 focus groups (two in each partner country), and the involvement of relevant stakeholders to validate and enrich the interpretation of the results.
The integration of these tools made it possible to explore both the technological and educational dimensions in depth, offering a realistic and multi-level view of the European context in which the ET4Digital project is situated.

3.1 The data collection tools: surveys and focus groups.

To meet the analytical objectives of WP2, two main data collection tools were adopted: online questionnaires (surveys) and qualitative focus groups. These tools were designed to be complementary, with the aim of obtaining, on one hand, structured and comparable data across the different partner countries, and on the other, qualitative insights capable of capturing the complexity of the context and the direct voice of the stakeholders involved.
The first questionnaire, addressed to professionals and technicians in the construction sector, gathered information on the diffusion and use of digital technologies, perceived barriers, obtained benefits, level of adoption, and technologies considered a priority for the future. The questions were structured to cover four main areas: surveying and monitoring tools, design and simulation software, construction site management tools, and innovative and cross-cutting technologies. The questionnaire was administered online and completed by 70 participants from all seven partner countries of the project.
The second questionnaire was aimed at trainers, teachers, and managers in vocational education and training (VET), with the goal of exploring the perceived level of digital competence, previous training experiences, training needs, and difficulties encountered in integrating technologies into teaching practices. The questionnaire collected 76 complete responses and enabled the development of an initial mapping of the digital competences considered relevant in the context of technical and vocational education.

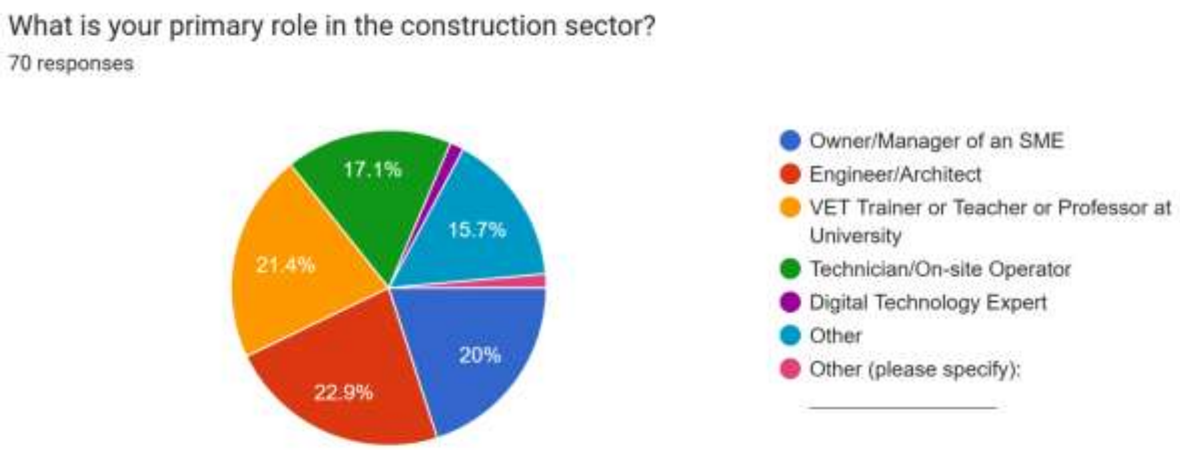
In parallel with the administration of the questionnaires, each national partner organised two focus groups: one with experts from the construction sector (Focus Group 1) and one with VET trainers (Focus Group 2). The focus groups were conducted using a shared and harmonised European guide, which included common macro-themes (experiences, barriers, opportunities, recommendations) while allowing for national customisation. A total of 14 focus groups were held, involving over 40 professionals and trainers from various backgrounds (SMEs, training centres, universities, trade associations, public bodies).

The combined use of the two surveys and the focus groups made it possible to integrate quantitative and qualitative data, providing a multi-level understanding of the European situation and validating the collected evidence through participatory methodologies.

3.2 The sample characteristics.

The sample analysed within WP2 includes both professionals active in the construction sector and trainers from vocational education and training (VET), thus ensuring a broad and consistent representation of the final target groups of the ET4Digital project activities.

The first questionnaire, addressed to technicians, designers, consultants, and professionals in the AECO sector, collected 70 valid responses from all partner countries. The participants work in organisations of varying sizes, from micro-enterprises to large companies, and hold a wide range of professional roles: architects, civil engineers, BIM managers, project managers, researchers, and environmental consultants. The responses provide a detailed overview of the technologies already in use in the sector, the main barriers to adoption, and future innovation priorities. The most well-known or widely used technologies include surveying tools (GPS, laser scanners, photogrammetry), design and simulation software (AutoCAD, Revit, EnergyPlus), and emerging technologies such as Digital Twin, Internet of Things, Artificial Intelligence, and 3D printing. The main reported barriers concern implementation costs, lack of in-house digital skills, resistance to change, and the inadequacy of the current training offer.



The second questionnaire, aimed at VET trainers, gathered 76 valid responses, exceeding initial expectations. Participants included vocational education teachers, technical school instructors, university professors, corporate trainers, and consultants. Most of them have more than six years of experience in construction-related training and report a growing interest in the adoption of digital tools in their teaching practices.

However, the data show a gap between the technologies perceived as relevant and those actually used. BIM is widely known, but few use it regularly in their courses. Digital Twin is still poorly understood, and the use of virtual and augmented reality remains experimental. Participants highlighted the lack of updated teaching tools, the difficulty of integrating technologies into existing curricula, and the need for targeted and accessible upskilling programmes.

To complement the data collection, each partner conducted two focus groups: one with construction sector experts and one with VET trainers, for a total of 14 meetings and over 40 participants. The groups were conducted following a shared guideline that ensured methodological consistency and comparability across countries. Participants were selected to represent a variety of experiences and perspectives, and came from SMEs, training centres, universities, professional associations, public bodies, and institutional stakeholders. The focus groups made it possible to validate the questionnaire results, explore the operational context in different countries, and collect concrete proposals from those who experience the challenges of digital transition in the construction sector on a daily basis.

The integration of quantitative and qualitative methods, together with the diversity of the profiles involved, allowed for the construction of a solid, representative knowledge base, useful for realistically guiding the project activities of the following Work Packages.

3.3 The analytical approach.

The analysis of the data collected in WP2 was based on a mixed-method approach, combining quantitative and qualitative tools in order to rigorously and coherently explore the technological and educational dimensions under investigation. The two online questionnaires were analysed using basic descriptive statistical techniques, with particular attention to the distribution of responses, the absolute and relative frequency of selected options, and the identification of prevailing trends. Frequency tables and graphical representations were created to display the data in a concise and communicative manner.

In the first questionnaire, addressed to professionals in the construction sector, the analysis focused on:

- the frequency of use
- the knowledge of digital technologies
- the main perceived barriers to adoption
- the intended uses
- the technologies considered a priority for the future.

The responses were analysed by thematic area (surveying and monitoring, design, site management, innovative technologies), allowing for the construction of an initial structured overview of the current technological landscape.

In the second questionnaire, dedicated to VET trainers, attention was focused on:

- the technologies known or used in teaching,
- the difficulties encountered,
- the perception of barriers,
- the preferences expressed regarding digital tools and methodologies.

Multiple-choice questions were analysed in terms of selection frequency, while open-ended questions underwent an initial thematic reading to extract recurring qualitative elements.

The focus groups conducted in each partner country were analysed using a qualitative approach based on a shared thematic framework, structured around six areas: training experiences, needs and competence gaps, effectiveness of existing provision, teaching approaches, cultural and operational barriers, and proposals for ET4Digital. The data were aggregated and compared across different national contexts, highlighting both common trends and local specificities. The method followed a content analysis logic to support the interpretation of the quantitative data.
Although the data processing at this stage was descriptive in nature, the volume and structure of the information collected would, in theory, also allow for the development of inferential estimates in subsequent WPs. For example, it would be possible to further explore differences between subgroups (by country, role, experience level), verify correlations between variables, or estimate the likelihood of adoption of specific technologies based on predictive variables. The use of inferential techniques could therefore represent a valuable evolution—either comparative or predictive—of the evidence produced in WP2.

3.4 Methodological limitations and reliability.

The methodology adopted in WP2 made it possible to build a solid and coherent framework for analysing the digital ecosystem in the construction sector and mapping trainers' competences. The combined use of primary sources (surveys and focus groups) and secondary sources (literature review and European strategic documents), together with the direct involvement of all partner countries, ensured:

- a good geographical coverage
- a variety of professional profiles,
- a balance between quantitative and qualitative approaches.

However, as with any applied research conducted in a European and multicultural context, certain methodological limitations should be acknowledged. Firstly, participation in the questionnaires was voluntary and non-probabilistic, meaning that the data collected are not statistically representative of the entire European construction sector or the VET system. Although a significant number of respondents were involved (over 180 across the two surveys and focus groups), it was not possible to ensure a perfectly even distribution of responses across countries, nor a rigorous balance among the different professional categories.

Secondly, the focus groups yielded a wealth of qualitative content, but their composition was inevitably influenced by the availability of participants and local specificities. Some countries were able to involve high-level institutional and academic figures, while others focused more on operational trainers or small enterprises. This heterogeneity, while not compromising the quality of the evidence gathered, calls for caution when generalising conclusions.

It should also be noted that the collected data were not subjected to inferential statistical analysis (such as significance testing or predictive modelling), but were treated using descriptive approaches. This choice was driven by the exploratory nature of WP2 and the intention to prioritise clarity, immediacy, and the transferability of results to the following project phases. Nonetheless, the dataset produced—thanks to its coherent structure and the completeness of its variables—could be used in WP3 or WP4 for more advanced analyses or the development of synthetic indicators.

Finally, the work carried out was characterised by methodological transparency, attention to data reliability, and consistency between objectives and tools. The shared guide for conducting focus groups, the cross-validation process among partners, and the systematisation of the evidence collected represent strengths of WP2, which reinforce the credibility of the results produced and their usefulness for the development of concrete solutions in the subsequent Work Packages.

4. Analysis of the sample and survey responses.

This chapter presents the main findings from the analysis of the two online questionnaires administered during WP2. The first survey was addressed to professionals in the construction sector (AECO) and aimed to collect information on the diffusion of digital technologies, perceived benefits, barriers to adoption, and future priorities.

The second survey involved trainers, teachers, and operators in vocational education and training (VET), with the goal of investigating the level of digital competence held, the use of technologies in teaching, the difficulties encountered, and expectations regarding the digital transformation of training pathways.

The analyses presented in this chapter are descriptive and offer a comparative overview of the two target groups involved.

The data are organised by theme and are complemented, where relevant, by qualitative insights drawn from the open-ended questionnaire responses and focus groups. The aim is to build a coherent and actionable picture that highlights strengths, critical issues, and opportunities for the development of digital competences in the two analysed contexts

4.1 The professional profiles of participants.

The two questionnaires administered as part of WP2 involved a total of 143 participants, divided between professionals in the construction sector (70 responses) and vocational education and

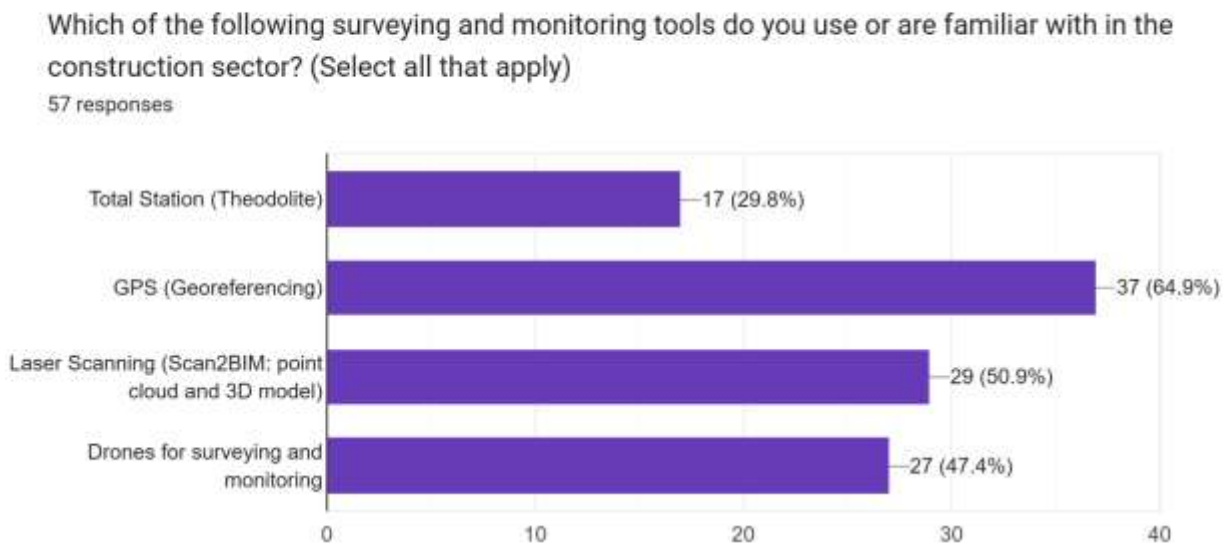
training (VET) trainers (76 responses). The analysis of responses to the question on professional roles revealed a rich and varied picture, consistent with the inclusive approach of the ET4Digital project.
In the first survey, aimed at construction sector professionals, five main categories were identified: engineers and architects (16 participants), university or VET trainers (15), SME owners or managers (14), site technicians or on-site operators (12), and a residual category labelled “other” (11). There were also individual responses from a digital technology expert (1) and a participant who selected “other (please specify)” (1), specifying roles such as project consultants or software specialists.
In the second survey, aimed at trainers and teachers in the VET system, the most represented category was that of VET trainers (22 responses), followed by business consultants or corporate trainers (16), “Other” (18)—which may refer to an unspecified predefined answer—university lecturers (11), and technical school teachers (9).

Once again, the roles covered a significant range of professional profiles, including both individuals active in academic settings and those operating in more practical or business contexts.
Taken together, the participants in the two surveys provide a balanced representation of the key actors involved in the digital transformation of the construction sector and in technical training pathways. The diversity of roles made it possible to gather complementary perspectives, which are essential to understanding technological and training needs across different European contexts, and represents a key strength of the analysis developed within WP2.
The focus groups organised within the ET4Digital project engaged over 40 professionals with diverse backgrounds, roles, and areas of expertise, all operating within the construction and vocational education and training (VET) ecosystem.
Participants were carefully selected by the national partners to ensure a meaningful representation of the various perspectives and competencies relevant to the digital transformation of the construction sector.
The groups included VET trainers, technical and vocational school teachers, university professors and researchers, consultants, construction engineers, site managers, digital innovation experts, and representatives from SMEs, training centres, and technology providers.
Many of them hold senior or strategic positions, such as technical directors, heads of department, or project coordinators, and are directly involved in the implementation or promotion of digital tools and processes in both educational and professional settings.
This multi-stakeholder configuration allowed for a comprehensive and cross-cutting discussion, integrating operational, strategic, pedagogical, and technological viewpoints. The presence of both educators and industry practitioners ensured that the focus group outcomes reflected not only current training practices and pedagogical gaps, but also the real needs, limitations, and opportunities faced by construction companies—particularly SMEs—in adopting digital technologies.
The participants' expertise covered a broad range of digital tools and concepts, including Building Information Modelling (BIM), Internet of Things (IoT), Artificial Intelligence (AI), Digital Twin applications, AR/VR technologies, and energy modelling.

Their active contributions helped identify common barriers (e.g., lack of digital skills, resistance to change, limited resources), as well as enablers (e.g., continuous professional development, access to demonstrators, institutional incentives) for digital adoption in the construction sector.
Finally, the diverse national and institutional affiliations of the participants helped to highlight contextual differences while also underlining shared challenges across Europe.
Their insights provided valuable input for shaping the *digital technology framework* and the *skills map for trainers* developed in WP2, and will also inform the design of the Capacity Building Programme in WP4.

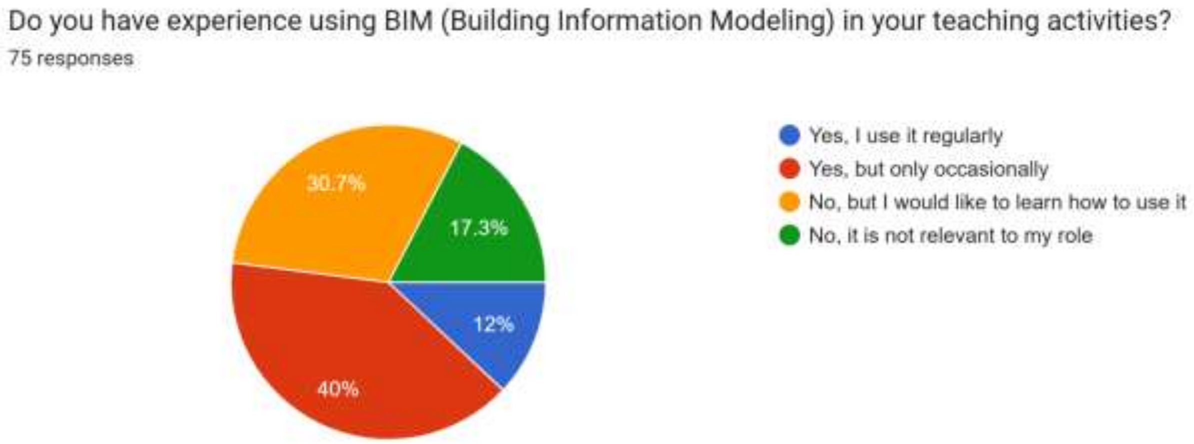
4.2 Levels of familiarity with digital technologies.

The data collected through the two questionnaires reveal an overall good level of familiarity with basic digital technologies, but also highlight significant differences between professionals in the construction sector and trainers in vocational education.
Perceptions of technologies, their frequency of use, and interest in emerging tools vary depending on the operational context and the role held.
In the first questionnaire, aimed at technicians, designers, and other AECO sector professionals, a good knowledge of surveying and monitoring tools emerges. Among the most familiar technologies are GPS (reported by 37 respondents), 3D laser scanning and point clouds (29 responses), monitoring drones (27), and total stations (17).



These data confirm that technologies directly related to the phases of surveying, design, and site control are already partially integrated into operational practices. However, the adoption of more advanced tools, such as digital twins, artificial intelligence, or predictive technologies, remains very limited, as also emerged in the focus groups.

In the second questionnaire, aimed at trainers, participants were asked whether they have experience using BIM (Building Information Modelling) in their teaching activities.
The results show a certain gap between the theoretical relevance of BIM and its actual use in daily training practice. Only 9 respondents report using BIM regularly, while 30 use it only occasionally. As many as 23 trainers expressed interest in learning how to use it, while 13 considered it irrelevant to their role.



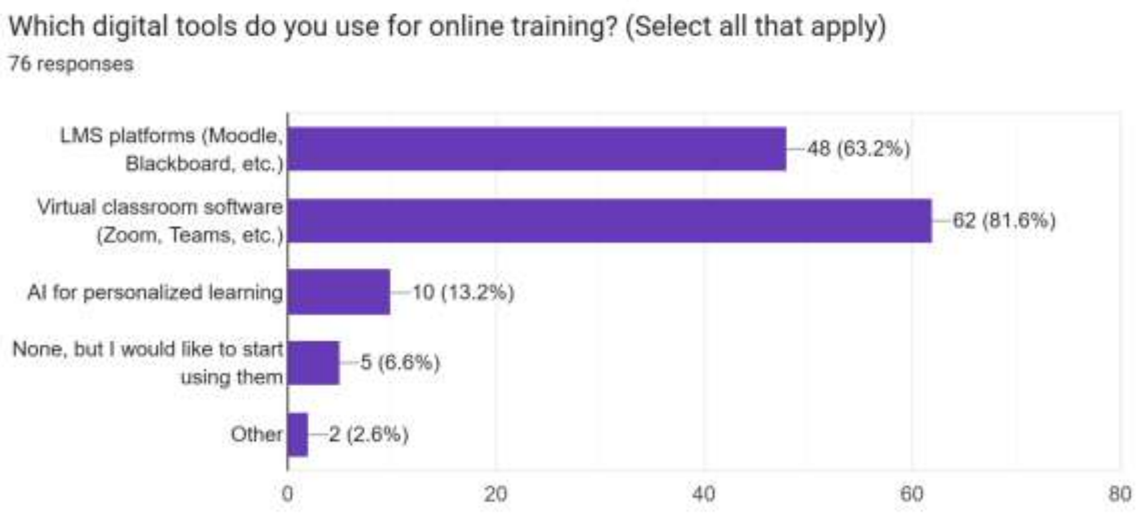
Although partly expected, this finding highlights the need to strengthen BIM-related digital skills within the VET system, including through targeted upskilling paths and simplified teaching tools.

Overall, the data suggest that familiarity with digital technologies is mainly linked to the functional proximity of the tools to the role performed. In production contexts, tools related to surveying and monitoring prevail, while in education, knowledge of advanced digital technologies remains fragmented.
This gap between professional and educational use will be a key aspect to consider in the training design phase of WP4.

4.3 Digital competences perceived by trainers.

The analysis of the responses collected through the second questionnaire made it possible to outline an initial profile of the digital competences held by trainers active in the vocational education and training (VET) sector. The results reveal a diverse landscape, in which experienced professionals in the use of digital technologies coexist with trainers who report limited preparation or difficulties integrating tools into their teaching practices.
Regarding BIM, one of the key tools for the digitalisation of the construction sector, only a minority of respondents report using it regularly in their courses. Most have sporadic experience or do not

use it at all, despite recognising its relevance and expressing the desire to acquire the necessary skills. This finding suggests that the presence of BIM in training is still limited and that there is a latent demand for both technical and pedagogical upskilling in this area.
A similar situation is observed with respect to Digital Twins. Many respondents have heard of this technology but state they do not fully understand its applications or educational potential. Only a very small number of participants report using it actively in training. The gap between theoretical knowledge and actual use is also a recurring theme for immersive technologies such as augmented and virtual reality. Some trainers have begun experimenting with them, often in pilot projects or extracurricular activities, but the majority express curiosity and interest rather than consolidated expertise.
As for the Internet of Things (IoT), a significant proportion of trainers report being familiar with the use of sensors for monitoring safety and performance on construction sites. However, even in this case, the educational integration of sensor data remains fragmented, hindered by technical difficulties, a lack of appropriate tools, and the limited availability of examples applicable to everyday teaching.
Finally, greater familiarity emerges with online training tools, such as videoconferencing platforms or learning management systems (LMS), which have become a structural component of post-pandemic education. Nevertheless, trainers report a lack of features specifically designed for vocational training and highlight the need for more interactive, intuitive, and customisable tools.



Overall, the picture emerging from the questionnaire reveals an uneven level of digital competence: while some trainers appear proactive and technologically well-equipped, a significant portion of the sample expresses a strong need for training, upskilling, and support. Mapping these competences represents an essential foundation for designing the training programme foreseen in WP4.

4.4 Simplified classification of competence levels.

Based on the results of the second questionnaire, it is possible to propose an initial simplified classification of the digital competence levels of the VET trainers involved. This classification does not aim to be exhaustive or formally standardised, but provides an operational framework useful for guiding project and training choices in the following Work Packages.
The first level can be described as “theoretical exposure”: this includes trainers who state that they are familiar with certain digital technologies (such as BIM, IoT, or Digital Twin) but have never used them actively. This group is large and includes a significant portion of the sample, particularly when it comes to emerging technologies or those that are complex to integrate into traditional training pathways.
The second level, which can be defined as “occasional or experimental use,” includes trainers who have had some hands-on experience with digital tools, often in marginal or pilot contexts. This is the case, for example, for those who use BIM only occasionally, have taken part in projects involving VR/AR components, or have experimented with sensors in demonstration activities. These trainers show interest, but often report difficulties in structurally integrating technologies into their everyday teaching.
The third level concerns a minority of the sample and can be described as “regular and intentional use.” This group includes trainers who systematically use digital tools in course design, class management, or lab-based activities. These are more experienced profiles, often involved in innovative projects or affiliated with training centres equipped with advanced infrastructures. This group serves as an important point of reference for the potential transfer of best practices.
Although this is an empirical classification, these three competence levels — theoretical, experimental, advanced — provide a useful initial reference for designing upskilling paths tailored to actual needs. Looking ahead, this typology could be integrated into a dynamic map of trainers’ digital competences, aligned with European frameworks (such as DigCompEdu), and used as a basis for the personalisation of training content in WP4.

5. The digital technologies framework.

This chapter gathers and organises in a structured format the evidence related to digital technologies currently adopted, known, or considered a priority in the construction sector. The information presented here is primarily based on the results of the first questionnaire addressed to AECO professionals, as well as on the national focus groups, which helped validate and enrich the data through direct engagement with operators, technicians, and entrepreneurs.
The aim of the chapter is to provide a systemic overview of the most relevant technologies, grouping them by functional areas and assessing their diffusion, usage, perceived barriers, and adoption prospects. This framework serves as a reference point to guide future project activities, particularly the design of the training programme (WP4) and the definition of a European model of digital competences in the construction sector (WP3).

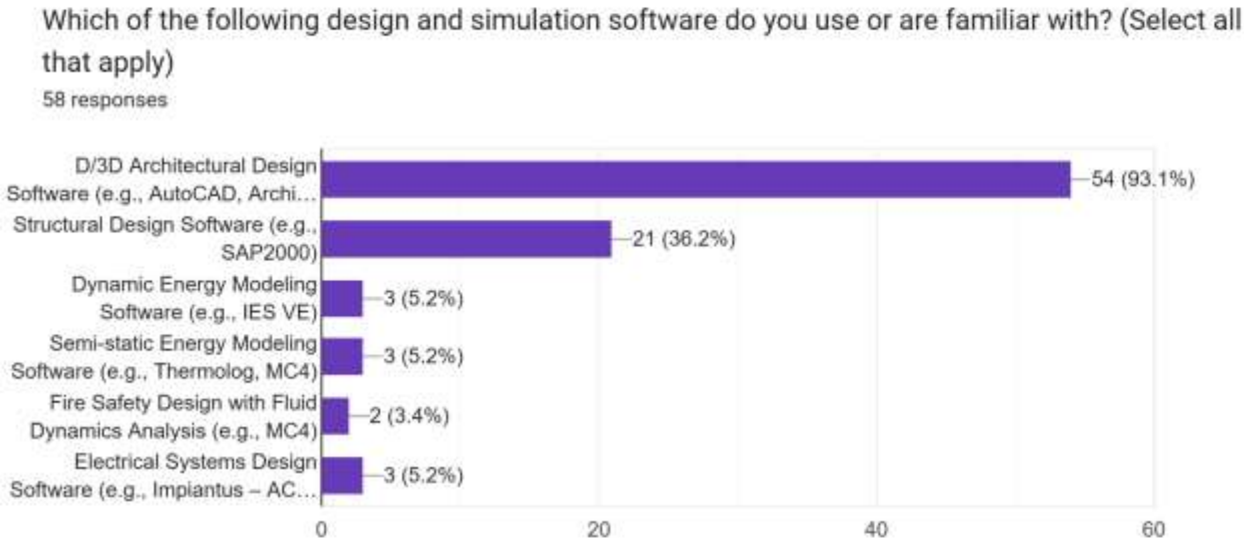
5.1 The technologies mentioned and categorised in the surveys.

The analysis of responses to the first questionnaire made it possible to identify a wide range of digital technologies currently used, known, or considered relevant by professionals in the construction sector. To make the findings more readable, the technologies have been grouped into five functional areas:

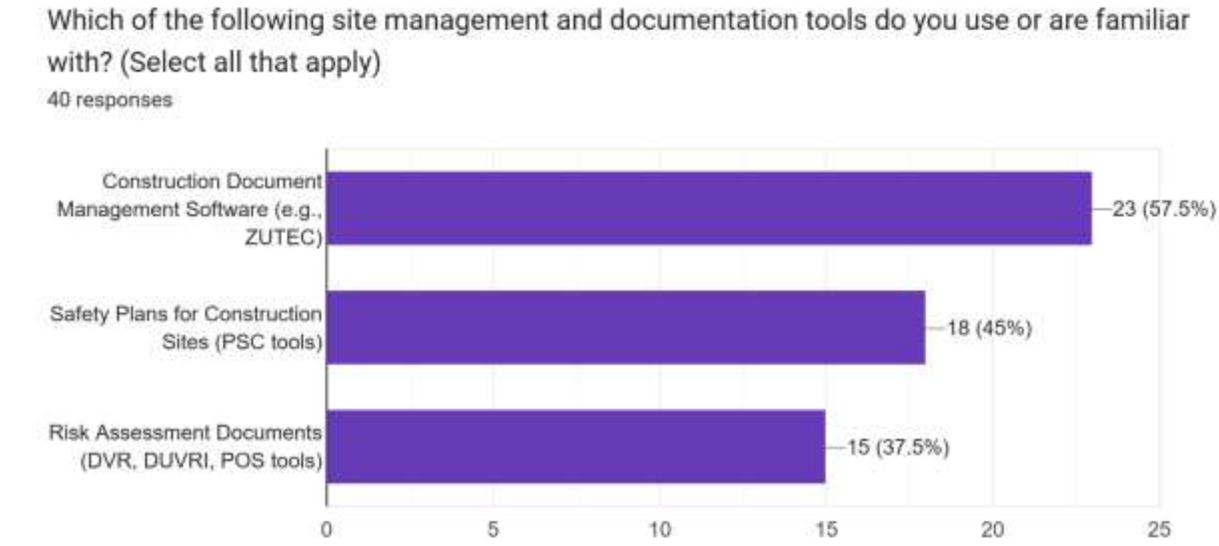
- surveying and monitoring tools,
- design and simulation software,
- site management tools,
- innovative technologies,
- complementary tools.

In the area of surveying and monitoring, the most frequently mentioned technologies are GPS (37 responses), laser scanning (29), and drones (27), followed by total stations (17). These tools are widely known and already adopted for georeferencing, 3D surveying, progress monitoring, and digital documentation.

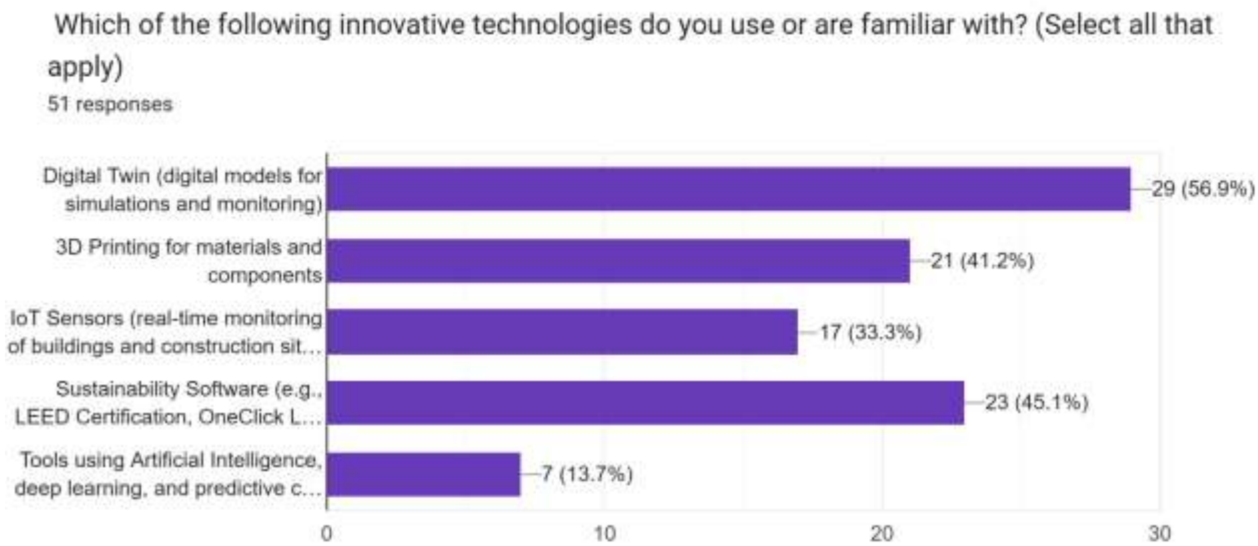
With regard to design and simulation software, AutoCAD and ArchiCAD are among the most widely used (both with 54 mentions), often accompanied by structural software such as SAP2000 (21 responses) or MC4. Tools for energy modelling (such as Thermolog or IES VE) also emerge, though to a lesser extent, along with specific tools for fire safety analysis.



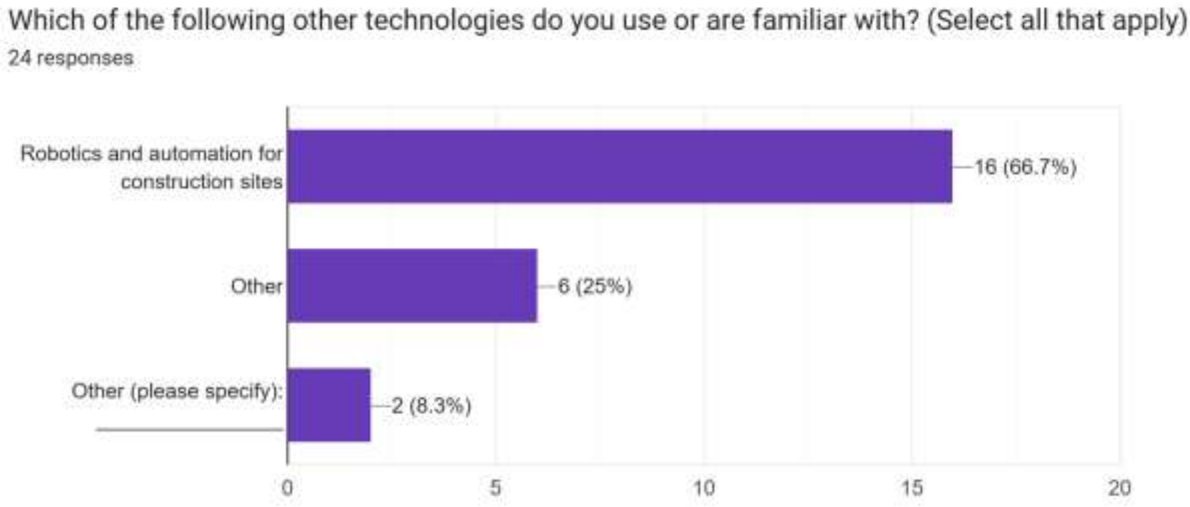
In the area of site management and documentation, respondents reported the use of software for managing technical documentation (e.g., ZUTEC – 23 responses), tools for drafting safety plans (18), and applications for risk assessment (DVR, DUVRI, POS – around 15 each). These solutions are mainly used by safety technicians and project managers.



The section on innovative technologies reveals a more varied picture, though already significant in terms of attention and interest. Digital Twin was cited 29 times, confirming a growing theoretical familiarity with this technology, even though its actual use remains limited. Other relevant tools include software for environmental sustainability and LEED certification (23), 3D printing for materials and components (21), and IoT sensors for real-time monitoring (17). Less widespread but rapidly expanding are technologies based on artificial intelligence and machine learning, with 7 mentions linked to applications such as predictive energy control (e.g., BrainBox AI).



Finally, among complementary technologies, respondents mentioned robotics and automation systems for construction sites (16 responses), along with a small group who indicated customised solutions or "other technologies" (8 in total), confirming the heterogeneity of digital solutions currently in use or in the experimentation phase.



Overall, the collected data show a good level of awareness regarding technologies related to traditional operational phases (surveying, design, safety), but also a growing interest in more advanced and integrated solutions, which may be further explored and developed in the upcoming Work Packages.

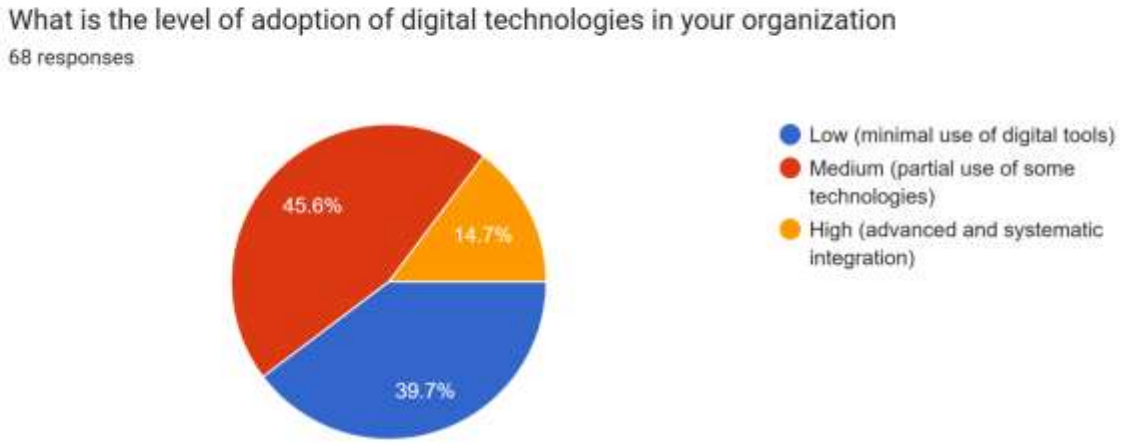
5.2 Reported level of awareness and use.

In addition to identifying the digital technologies known or used, the first questionnaire included a specific question on the general level of digital technology adoption within the respondents' organisations. The responses to this question provide an initial perceived estimate of the degree of digitalisation in the construction sector, as directly experienced by professionals working in the various partner countries.

The data collected indicate that most respondents fall into an intermediate category: 31 participants selected the "medium" option, corresponding to partial use of some technologies. This group includes companies that have begun integrating digital tools into their processes, often in a non-systematic way or limited to specific areas (surveying, design, safety), but which have not yet developed a strategic approach to digital transformation.

A second significant group (27 responses) identified with a low level of adoption, reporting minimal use of digital tools. This finding confirms that, despite the growing availability of technologies, many companies—particularly micro and small enterprises—remain on the margins of the digitalisation process, often due to economic or cultural barriers or a lack of skills.

Only 10 respondents reported working in contexts with a high level of adoption, characterised by advanced and systematic integration of digital technologies into business processes. Although this group represents a minority, it offers useful case studies for identifying best practices and replicable models at the European level.



Overall, the distribution of responses confirms the image of a sector undergoing a gradual and still uneven digital transition. The most significant figure is that over 80% of participants identify with a medium or low level of adoption, indicating substantial room for improvement and the need for targeted training and strategic interventions. This result further reinforces the relevance of ET4Digital's project objectives and the centrality of the actions planned in the upcoming Work Packages.

5.3 The barriers and opportunities according to participants.

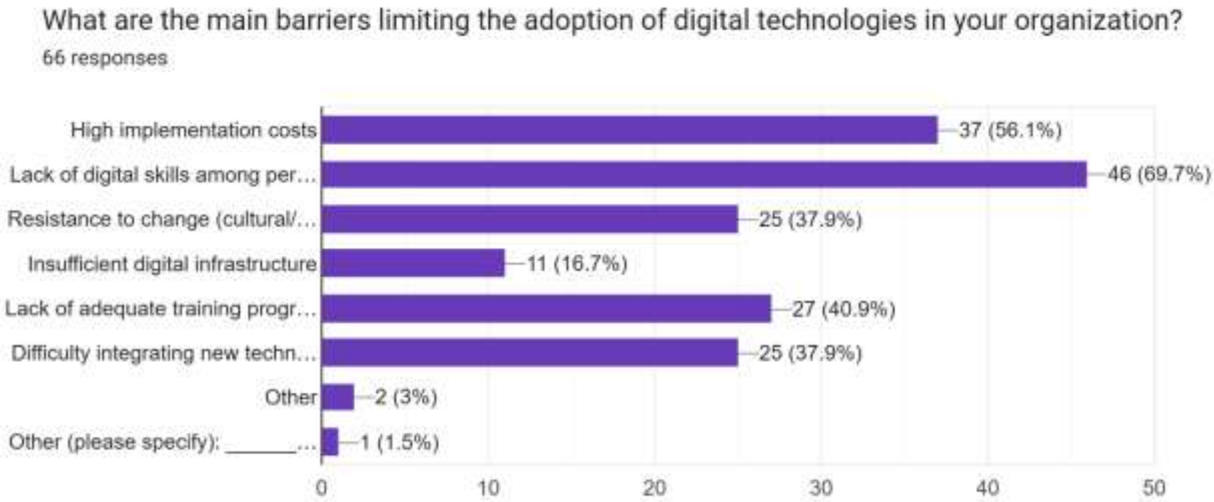
The adoption of digital technologies in the construction sector is hindered by a series of recurring barriers, which clearly emerge from the responses to the first questionnaire. Participants were able to select multiple options from those provided, offering a detailed view of the challenges perceived at organisational, economic, and training levels.

The most frequently mentioned barrier is the lack of digital skills among staff, indicated by 46 out of 70 respondents. This finding highlights how the shortage of technical knowledge is the main obstacle to the introduction of digital tools, especially in small and medium-sized enterprises where the workforce is often limited and professional development opportunities are scarce.

This is followed by “high implementation costs,” selected by 37 respondents, which shows that economic factors continue to represent a critical threshold—particularly in the absence of public incentives, economies of scale, or resource-sharing models. These costs not only concern the purchase of technologies, but also training, process adaptation, and potential external consultancy.

Other relevant barriers include the lack of adequate training programmes (27 responses), resistance to change (25), and difficulties in integrating new technologies with existing processes (25). These findings indicate that digital adoption is not only a technical issue but also a cultural and organisational one: many companies struggle to revise their operational methods, adapt workflows, or approach change in a systemic way.

More limited, though still significant, is the mention of inadequate digital infrastructure (11 responses), a factor that particularly affects poorly connected regions or construction sites located in remote areas.

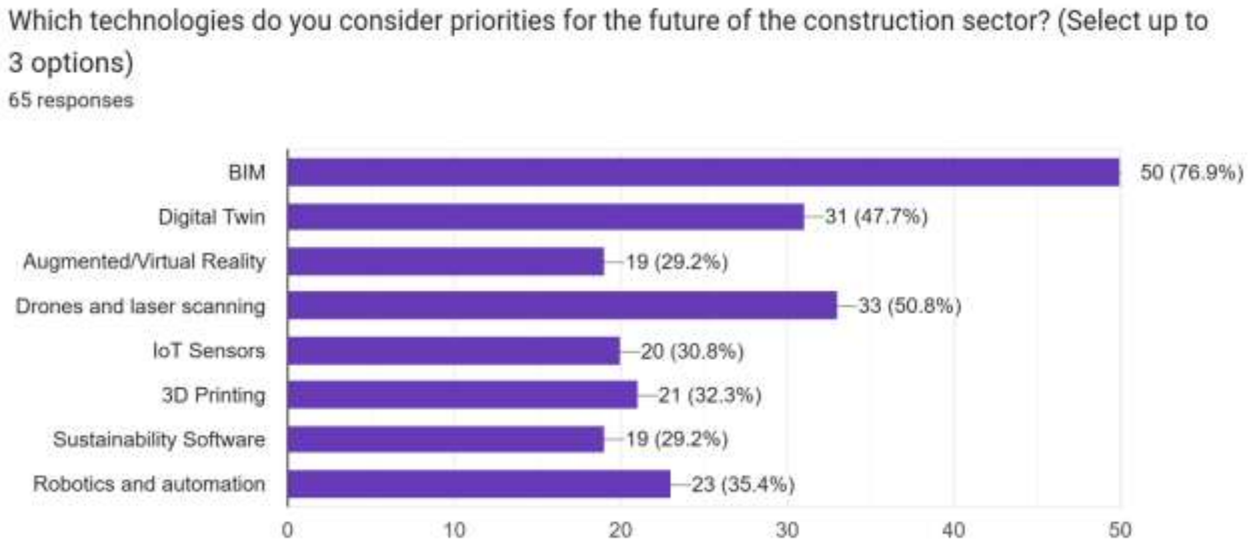


Despite these barriers, the open responses and focus groups also reveal a widespread recognition of the potential of digital technologies. In particular, technologies are seen as having the capacity to improve efficiency, traceability, safety, and sustainability in construction processes. Many participants express a willingness to invest in digitalisation, provided that the tools are simple, economically accessible, and supported by dedicated training pathways.
Understanding these barriers is a key element for designing supportive policies, capacity-building programmes, and operational tools that are more closely aligned with the real needs of businesses and professionals in the sector.

5.4 Priority technologies according to trainers.

In addition to identifying the technologies currently in use, the questionnaire asked participants to indicate, from a forward-looking perspective, which digital tools should be considered a priority for the future of the construction sector. The responses largely confirm the findings that emerged from the focus groups and outline a picture of convergence between practitioners' perceptions and emerging technological trends.
The technology identified as the top priority is Building Information Modeling (BIM), selected by 50 out of 70 respondents. BIM is seen not only as a tool for integrated design but also as an interoperability platform capable of connecting the various phases of the construction lifecycle. The centrality of BIM is therefore confirmed as a cornerstone of the sector's digital transformation.
Following closely behind with significantly high scores are drones and laser scanners (33), Digital Twin (31), and robotics and automation on construction sites (23). These technologies are often viewed as complementary: on the one hand, they enable increasingly precise and automated data

collection; on the other, they open up new possibilities for monitoring, control, and optimisation of on-site activities.
Other frequently mentioned technologies include 3D printing (21), IoT sensors (20), and augmented and virtual reality solutions (19), used for visual support in design, immersive training, and the simulation of operational scenarios. Equal attention is given to software for environmental sustainability (19), reflecting a growing awareness of the need to integrate energy and environmental criteria into decision-making processes.



Overall, the responses suggest that sector stakeholders are oriented towards technologies that combine precision, automation, efficiency, and sustainability. The preferences expressed reflect a mature demand for innovation—one that goes beyond the isolated adoption of tools and seeks systemic and interoperable solutions. This orientation will need to be carefully considered in the design of the training framework and digital competences in the upcoming Work Packages.

5.5 Recommendations for technology adoption.

The results from the first questionnaire and the focus groups clearly show that the adoption of digital technologies in the construction sector remains uneven, hindered by cultural, economic, and educational barriers. However, there is also a strong demand for change and growing interest in technological solutions that can enhance efficiency, safety, and sustainability within the sector. In this context, developing concrete recommendations for technology adoption is a crucial step in guiding the activities of the upcoming Work Packages.
The first recommendation concerns the need to simplify access to digital technologies, particularly for SMEs. Surveyed professionals often highlighted technical complexity and high costs as primary obstacles. The dissemination of more user-friendly, lightweight, and low-cost tools—potentially in open-source format or via shared platforms—could help increase the uptake of basic technologies (e.g., surveying, document management) even in less structured environments.

A second recommendation is to pair each digital tool with a specific training path that supports not only technical learning but also understanding of the operational and organisational implications. WP2 results show that many technologies are known at a theoretical level but remain underused due to a lack of concrete examples or application contexts. In this regard, the integration of case studies, demonstrators, simulations, and short “learning by doing” courses is essential.

A third key element is the direct involvement of trainers in the design and dissemination of technologies. Trainers should not be just end users of content, but rather act as true mediators of the digital transition, capable of conveying value and meaning to students, companies, and professional settings. To do so, they need simple, adaptable tools that align with the practical reality of vocational education.

Finally, it is essential to create a supportive ecosystem for adoption, which includes public incentives, networks for technical support, innovation-oriented procurement policies, and stable collaboration among institutions, training providers, and businesses. In this perspective, the role of the ET4Digital partners will be to support technology adoption not only with technical solutions but also through replicable, inclusive, and impact-oriented organisational and educational models.

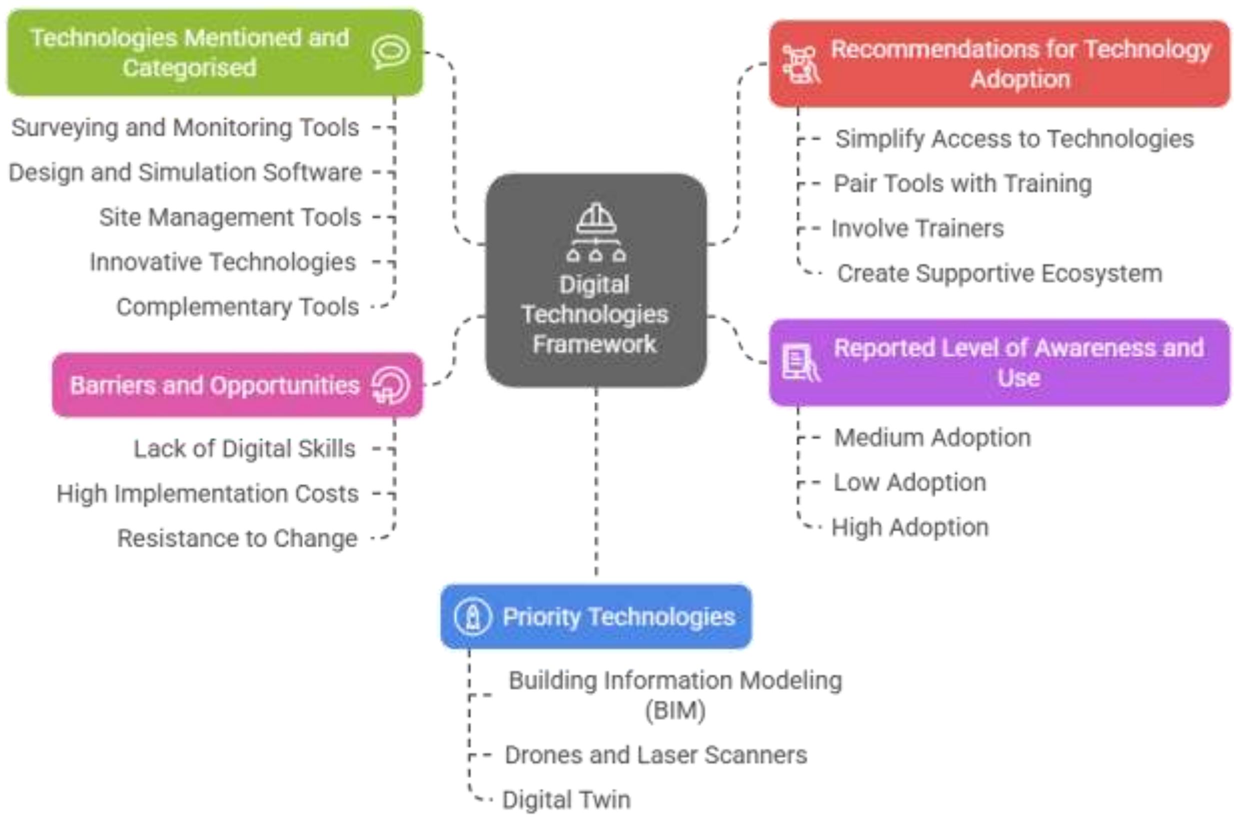


Figure 1 Framework and adoption of digital technologies in construction

6. Mapping the digital competences of trainers.

This chapter is dedicated to mapping the digital competences currently held, perceived, or required by trainers working in vocational education and training (VET) within the construction sector. The information presented here is primarily based on the second questionnaire and the second round of focus groups conducted in the seven partner countries. The aim is to identify strengths, gaps, and priority areas on which to build, in the subsequent Work Packages, a targeted training programme aligned with the real needs of the sector.

Unlike the technological framework, which describes the supply of tools available on the market, the competence mapping focuses on the demand for digital knowledge and skills from the trainers' perspective. It explores not only the levels of tool usage but also familiarity with emerging technologies, difficulties encountered, and the ability to transfer innovations into educational pathways. This work represents a key step in the development of the digital skill map for the ET4Digital project.

6.1 The relevant competence areas.

The responses collected through the second questionnaire make it possible to outline several digital competence areas that VET trainers currently consider essential for operating effectively within the context of construction and technical education. These competences are not limited to technical knowledge of the tools, but also include the ability to integrate them into coherent, useful, and transferable teaching activities.

A first relevant area is related to Building Information Modeling (BIM). Although many trainers report not using it regularly, most acknowledge the central role of this technology in contemporary design and construction processes. Interest in BIM is widespread, but actual competence appears limited, highlighting a clear need for professional development.

A second area concerns Digital Twins, which generate curiosity and interest but are still poorly understood in terms of both functionality and educational application.

The Digital Twin is often perceived as an advanced and abstract technology, with strong potential for simulation, monitoring, and predictive management, but still distant from everyday training practices.

The Internet of Things (IoT) also emerges as an important and growing competence area. Many trainers are aware of the value of sensors and data collection on construction sites, particularly in relation to safety and performance monitoring. However, the competences required to translate these concepts into training programmes remain weak and fragmented.

Immersive technologies such as Virtual Reality (VR) and Augmented Reality (AR) represent a fourth high-potential area. Trainers recognise the relevance of these tools for simulation, orientation, 3D visualisation, and safety management, but often lack the necessary skills to develop structured learning experiences.

Finally, questionnaire participants highlighted the growing importance of digital platforms for online learning and collaborative tools. Competence in this area is more widespread, thanks to experience gained during and after the pandemic, but there is still a need for more interactive, integrated, and VET-appropriate solutions.

Overall, the questionnaire shows that trainers are aware of the technological areas in which they need to strengthen their skills, and they generally demonstrate an open and motivated attitude toward upskilling. Identifying these areas represents a fundamental first step in building a digital competence map on which to base the training content of WP4.

6.2 The gaps highlighted in the survey.

The analysis of responses to the second questionnaire reveals a number of significant gaps in the digital preparedness of trainers active in vocational education for the construction sector. These competence gaps are not limited to the technical mastery of specific tools, but also involve the ability to consciously and systematically integrate technologies into training pathways.

One of the main gaps concerns Building Information Modeling (BIM). Although most participants acknowledge the importance of BIM in professional practice, a substantial portion report not knowing how to use it or having only theoretical knowledge. Many trainers express a desire to learn how to use BIM but complain about the lack of accessible training, adequate tools, and applicable teaching contexts. BIM is therefore perceived as a necessary competence, but one that remains underdeveloped in day-to-day teaching practice.

Another notable gap relates to Digital Twins, which are often poorly known or misunderstood in terms of how they work. The lack of practical experience, combined with the absence of concrete application cases, makes it difficult for trainers to understand how to translate this technology into clear and meaningful educational activities.

Responses related to IoT and smart sensors show an intermediate level of familiarity: trainers understand the potential of these technologies, particularly for safety and performance monitoring, but often lack the skills needed to use the data in a pedagogically effective way.

They also report barriers linked to limited access to devices, software, simulated environments, and financial resources.

Immersive technologies (VR and AR) represent a high-potential area that is currently underused. Trainers express interest and willingness to experiment but highlight key barriers such as technical complexity, equipment costs, lack of ready-made content, and difficulty in assessing the effectiveness of immersive activities against learning objectives.

A final critical area concerns the pedagogical integration of technologies. Even when trainers report knowing and using digital tools (online platforms, LMS, collaborative tools), they often struggle to design training experiences that are truly interactive, modular, and competence-based. There is a lack of methodological support for designing coherent, effective, and customisable digital learning activities.

Overall, the questionnaire confirms that there is a clear demand among VET trainers for digital professional development—one that goes beyond simply introducing new tools and requires strengthening of the transversal competences needed to design, manage, and assess digital training pathways in the construction sector. Bridging these gaps will be one of the main objectives of the training programme developed in WP4.

6.3 Key cases and open-ended comments

The open-ended responses from the second questionnaire, together with insights gathered during the national focus groups, helped identify a set of recurring themes and emblematic cases that illustrate how trainers are experiencing the digital transition. These qualitative elements enrich the quantitative data, helping to understand the operational challenges and expectations related to the integration of technologies into vocational education and training.

A first highlighted theme concerns the fragmentation and accessibility of training opportunities. Many trainers report difficulty in finding structured and up-to-date learning paths for acquiring digital competences specific to the construction sector. There is a shortage of targeted courses—especially in the field of BIM—as well as a lack of teaching materials designed for the VET context. Some participants reported having acquired digital skills mainly through self-learning or European projects, but struggled to translate these experiences into stable or officially recognised training activities.

A second critical area relates to the gap between theory and practice.

While aware of technologies such as BIM, Digital Twin, or IoT, many trainers state that they lack the technical or methodological conditions to apply them in daily teaching contexts. This difficulty often results in limited or marginal use of these tools, confined to pilot initiatives or extracurricular activities.

Another frequently mentioned issue is the presence of infrastructural and organisational barriers. Some trainers point to outdated equipment in training centres, lack of time for professional development, insufficient technical support, and the limited availability of intuitive, VET-appropriate educational software. In several cases, there is also a call to raise awareness among school leadership and institutions about the importance of investing in digitalisation.

Nonetheless, participants also put forward concrete suggestions and proposals. They hope to see the development of virtual learning environments, low-cost digital labs, easily customisable interactive tools, and open-source resources to simulate construction site scenarios, maintenance, safety, or energy management. Technologies enabling immersive and hands-on experiences, which foster active student participation, are seen as particularly valuable.

Overall, the collected observations reveal a community of trainers that is attentive, motivated, and aware—but in need of practical tools, methodological support, and enabling conditions to fully perform their role as drivers of innovation. These elements will be central to the design of the skill map and training content in the upcoming Work Packages.

6.4 Visual skill map and educational recommendations.

Based on the data collected from the second questionnaire and national focus groups with trainers, it was possible to develop an initial qualitative map of the digital competences needed in vocational education for the construction sector. Although this map has not yet been formalised as a definitive visual tool, it allows for the identification of key competence clusters that can later be translated, in the upcoming Work Packages, into teaching modules, training content, and upskilling pathways.

The identified competences can be grouped into four main areas:

1. Operational competences on digital tools: these include the use of software such as BIM, 3D modelling environments, simulators, collaborative platforms, sensors, and augmented and virtual reality tools. In this area, knowledge is often fragmented and mostly theoretical, with strong demand for practical support to integrate these tools into teaching practices.
2. Instructional design and methodological competences: these relate to the ability to integrate technologies into training programmes in a way that aligns with educational goals. Trainers report a need to develop strategies for designing hybrid courses, managing virtual labs, using digital assessment tools, and adapting teaching to the features of digital environments.
3. Adaptability and upskilling competences: these include the ability to monitor technological developments and independently update content. This area is closely linked to critical awareness of the role of technologies in transforming work and education, and to the willingness to actively participate in innovation processes.
4. Relational and facilitation competences: these are connected to the trainer's role as a facilitator of digital learning, able to engage, motivate, and guide students in exploring technologies. This dimension is considered crucial for overcoming resistance and promoting responsible and informed use of digital tools.

The educational recommendations derived from this analysis can be summarised into several guiding principles: build modular learning pathways differentiated by level and role; promote experiential learning through simulations, projects, and immersive environments; integrate tools for self-assessment and progress monitoring; foster accessibility and scalability of content; support the trainer community with practical tools, tutorials, replicable examples, and collaborative environments.

Although qualitative, this initial skill map serves as a strategic reference for the training design in WP4 and a starting point for the potential formalisation of a European framework of digital competences for VET trainers in the construction sector.

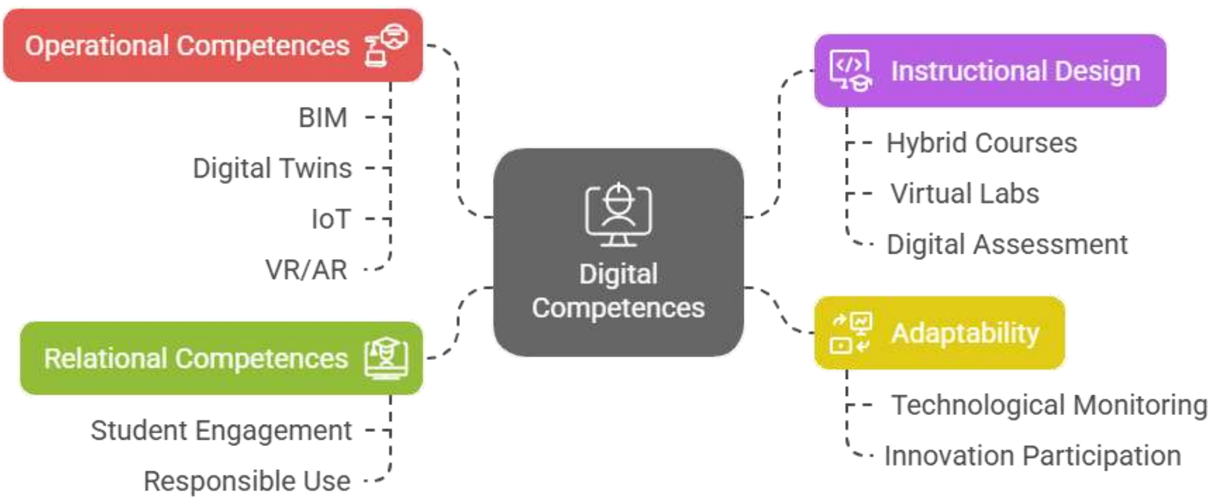


Figure 2. Digital competences for VET trainers in construction

7. Conclusions and strategic recommendations

Work Package 2 (WP2) of the ET4Digital project has constituted a crucial exploratory phase aimed at understanding the current state of digital transformation within the European construction sector, with a particular focus on the role and readiness of the VET training ecosystem. Through the integration of quantitative and qualitative methodologies—two online surveys, 14 national focus groups, and a structured literature review—this work package has enabled the collection of a robust body of evidence, highlighting both common trends and local specificities across the participating countries.

The findings reveal a dual scenario: on the one hand, the construction industry shows increasing awareness and interest in digital tools, especially in the areas of surveying, design, and safety. Technologies such as Building Information Modelling (BIM), Digital Twins, Internet of Things (IoT), 3D printing, and Augmented/Virtual Reality are widely recognised for their potential. However, their actual implementation remains fragmented and limited, particularly within small and medium-sized enterprises (SMEs) and among training providers who often lack the necessary infrastructure and competences.

On the other hand, the picture emerging from the trainer side is one of opportunity and dynamism, but also of significant challenges.

While some trainers demonstrate a high level of digital maturity and actively integrate new technologies into their teaching, many others report a lack of confidence, technical support, and structured training opportunities. The surveys and focus groups revealed a clear demand for practical, easy-to-use digital tools, along with a strong desire for continuous professional development pathways that are aligned with real-world applications and pedagogical effectiveness. Several structural barriers were consistently reported, including high costs of digital tools, limited access to up-to-date equipment, insufficient time and institutional support for upskilling, and a general resistance to change—particularly among more traditional stakeholders. These obstacles are compounded by the rapidly evolving nature of digital technologies, which often outpace the ability of training institutions to adapt curricula, acquire hardware, or update teaching methodologies.

Despite these limitations, WP2 has laid the foundations for a solid and actionable roadmap. It delivered two key results:

1. A structured framework of relevant digital technologies applicable to the AECO (Architecture, Engineering, Construction, and Operation) sector, classified according to their current and potential impact, areas of application, and degree of adoption.
2. A preliminary mapping of digital competences required by trainers to effectively support the sector's transition, highlighting both technical and pedagogical dimensions of digital readiness.

These two frameworks will inform and guide the development of the next phases of the project:

In WP3, they will contribute to the design of a European training model, incorporating the diversity of trainer profiles and digital maturity levels.

In WP4, they will underpin the co-creation of modular, adaptable, and context-aware training resources and curricula, to be tested and validated at national and European levels.

7.1 Strategic Recommendations.

Based on the WP2 findings, the following strategic directions are proposed to support the upskilling of trainers and foster digital innovation in the construction sector:

- Invest in the professional development of trainers, offering tailored, multi-level learning pathways that focus not only on technological literacy but also on digital pedagogy and hands-on applications. Peer learning, mentoring, and communities of practice should be encouraged as effective formats.
- Promote the accessibility of digital tools and content, by integrating open-source solutions, affordable software, and simulation platforms that can be easily implemented even in resource-constrained environments. This includes providing trainers with repositories of ready-to-use examples, templates, and case studies.
- Foster a collaborative innovation ecosystem where VET providers, companies, technology developers, policy makers, and local stakeholders work together. This includes establishing stable partnerships, promoting co-design and co-validation of training content, and facilitating exchanges between academia and the labour market.
- Encourage institutional and policy-level support for digital transformation, including funding schemes for digital infrastructure in training centres, incentives for innovation projects, and the integration of digital competences into national qualification frameworks.
- Monitor and evaluate the effectiveness of digital training initiatives to ensure continuous improvement. Metrics should assess not only knowledge acquisition, but also real-life applicability, learner engagement, and the impact on organisational practices in construction enterprises.

The ET4Digital project was conceived as a response to the increasing digitalisation needs of the construction sector and the strategic role of trainers in enabling this transformation. WP2 has provided a solid knowledge base and an evidence-based orientation for action. It has demonstrated that while challenges remain, the willingness to innovate, learn, and collaborate is present among European trainers and stakeholders.

Moving forward, the project's success will depend on our ability to translate this potential into scalable solutions, to create inclusive and future-proof training environments, and to empower trainers as agents of change within an evolving and increasingly digital construction industry.

ANNEX

A. SURVEYS STRUCTURE.

SURVEY N.1

Mapping Digital Technologies in the AECO Sector
(Architecture, Engineering, Construction, and Operation)

Section 1. General information

1. **What is your primary role in the construction sector?**
   ☐ Owner/Manager of an SME
   ☐ Engineer/Architect
   ☐ VET Trainer or Teacher
   ☐ Technician/On-site Operator
   ☐ Digital Technology Expert
   ☐ Other (please specify): _______________

2. **Which country do you primarily operate in?**
   ☐ Italy
   ☐ Spain
   ☐ Germany
   ☐ Greece
   ☐ Estonia
   ☐ North Macedonia
   ☐ Austria

3. **What is the size of your organization?**
   ☐ Micro (1-9 employees)
   ☐ Small (10-49 employees)
   ☐ Medium (50-249 employees)
   ☐ Large (>250 employees)

Section 2. Use of digital technologies

4. **Which of the following digital technologies do you use or are familiar with in the construction sector?** *(Select all that apply)*

   A. Surveying and Monitoring Tools

☐ Total Station (Theodolite)
☐ GPS (Georeferencing)
☐ Laser Scanning (Scan2BIM: point cloud and 3D model)
☐ Drones for surveying and monitoring

B. Design and Simulation Software
☐ 2D/3D Architectural Design Software (e.g., AutoCAD, ArchiCAD)
☐ Structural Design Software (e.g., SAP2000)
☐ Dynamic Energy Modeling Software (e.g., IES VE)
☐ Semi-static Energy Modeling Software (e.g., Thermolog, MC4)
☐ Fire Safety Design with Fluid Dynamics Analysis (e.g., MC4)
☐ Electrical Systems Design Software (e.g., Impiantus – ACCA software)

C. Site Management and Documentation Tools
☐ Construction Document Management Software (e.g., ZUTEC)
☐ Safety Plans for Construction Sites (PSC tools)
☐ Risk Assessment Documents (DVR, DUVRI, POS tools)

D. Innovative Technologies
☐ Digital Twin (digital models for simulations and monitoring)
☐ 3D Printing for materials and components
☐ IoT Sensors (real-time monitoring of buildings and construction sites)
☐ Sustainability Tools (e.g., LEED Certification, OneClick LCA)
☐ Artificial Intelligence (e.g., BrainBox or similar tools)

E. Other Technologies
☐ Robotics and automation for construction sites
☐ Other (please specify): _________________

5. **What is the primary purpose for using these technologies?** *(Select all that apply)*
☐ Surveying and monitoring construction sites
☐ Architectural/structural design
☐ Energy simulation and sustainability
☐ Management and control of construction documents
☐ Safety (on-site and within the company)
☐ Training and skill development
☐ Other (please specify): _________________

6. **What is the level of adoption of digital technologies in your organization?**
☐ Low (minimal use of digital tools)
☐ Medium (partial use of some technologies)

☐ High (advanced and systematic integration)

Section 3. Benefits and barriers

7. **What benefits have you observed from adopting digital tools?** *(Select all that apply)*
   ☐ Increased productivity
   ☐ Reduced operational costs
   ☐ Improved work quality
   ☐ Enhanced safety
   ☐ Energy savings and environmental sustainability
   ☐ More effective collaboration between teams
   ☐ Reduced project timeframes
   ☐ Other (please specify): _________________

8. **What are the main barriers limiting the adoption of digital technologies in your organization?**
   ☐ High implementation costs
   ☐ Lack of digital skills among personnel
   ☐ Resistance to change (cultural/organizational)
   ☐ Insufficient digital infrastructure
   ☐ Lack of adequate training programs
   ☐ Difficulty integrating new technologies with existing processes
   ☐ Other (please specify): _________________

Section 4. Future needs and suggestions

9. **Which technologies do you consider priorities for the future of the construction sector?** *(Select up to 3 options)*
   ☐ BIM
   ☐ Digital Twin
   ☐ Augmented/Virtual Reality
   ☐ Drones and laser scanning
   ☐ IoT Sensors
   ☐ 3D Printing
   ☐ Sustainability Software
   ☐ Robotics and automation

10. **What would help facilitate the adoption of these technologies in your organization?**
   ☐ Specific training programs for personnel
   ☐ Financial incentives or funding
   ☐ Access to more affordable digital tools

☐ Technical and operational consultancy
☐ Other (please specify): ________________

11. **Do you have any suggestions or comments regarding the use of digital technologies in the construction sector?**

____
____
____

SURVEY n. 2

Digital Skills and Training Needs of Trainers in the Construction Sector.

Section 1. General information

1. **What is your primary role in construction training?**
☐ VET trainer (Vocational Education and Training)
☐ University lecturer
☐ Technical school teacher
☐ Consultant/corporate trainer
☐ Other (please specify): ________________
2. **In which country do you primarily work?**
☐ Italy
☐ Spain
☐ Germany
☐ Greece
☐ Estonia
☐ North Macedonia
☐ Austria
3. **How many years have you been working in construction training?**
☐ Less than 1 year
☐ 1-5 years
☐ 6-10 years
☐ More than 10 years

Section 2. BIM and Digital Twin in training

4. **Do you have experience using BIM (Building Information Modeling) in your teaching activities?**
☐ Yes, I use it regularly

☐ Yes, but only occasionally
☐ No, but I would like to learn how to use it
☐ No, it is not relevant to my role

5. **Have you heard of Digital Twins for training in the construction sector?**
☐ Yes, and I already use them in my courses
☐ Yes, but I don't fully understand how to apply them
☐ No, but I would like to learn more
☐ No, I am not interested

What are the main challenges in using BIM/Digital Twin in training? *(Select all that apply)*
☐ Lack of specific training
☐ High software costs
☐ Difficulty integrating it into existing courses
☐ Resistance to change from students/teachers
☐ Other (please specify): _________________

Section 3. IoT and sensors for site monitoring in training.

7. **Are you familiar with the use of sensors and IoT (Internet of Things) for monitoring safety and performance on construction sites?**
☐ Yes, and I use them in training
☐ Yes, but I have never had the opportunity to use them
☐ No, but I am interested in exploring their potential
☐ No, this is not an area of interest for me
8. **Which sensor-collected data could be useful for training?** *(Select all that apply)*
☐ Worker safety monitoring
☐ Air quality and material analysis
☐ Structural stability control
☐ Energy consumption optimization
☐ Other (please specify): _________________
9. **What are the main difficulties in integrating IoT into training?** *(Select all that apply)*
☐ Cost of equipment and installation
☐ Complexity of use and data interpretation
☐ Lack of compatible educational software
☐ Lack of training on these tools
☐ Other (please specify): _________________

Section 4. Virtual and augmented reaality (VR/AR) in training.

10. **Have you ever used Virtual Reality (VR) or Augmented Reality (AR) in your courses?**
☐ Yes, regularly

☐ Yes, but only experimentally
☐ No, but I am interested in trying it
☐ No, I do not see it as useful for my role

11. **Which VR/AR applications could be useful for training?** *(Select all that apply)*
☐ Simulation of safety procedures
☐ Virtual tours of construction sites and buildings
☐ Practical training on machinery
☐ Other (please specify): ________________

12. **What are the main barriers to adopting VR/AR in training?** *(Select all that apply)*
☐ Cost of devices and software
☐ Technical complexity and need for specific skills
☐ Difficulty integrating it into traditional courses
☐ Lack of case studies and concrete examples
☐ Other (please specify): ________________

Section 5. Digital platforms and AI for training.

13. **Which digital tools do you use for online training?** *(Select all that apply)*
☐ LMS platforms (Moodle, Blackboard, etc.)
☐ Virtual classroom software (Zoom, Teams, etc.)
☐ AI for personalized learning
☐ None, but I would like to start using them
☐ Other (please specify): ________________

14. **What improvements would you like to see in digital training platforms?** *(Select all that apply)*
☐ More interactivity and gamification
☐ AI-based features for personalized learning
☐ Better integration with simulation and VR tools
☐ Other (please specify): ________________

Section 6. Comments and suggestions.

15. Do you have any suggestions or comments on how to improve the use of digital technologies in construction training? Additionally, do you have any general proposals or innovative ideas regarding technological advancements that could benefit the construction sector?

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