



DELIVERABLE 5.1

Educational Training Material Specification Document

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Executive Summary

The purpose of Deliverable 5.1, Educational Training Material Specification Document is to define the foundational framework for the design, structure, and implementation of hydrogen-related training content within the H2VE project. Serving as the cornerstone of Work Package 5, this document provides the conceptual, pedagogical, and methodological blueprint for the development of high-quality vocational education and training materials aligned with the European Qualifications Framework (EQF).

The document begins by analysing the specific educational needs of three key target groups:

- VET learners
- Trainers and educators
- Industry professionals and Workforce

These profiles serve as the basis for constructing an adaptable and inclusive curriculum model, with training content mapped to EQF levels 3 through 8. This approach ensures that the material is appropriately structured to meet a wide range of technical, intellectual, and independent working capacities, while remaining relevant to diverse learning and professional development contexts. To support comparability and national adaptability, the document includes a detailed mapping of the national qualifications frameworks of the partner countries, including a functional alignment of the Ghana National Qualifications Framework with the EQF.

The curriculum architecture is built around a thematic model comprising 15 content areas that reflect the complexity and interdisciplinarity of the hydrogen sector. Each section represents a distinct knowledge domain and technical competence, accompanied by a sample structure of training courses and their indicative level alignment. The curriculum is designed to be modular, learner-centred, and context-sensitive, supporting formal education programmes as well as non-formal and lifelong learning initiatives.

To guide the development of the educational materials, D5.1 introduces a standardized learning unit format that includes clearly defined learning outcomes, instructional guidance, assessment strategies, and resource recommendations. This structure ensures consistency across all modules while allowing flexibility in delivery formats tailored to the specific needs of training providers and target learners.

The document also outlines the processes through which the curriculum will be validated, piloted, and continuously improved. These include mechanisms for internal partner review, external

stakeholder consultation, implementation pilots within the H2VE CoVEs, and quality assurance processes coordinated under WP10. These activities are designed to ensure that the training content remains responsive to technological developments, pedagogical advances, and evolving regional and sectoral needs.

It is essential to note that D5.1 does not constitute a final curriculum but rather a dynamic framework that will guide the development of subsequent outputs: D5.2, D5.3, D5.4 and D5.5. It lays the structural and methodological foundation upon which these deliverables will be built and continuously refined. By articulating a coherent curriculum strategy based on a shared EQF reference structure, while allowing for national adaptation, D5.1 supports the broader aims of the H2VE project: fostering vocational excellence, promoting inclusive skills development, and contributing to Europe's and its partner regions' transition toward a sustainable hydrogen economy.

1. Introduction

The Educational Training Material Specification Document (D5.1) constitutes the foundational deliverable of Work Package 5 (WP5) within the framework of the Hydrogen Valley Education for Europe (H2VE) project, funded under the Erasmus+ Programme. The overarching aim of WP5 is to foster the design and development of innovative and structured training materials that support vocational education and skills acquisition across the hydrogen value chain. In alignment with the objectives of H2VE, D5.1 sets out a comprehensive framework that informs the subsequent development, delivery, and validation of educational content in the project.

This document delineates the pedagogical and thematic architecture upon which training resources for hydrogen-related material will be developed. It aims to address the specific needs of three distinct yet interrelated target groups:

- Vocational Education and Training (VET) learners,
- Trainers and educators, and
- Professionals and skilled workers in the hydrogen industry.

Clarifying the content areas, competency levels, and qualification alignment strategies, this deliverable ensures that the forthcoming educational materials are both responsive to labour market needs and grounded in a robust, learner-centred approach.

A central feature of D5.1 is its alignment with the European Qualifications Framework (EQF). The EQF provides a common reference structure that facilitates the comparability and transparency of qualifications across Europe. In this context, the document outlines how educational content will be mapped to EQF levels, ranging from EQF 3 to EQF 8, ensuring that the proposed training pathways are consistent with European standards for learning outcomes and qualification descriptors. Furthermore, consideration is given to the National Qualifications Frameworks (NQFs) of participating countries, in order to support cross-border recognition and their alignment with the EQF through the programme.

It is important to emphasize that D5.1 does not aim to prescribe finalised curricula or ready-to-deploy learning materials. These outputs are the focus of later deliverables in WP5 namely, D5.2 (Guide for the Trainer Curriculum), D5.3 (Training Workshops and Webinars), D5.4 (Guide for the Students Curriculum), and D5.5 (Finalised Curriculum Outline). Rather, D5.1 offers a methodological and structural foundation that will guide the creation and harmonization of those resources. This specification document therefore plays a pivotal role in ensuring coherence, consistency, and quality throughout the educational development process in H2VE.

In summary, D5.1 functions as both a conceptual framework and an operational guide within WP5. It articulates the educational strategy underpinning the H2VE project and establishes the structural basis upon which subsequent curriculum development activities will be systematically carried out.

2. Target Groups and Learning Needs

A core aim of the H2VE project is to address the skills and training requirements emerging from the deployment of Hydrogen Valleys - integrated regional ecosystems that connect hydrogen production, storage, distribution, and end-use across diverse sectors such as energy, transport, industry, and the built environment. These ecosystems rely on a multi-level workforce, composed of individuals with varying qualifications, experience, and roles along the hydrogen value chain. Accordingly, any educational material developed under this initiative must be rooted in a clear understanding of who the learners are, and what specific knowledge and competences they are expected to acquire.

In line with the general objectives of the call, H2VE promotes regional cooperation in vocational excellence across the full spectrum of the EQF levels 3 to 8. This broad scope reflects the ambition to support a wide range of educational and professional profiles, from entry-level technicians to advanced practitioners and specialists. It also underscores the need for flexible, modular, and scalable training content that can be adapted to national systems and institutional contexts while remaining aligned with European standards.

As part of the deliverable's foundation, it is essential to define the key target groups who will engage with the training materials, as well as the overarching learning needs that those materials must address. By identifying these groups at an early stage, WP5 ensures that the structure and format of the educational material will be fit-for-purpose, pedagogically sound, and capable of delivering impact across the varied landscape of hydrogen-related education.

This section identifies three core categories of learners:

1. **Vocational Education and Training (VET) learners**, engaged in formal education programmes and progressing toward recognized qualifications
2. **Trainers and educators**, responsible for facilitating learning and ensuring the delivery of high-quality, relevant instruction
3. **Industry professionals and workforce members**, typically engaged in non-formal or informal learning pathways aimed at upskilling or reskilling

Each of these groups plays a distinct role in the growth of the hydrogen sector and contributes to the long-term sustainability of Hydrogen Valleys. Their learning needs differ not only in content and complexity but also in delivery format, educational context, and expected outcomes. While

only VET learners are formally aligned with EQF levels, it remains important that all training material draws upon the learning outcome-oriented structure of the EQF, particularly when defining competencies, responsibilities, and autonomy.

In the sections that follow, each group is examined in greater detail, providing the necessary pedagogical rationale for the thematic organisation and structural decisions made later in this document.

2.1 Vocational Education and Training Learners

VET learners constitute a key focus of the H2VE project, as they represent the future workforce of the Hydrogen Valleys sector - an integrated, cross-sectoral model of hydrogen development encompassing production, storage, distribution, and application. These learners are engaged in formal educational programmes across a broad spectrum of qualification levels, typically mapped to EQF levels 3 through 8, depending on the depth, specialization, and progression of their studies.

At the lower end of the spectrum (EQF 3–4), learners are developing basic operational competences and foundational understanding of hydrogen systems. This may include introductory exposure to hydrogen safety, energy systems, or infrastructure-related processes, aimed at preparing individuals for entry-level technical roles or apprenticeships.

At intermediate levels (EQF 5–6), learners are expected to engage more deeply with technical content, including:

- Hydrogen production and storage technologies
- Fuel cell systems, electrolyser operation, and hydrogen-powered mobility
- Applied safety practices, environmental impacts, and sectoral integration
- The use of digital tools and simulations for design, control, or monitoring applications

These learners are typically enrolled in post-secondary VET programmes or higher vocational institutions and are being prepared for skilled employment or advanced technician roles within the Hydrogen Valleys ecosystem.

At the higher levels (EQF 7–8), VET learners may be undertaking specialized or professional qualifications, including advanced technical degrees, applied research programmes, or innovation-oriented tracks. While less common in traditional VET structures, EQF 7–8 learners:

- Engage with systems-level thinking, innovation, and emerging hydrogen technologies

- Participate in design, development, or optimisation of hydrogen infrastructure
- Require knowledge in project planning, regulation, sustainability, and cross-sector coordination
- Often work in applied research settings or leadership positions in industry–academia partnerships

The inclusion of EQF levels 7 and 8 reflects the evolving landscape of vocational education, where higher qualifications with strong industry relevance are increasingly delivered outside the traditional university system, particularly in fields such as energy and sustainability.

Pedagogical Considerations

Training material aimed at VET learners must be:

1. EQF-aligned, with learning outcomes clearly articulated for each level (3–8)
2. Scalable, allowing educators to adapt content complexity according to learner needs and institutional level
3. Modular and stackable, supporting both full qualification programmes and micro-credentialing approaches
4. Strongly connected to the Hydrogen Valleys context, emphasizing local relevance and sectoral applicability.

This broad and inclusive approach to VET learners ensures that the H2VE project addresses the full range of educational pathways necessary to support a sustainable and future-ready hydrogen workforce across Europe.

2.2 Trainers and Educators

Trainers and educators are central to the realization of high-quality vocational education within the hydrogen sector. Within the H2VE project, they serve as essential conduits for knowledge transfer, bridging the gap between technical content and learner engagement across a variety of settings. In the context of Hydrogen Valleys, where hydrogen technologies intersect with multiple domains and rapidly evolving practices, the role of trainers is both pedagogically and professionally complex.

This target group includes a wide range of professionals involved in education and capacity building. It encompasses VET teachers within formal education institutions, instructors at vocational training centres, subject matter experts collaborating with industry, and technical

facilitators supporting upskilling programmes for workers already active in the hydrogen field. Although trainers themselves are not categorized according to EQF levels, their practice is closely aligned with EQF-based learning design. They are responsible for delivering content mapped to specific qualification levels and ensuring that learners achieve clearly defined outcomes in terms of knowledge, skills, and autonomy.

To operate effectively in this environment, trainers require a combination of technical and pedagogical competences. They must possess up-to-date understanding of hydrogen systems, including production, storage, distribution, and end-use applications. This technical knowledge must be accompanied by expertise in instructional design, including the capacity to develop learning activities that reflect EQF descriptors and promote competence-based progression. Furthermore, trainers are increasingly expected to facilitate learning across a range of delivery environments, including classroom-based teaching, digital platforms, and practical training settings. The ability to integrate blended learning tools - such as simulations, remote laboratories, and e-learning modules - has become essential, particularly as vocational education evolves toward more flexible and hybrid models.

Another important aspect of the trainer's role lies in contextualizing learning within the broader economic, environmental, and policy dimensions of the hydrogen transition. Trainers who are aware of regulatory developments, sectoral priorities, and labour market trends within Hydrogen Valleys are better equipped to deliver instruction that is relevant, future-oriented, and regionally grounded. In many cases, they must also respond to the needs of diverse learner profiles - ranging from entry-level VET students to experienced professionals seeking to reskill. This demands a high degree of didactic adaptability and sensitivity to differing levels of prior knowledge, professional experience, and learning motivation.

From a content development perspective, educational materials must be designed in a way that supports the needs of trainers. This includes providing clear learning outcomes, structured thematic content, and pedagogical guidance to support flexible implementation. Teaching resources should also include elements such as assessment strategies, teaching notes, and examples of how to apply content in practical or work-based settings. These design features will enable trainers to confidently deliver hydrogen-related education that is pedagogically sound, technically accurate, and adaptable to a variety of learning contexts.

While the creation of trainer-specific curricula will be addressed in greater depth in Deliverable D5.2 (Guide for the Trainer Curriculum), the framework provided in this document (D5.1) ensures that the foundational structure of the educational material is responsive to the professional needs and instructional responsibilities of trainers. Supporting this target group is vital to the success of

the H2VE project's broader aim of promoting vocational excellence and workforce readiness across the Hydrogen Valleys sector.

2.3 Industry Professionals and Workforce

Industry professionals and members of the existing workforce represent a distinct but equally vital target group within the H2VE project. This group includes individuals already employed in the hydrogen sector or in adjacent fields such as energy, transport, industrial processing, and environmental engineering - many of which are actively engaged in the development or operation of Hydrogen Valleys. These professionals are typically not part of formal education systems but engage in non-formal or informal learning to upskill, reskill, or deepen their sector-specific knowledge in response to technological innovation and evolving regulatory frameworks.

The learning needs of this group are highly contextual and application-driven. Unlike VET learners, who progress through structured curricula, industry professionals often seek short, focused learning interventions that support immediate performance needs or career advancement. Their learning preferences are shaped by professional experience, job-specific demands, and time constraints. As such, the training materials intended for this audience must be modular, flexible, and accessible, with content that is directly applicable to their work environments.

In many cases, these learners require specialized knowledge in one or more sectors of the hydrogen value chain, for example, safety protocols in hydrogen transport, operational procedures for electrolyser systems, or integration of hydrogen technologies in industrial decarbonization processes. They may also benefit from cross-disciplinary insights that link hydrogen deployment to digital technologies, environmental regulation, or circular economy models. The focus, therefore, must be on delivering competence-based learning, often through real-world case studies, technical demonstrations, and scenario-based applications.

While this group is also not directly associated with EQF levels, the structuring of training materials according to EQF-aligned learning outcomes remains beneficial. It enables content designers to define clear learning objectives in terms of what learners are expected to know, understand, and be able to do, regardless of whether their learning is formally accredited. Furthermore, such alignment opens pathways for validation of non-formal learning, including the use of micro-credentials or recognition of prior learning (RPL), which can be important for workforce mobility and certification.

The delivery of training to this group may take place within companies, sectoral training centres, or professional development programmes offered by public or private institutions. In each case,

materials must be designed for ease of integration into diverse formats and schedules. This includes asynchronous digital modules, on-site technical workshops, and blended approaches that combine remote instruction with practical, hands-on training.

By addressing the educational needs of industry professionals and the wider workforce, the H2VE project acknowledges that the success of Hydrogen Valleys depends not only on new entrants to the sector, but also on the continuous development of those already working within it. Ensuring that these individuals have access to high-quality, relevant, and recognizable training opportunities is essential to supporting innovation, operational excellence, and the long-term sustainability of the hydrogen economy.

3. Qualifications Framework Mapping

In the context of transnational education and training initiatives such as H2VE, ensuring a common language for describing qualifications is essential for transparency, recognition, and learner mobility. The European Qualifications Framework (EQF) serves as a foundational tool for this purpose, offering a unified structure of eight reference levels that describe learning outcomes in terms of knowledge, skills, and autonomy/responsibility. By mapping national qualifications frameworks (NQFs) to the EQF, it becomes possible to align educational efforts across countries, thereby promoting mutual recognition of learning and the transferability of qualifications.

The present section aims to contextualize the structure and function of the EQF and examine its relevance for the design and implementation of hydrogen-related vocational training content under the H2VE project. It also explores how the EQF is reflected in the national frameworks of the participating partner countries - namely Germany, Greece, Italy, Latvia, Poland, and Ghana. Although Ghana is not formally referenced to the EQF, its national framework (GNQF) is sufficiently compatible in structure and ambition to allow for a functional alignment within the scope of the project.

This mapping exercise is central to D5.1, as it underpins the classification of the educational material according to qualification levels. It ensures that the learning outcomes developed within each thematic section are appropriate to the cognitive and technical capacities of the target groups identified in Section 2, particularly VET learners ranging from EQF levels 3 to 8. In doing so, this alignment facilitates both the modular design of the curriculum and its potential uptake across a variety of formal and non-formal learning environments in Europe and beyond.

3.1 The European Qualifications Framework

The EQF is a meta-framework developed by the European Union to promote the transparency, comparability, and portability of qualifications across member states. Initially established in 2008 and updated in 2017, the EQF provides a reference structure of eight levels that describe what a learner knows, understands, and is able to do, expressed through learning outcomes. These levels are defined in terms of knowledge, skills, and responsibility and autonomy, enabling a shift from input-based to outcome-based education.

The primary aim of the EQF is to improve cross-border recognition of qualifications and to facilitate lifelong learning by providing a shared reference point for different national and sectoral qualifications frameworks. By 2024, most EU member states, along with several non-EU countries,

have established and referenced their NQFs to the EQF, creating a coherent system for education and vocational training across Europe.

Each EQF level builds progressively on the previous one, starting from basic general knowledge and simple task performance (Level 1), and culminating in the most advanced academic and professional competence (Level 8). These levels span the full spectrum of learning - from vocational education and training (VET) to higher education and professional qualifications.

A summary of the EQF levels and the typical qualifications associated with each is provided in the following table.

Table 1 - EQF levels and typical associated qualifications

EQF Level	Level Description	Typical Qualification / Degree
Level 1	Basic general knowledge; ability to carry out simple tasks under direct supervision in a structured context.	Completion of primary/basic education
Level 2	Basic factual knowledge; ability to carry out tasks using simple rules and tools with limited autonomy.	Lower secondary education certificate
Level 3	Knowledge of facts, principles, and general concepts; ability to complete tasks and solve routine problems under supervision.	Upper-secondary vocational qualification / Basic VET
Level 4	Factual and theoretical knowledge in broad contexts; ability to work independently and supervise others.	High school diploma / Technical or general secondary education
Level 5	Comprehensive, specialized knowledge; ability to manage tasks and adapt to change in a field of work or study.	Short-cycle tertiary education / Higher technician diploma
Level 6	Advanced knowledge and critical understanding; ability to manage complex activities or projects.	Bachelor's degree / Engineering diploma
Level 7	Highly specialized knowledge; capacity to innovate and lead in unpredictable contexts.	Master's degree / Postgraduate Diploma
Level 8	Knowledge at the most advanced frontier; ability to demonstrate substantial autonomy and conduct original research.	Doctoral degree / PhD / Professional Doctorate

The EQF plays a pivotal role in the H2VE project as a guiding reference for the structuring of training materials and the classification of learners. The design of D5.1, and indeed the broader educational objectives of WP5, is shaped by the EQF's structure. Each learning module or thematic section is conceived to correspond with clearly defined learning outcomes that are consistent with one or more EQF levels.

Importantly, this framework supports the integration of multiple types of learners, ranging from vocational students and technicians to industry professionals and postgraduate researchers. By aligning the educational material with the EQF, the project ensures that each target group is presented with appropriately challenging content that supports career development, professional mobility, and the acquisition of recognized qualifications in the hydrogen sector.

3.2 National Qualifications Frameworks of Partner Countries

Although the EQF offers a common meta-framework for describing qualifications across Europe, it is through each country's individual NQF that the EQF becomes meaningful and actionable within national education and training systems. NQFs serve as internal classification systems that structure qualifications based on learning outcomes and levels of complexity, autonomy, and responsibility. They enable better coordination between formal, non-formal, and informal learning and enhance national coherence while also facilitating cross-border comparability through referencing to the EQF.

Within the scope of the H2VE project, understanding the structure and application of each partner country's NQF is essential to ensuring that the hydrogen-related educational materials are appropriate, accessible, and aligned with national learning expectations. While most EU countries participating in H2VE, (namely Germany, Greece, Italy, Latvia, and Poland) have formally referenced their NQFs to the EQF, each framework maintains its own descriptors, regulatory mechanisms, and approaches to validation and certification. Recognizing these distinctions is crucial for the development of a curriculum that is both harmonized at the European level and responsive to national contexts.

The project also includes Ghana, a non-EU country whose national framework, the Ghana National Qualifications Framework (GNQF), is not formally aligned with the EQF. Nevertheless, the GNQF exhibits structural parallels with international frameworks, including the EQF, and is built around a learning-outcomes-based approach. This allows for a functional alignment between the two frameworks and enables Ghanaian partners to actively contribute to and benefit from the shared educational infrastructure developed through the project.

The following sub-sections present an in-depth examination of each participating country's NQF. For each framework, the analysis considers its structural design, referencing status to the EQF, relevant level descriptors, and the implications for mapping educational content in the hydrogen sector. These national overviews form the basis for the comparative alignment undertaken in Section 3.4, which synthesizes the similarities and differences across the frameworks and establishes a shared structure for curriculum development and qualification recognition.

3.2.1 Germany (DQR)

Germany's National Qualifications Framework, the Deutscher Qualifikationsrahmen (DQR), serves as a reference system for classifying qualifications obtained within the German education and training system. The DQR encompasses qualifications from general education, higher education, and vocational education and training (VET), and is structured according to the principles of the European Qualifications Framework (EQF), with which it is fully referenced. The framework was developed collaboratively by the Federal Government, the federal states, social partners, and education and training stakeholders, and officially referenced to the EQF in 2013.

The DQR is organised into eight levels, each defined by a matrix of descriptors that reflect learning outcomes in four dimensions: professional competence (knowledge and skills) and personal competence (social competence and autonomy). This multi-dimensional structure allows for a diversified assessment of qualifications that goes beyond subject matter to include communication, team leadership, problem-solving, and independent learning. These competencies reflect both occupational and academic contexts and enable the recognition of dual and non-traditional learning pathways.

In Germany, vocational qualifications, including those obtained through dual VET programmes, are highly regarded and often mapped at levels 3 to 6, depending on complexity and responsibility levels. The alignment with the EQF facilitates transparency across Europe and supports the mobility of German-trained professionals, especially in technical and engineering sectors that are critical to hydrogen-related value chains. Bachelor's degrees typically correspond to Level 6, Master's degrees to Level 7, and Doctorates to Level 8, mirroring the EQF structure.

Within H2VE, the DQR serves as a national anchor point for the design and delivery of training content for German learners. The framework's strong emphasis on both technical and transversal competences makes it particularly suitable for mapping hydrogen training modules that combine theoretical knowledge with hands-on applications and workplace relevance. Additionally, the integration of dual learning pathways and recognition of non-formal and informal learning within the DQR aligns well with the modular and outcome-oriented approach promoted by the project.

As Germany is home to the WP5 leader and a key provider of vocational excellence in hydrogen-related fields, the DQR's application within H2VE not only facilitates domestic implementation but also serves as a model for curriculum alignment across partner countries.

3.2.2 Greece (HQF)

The Hellenic Qualifications Framework (HQF) serves as the national reference system for classifying qualifications awarded through general, vocational, and higher education. Developed and coordinated by the National Organisation for the Certification of Qualifications and Vocational Guidance (EOPPEP), the HQF was formally referenced to the European Qualifications Framework (EQF) in 2016. The HQF is structured across eight levels, using learning outcome descriptors in line with the EQF categories: knowledge, skills, and competence.

The HQF includes qualifications awarded at all stages of the Greek education system, from compulsory schooling through to doctoral studies. Levels 3 to 5 encompass vocational and post-secondary non-tertiary qualifications, while Levels 6 to 8 correspond to higher education degrees, including Bachelor's, Master's, and Doctorates.

Vocational education and training (VET) in Greece is delivered through a range of institutions, including Vocational High Schools (EPALs) and Schools of Advanced Vocational Training (SAEKs). The latter were known until recently as Institutes of Vocational Training (IEKs), but were officially renamed in 2024 under Law 5082/2024. The renaming of both public and private IEKs to SAEKs reflects Greece's ongoing modernisation of its vocational education system and the effort to enhance its alignment with European standards and labour market demands.

These VET providers, along with specialized training centres and certified adult education structures, form the core delivery system for qualifications positioned at HQF Levels 4 and 5. In parallel, universities and higher education institutions award qualifications at Levels 6 through 8, contributing to the comprehensive scope of the HQF.

HQF supports modular and flexible training design, in line with the outcome-based approach adopted by H2VE. This ensures that hydrogen-related educational material can be effectively embedded within formal curricula, accredited training schemes, and industry-focused upskilling initiatives.

3.2.3 Italy (QNQ)

Italy's National Qualifications Framework, the Quadro Nazionale delle Qualificazioni (QNQ), provides a structured reference for classifying qualifications issued within the Italian education

and training system. Officially referenced to the European Qualifications Framework (EQF) in 2022, the QNQ consists of eight levels, each defined by learning outcomes expressed through three descriptors: knowledge, skills, and autonomy and responsibility. These descriptors correspond directly to those of the EQF, thereby facilitating international comparability and transparency of Italian qualifications.

The QNQ encompasses qualifications awarded by general education, vocational education and training, higher education, and professional certification bodies. The framework reflects the diversity of Italy's decentralized system, where regional authorities play a significant role in the design and delivery of vocational training. Despite this complexity, the QNQ functions as a unifying structure that allows qualifications from different pathways and regions to be positioned consistently within a single national and European reference system.

Vocational qualifications in Italy are issued both through the national VET system and through regional pathways that include training agencies, apprenticeship contracts, and adult learning programmes. Qualifications at EQF levels 3 to 5 are typically associated with technical and vocational diplomas, post-secondary technician programmes, and regional vocational qualifications. Levels 6 to 8 are reserved for academic degrees (such as Bachelor's, Master's, and Doctorate), offered by universities and recognized higher education institutions.

The QNQ has also integrated Italy's National Catalogue of Professional Qualifications, which lists standardized professional profiles and training outcomes for employment-related qualifications across sectors. This inclusion strengthens the role of the QNQ in supporting lifelong learning, recognition of non-formal learning, and validation of work-based competences.

Furthermore, the alignment of the QNQ with the EQF ensures that Italian learners, whether enrolled in initial VET, reskilling programmes, or academic studies, can engage with hydrogen training content that is both nationally recognized and internationally comparable. This is essential for supporting workforce mobility and sectoral innovation within Italy's hydrogen valleys and broader European networks.

3.2.4 Latvia (LQF)

The Latvian Qualifications Framework (LQF) provides a comprehensive structure for classifying qualifications issued within the national education and training system. Officially referenced to the European Qualifications Framework (EQF) in 2011, the LQF includes eight levels, aligned directly with the EQF, and based on the principles of learning outcomes, transparency, and lifelong learning.

The development and implementation of the LQF is coordinated by the State Education Development Agency under the supervision of the Ministry of Education and Science. The framework covers all formal qualifications, including general secondary education, vocational education, professional higher education, and academic degrees. It also supports the development of systems for recognizing prior learning and qualifications acquired outside formal education pathways.

Qualifications at levels 1 to 4 in the LQF are generally associated with basic and secondary education as well as initial vocational education. Level 4 qualifications typically include vocational secondary education and general secondary education diplomas. Level 5 corresponds to short-cycle higher education programmes and post-secondary vocational education. Levels 6 to 8 reflect higher education degrees: a Bachelor's degree at level 6, a Master's degree at level 7, and a Doctorate at level 8.

Latvia's VET system is characterized by strong integration between education and the labour market, with a focus on competence-based qualifications and practical experience. Vocational schools and colleges play a central role in delivering programmes that correspond to LQF levels 3 through 5. These institutions cooperate closely with sectoral expert councils and employers to ensure that training content aligns with labour market needs and technological advancements.

The inclusion of hydrogen-specific training materials in Latvian VET and higher education programmes, mapped to appropriate LQF levels, will contribute to the development of a future-ready workforce capable of supporting national and European climate goals.

3.2.5 Poland (PQF)

Poland's National Qualifications Framework, formally known as the Polish Qualifications Framework (PQF), was developed as part of the country's education reform and officially referenced to the European Qualifications Framework (EQF) in 2013. The PQF consists of eight levels, each corresponding directly to an EQF level, and is based on learning outcomes expressed in terms of knowledge, skills, and social competence.

The structure and implementation of the PQF are coordinated by the Educational Research Institute (IBE) in collaboration with the Ministry of National Education and other national stakeholders. The framework encompasses qualifications awarded through general education, vocational training, higher education, and non-formal learning pathways. Each level of the PQF is supported by detailed level descriptors, and the framework serves as the foundation for the Integrated Qualifications System, which is a central registry of all qualifications recognized in Poland.

Levels 1 to 4 of the PQF typically relate to general and vocational secondary education. Level 5 corresponds to post-secondary non-tertiary vocational qualifications, while levels 6 to 8 are associated with higher education degrees - Bachelor's, Master's, and Doctoral qualifications, respectively. The PQF has been developed to ensure consistency and clarity across these levels, promoting transparency for learners, employers, and educators.

Poland has invested heavily in aligning its vocational education and training system with the demands of a modern, innovation-driven economy. VET programmes are offered by a wide network of technical schools, sectoral education centres, and post-secondary colleges. The emphasis on professional competence, workplace learning, and adaptability makes the PQF particularly well suited to supporting modular and sector-specific training initiatives such as those envisioned in the H2VE project.

Whether targeting students in technical and vocational schools, higher education institutions, or upskilling adult professionals, the PQF ensures that qualifications can be accurately classified, recognized, and connected to the broader EQF-based curriculum structure. This alignment is essential for ensuring that training outcomes meet both national labour market needs and European standards for mobility and innovation.

The Polish framework's openness to integrating qualifications from non-formal learning and industry-based training also enhances its relevance for H2VE. It allows hydrogen-related competences developed through practical or blended learning environments to be formally validated and recognized within Poland's national system.

3.2.6 Ghana (GNQF)

Ghana's National Qualifications Framework (GNQF) was established by the Commission for Technical and Vocational Education and Training as a key policy instrument for classifying and coordinating qualifications across the country's education and training landscape. The GNQF consists of ten levels and covers a broad spectrum of learning, including general education, technical and vocational education and training, higher education, and professional qualifications. It supports both formal and non-formal learning pathways, with an emphasis on outcome-based progression and lifelong learning.

Although Ghana is not formally referenced to the EQF, the GNQF is structurally and conceptually compatible with it. Both frameworks are based on learning outcomes expressed in terms of knowledge, skills, and autonomy/responsibility. This enables a functional alignment between the two systems, facilitating international comparability and allowing for Ghana's integration into collaborative European initiatives such as the H2VE project.

The alignment adopted in H2VE is based on the comparative complexity, scope, and type of qualifications awarded at each level. GNQF Level 10, which includes doctoral degrees, is aligned with EQF Level 8, while GNQF Levels 9 and 8, representing Master's and postgraduate diploma programmes, correspond to EQF Level 7. This rationale continues down to GNQF Level 1, which represents foundational and pre-vocational education and aligns with EQF Level 1.

This alignment ensures that hydrogen-related training materials developed within the H2VE framework can be applied meaningfully across the full range of Ghana's qualification levels. It supports learner progression, curriculum integration, and the awarding of nationally recognized qualifications that are also comparable across borders.

The following table presents the adopted alignment between GNQF and EQF levels in ascending order from EQF Level 1 to 8:

Table 2 - GNQF and EQF alignment table

GNQF Level	GNQF Qualification / Title	Aligned EQF Level	EQF Qualification / Title
Level 1	Primary Schooling / Pre-vocational Certificate	EQF 1	Completion of primary/basic education
Level 2	Grade 9 (GABECE) / Vocational Education Certificate	EQF 2	Lower secondary education certificate
Level 3	Grade 12 (WASSCE) / Vocational Education & Training Certificate		
Level 4	TVET Certificate	EQF 3	Upper-secondary vocational qualification / Basic VET
Level 5	TVET Diploma / National Diploma	EQF 4	High school diploma / General or technical secondary education
Level 6	Higher Diploma / Higher National Diploma	EQF 5	Short-cycle tertiary education / Higher technician diploma / HNC
Level 7	Bachelor's Degree / Occupational Certificate 4	EQF 6	Bachelor's degree / Engineering diploma
Level 8	Postgraduate Diploma / Certificate	EQF 7	Master's degree / Postgraduate Diploma
Level 9	Master's Degree / Master of Philosophy (M.Phil)		
Level 10	Doctorate Degree	EQF 8	Doctoral degree / PhD / Professional Doctorate

This alignment provides a functional bridge between Ghana's national framework and the European context in which the H2VE project operates. It enables Ghanaian institutions and learners to participate fully in the hydrogen training ecosystem being developed, ensuring that courses can be designed, assessed, and recognized consistently across all partner countries. This is particularly important for ensuring quality assurance, validating learning outcomes, and facilitating future mobility and collaboration between African and European training systems in the hydrogen sector.

3.3 Comparative Alignment of National Frameworks

The diverse NQFs of the H2VE partner countries converge under a shared commitment to outcome-based education and international comparability. While each country maintains its own system of classification and quality assurance, the structural alignment to the EQF allows these systems to interoperate effectively within the project.

All five EU partners (Germany, Greece, Italy, Latvia, and Poland) have formally referenced their NQFs to the EQF. This enables direct mapping of qualification levels, from basic vocational training at EQF Level 3 to doctoral-level qualifications at Level 8. These countries differ in the administrative and regulatory details of how their frameworks are implemented, yet the alignment process ensures that learning outcomes across their systems can be positioned within a unified European reference structure. This coherence is critical for the cross-border recognition of hydrogen-related competences, especially in the context of the growing Hydrogen Valleys initiative and the need for interoperable skills standards.

Ghana, though not formally referenced to the EQF, participates in the H2VE project through a well-structured ten-level national framework. As established in the previous subsection, the GNQF is structurally compatible with the EQF and has been functionally aligned within the project based on learning outcomes and qualification types. This alignment enables Ghanaian institutions to meaningfully engage with the training content and contribute to a unified educational approach. Within this shared framework, Ghana's participation reinforces the project's inclusive, cross-continental dimension and supports the broader goal of creating a globally interoperable hydrogen skills ecosystem.

The comparative analysis conducted in this section reveals the following shared features across all frameworks:

- All frameworks define qualifications by learning outcomes rather than duration or type of institution.

- Each system offers a complete vertical progression pathway, from entry-level to advanced academic or professional qualifications.
- Vocational education and training occupy a central role between EQF Levels 3 and 5 in all countries, making this range a key target for hydrogen-related skills development.
- Levels 6 to 8 are commonly used for higher education and advanced sector-specific knowledge, where innovation and research play a greater role.

This convergence ensures that the H2VE curriculum can be designed and modularized to fit within national systems while remaining interoperable at the European level. For learners, it guarantees that acquired competences can be recognized and validated regardless of country of origin. For institutions, it supports flexible integration of training content into existing pathways. For industry, it builds a transparent, transferable skills framework that supports workforce mobility and standardization across borders.

The resulting qualification alignment not only enhances the technical credibility of D5.1 but also reinforces the long-term goal of establishing hydrogen training excellence as a recognized and portable credential across the European and African contexts.

3.4 EQF-Based Curriculum Structuring

The classification of educational content according to EQF levels serves as a foundational strategy for structuring the H2VE curriculum. This approach ensures that each learning module is aligned with the learner's expected level of competence, and that training materials are pedagogically coherent, appropriately complex, and transferable across different national systems. The EQF functions not only as a referencing framework for qualifications but also as a design tool that enables modular, flexible learning tailored to the needs of diverse target groups.

The H2VE curriculum will address learners spanning EQF Levels 3 to 8, in accordance with the project's target profiles, from vocational trainees and skilled technicians to engineers, trainers, and researchers. The planned structure allows key subject areas to be addressed at varying levels of complexity depending on the learner's background and training objective. For instance, introductory content in hydrogen fundamentals and basic safety may be positioned at EQF Levels 3 or 4, while more advanced topics such as electrochemical modelling, system integration, or regulatory frameworks may align with Levels 6 to 8. This allows the same theme to be explored at multiple depths and ensures inclusivity across the training spectrum.

To support this flexibility, the curriculum is designed with a modular architecture. Each unit can function independently or be grouped into broader learning pathways. Modules are defined using

the EQF's standard descriptors (knowledge, skills, and autonomy/responsibility) to ensure consistency in the formulation of learning outcomes and to facilitate cross-referencing with national qualifications frameworks. This approach enables integration into both formal and non-formal education systems, supports the recognition of prior learning (RPL), and lays the groundwork for the use of micro-credentials or other validation mechanisms.

Importantly, this structuring method reinforces the project's broader goals of learner mobility and cross-border qualification transparency. By mapping content to EQF levels and ensuring compatibility with national frameworks, training materials become easier to adopt, adapt, and recognize across Europe and internationally. In the case of non-EU partners such as Ghana, the functional alignment between the GNQF and EQF ensures the consistency and comparability of the curriculum without compromising national relevance.

The EQF-based structure outlined in this section provides the basis for the organisation of the thematic training content, which is detailed in the next section. It also establishes the framework that will guide the development of the trainer curriculum (D5.2), the training workshops and webinar series (D5.3), and the student curriculum guide (D5.4), while remaining open to refinement based on partner input and national implementation needs.

4. Thematic Structure of Educational Content

The development of high-quality educational training material requires a well-defined and coherent thematic framework. Given the cross-sectoral and multidisciplinary nature of Hydrogen Valleys, it is essential that the training content reflects the full complexity of the hydrogen ecosystem. This includes all stages of the value chain (production, storage, distribution, utilization), as well as considerations related to safety, regulation, sustainability, and integration with renewable and smart energy systems.

The thematic structure proposed in this section serves as a foundational reference for the modular design of learning units. This model is intended to support adaptation across varying institutional contexts, qualification levels, and learner profiles. It ensures compatibility with the EQF and promotes the implementation in both formal and non-formal learning settings.

Each thematic section consolidates a cluster of courses that correspond to specific knowledge domains and technical competences within the hydrogen field. The structure enables comprehensive coverage of core and emerging topics, from introductory concepts to specialized applications. It has been designed to accommodate the learning trajectories of vocational learners, to inform the instructional strategies of trainers, and to respond to the upskilling needs of professionals already active in the sector.

The model also promotes pedagogical coherence, enabling progression in complexity and depth across EQF levels. While modular in design, it maintains continuity across subject areas and alignment with overarching learning outcomes. It incorporates feedback from project partners and integrates several additional topical areas identified as essential to the evolving hydrogen sector, such as regulatory frameworks, certification systems, equipment life cycle analysis, comparative efficiency evaluation, maintenance practices, and smart systems. These enhancements ensure that the training materials remain industry-relevant, forward-looking, and pedagogically robust.

The thematic structure outlined below defines the educational pillars of the H2VE training curriculum. Each section corresponds directly to the final modular architecture, ensuring consistency across all learning units and alignment with the headings in this section.

1. Hydrogen Basics & Principles
2. Reaction Mechanisms & Thermochemistry
3. Electrochemical Processes
4. Hydrogen Storage & Distribution
5. Hydrogen Production Technologies
6. Hydrogen Combustion for Heat & Power
7. Fuel Cell Technologies & Applications
8. Hydrogen in Transportation & Mobility
9. Chemical Hydrogen Carriers & Conversion Pathways
10. Hydrogen Industrial Applications
11. Hydrogen for Buildings & Energy Systems
12. Hybrid Renewable–Hydrogen Energy Systems
13. Hydrogen Safety & Hazard Prevention
14. Policy, Standards & Regulatory Frameworks
15. Hydrogen, Sustainability & Circularity
16. H₂ Equipment & Exercises
17. Technical & Economic Case Studies in Hydrogen Ecosystems

The following subsections provide an overview of each thematic area along with a corresponding table of course titles. Together, they form the structural backbone for the educational training material to be developed under WP5.

4.1 Hydrogen Basics & Principles

This section introduces learners to the fundamental scientific and technological concepts that underpin hydrogen systems, including physical properties, thermodynamic behaviour, and the structure of the hydrogen value chain. It provides the essential grounding for all subsequent topics.

1. Hydrogen History and Roadmap
2. Properties of Hydrogen
3. Properties of Pure Substances
4. Properties of Gases and Gaseous Mixtures
5. Thermodynamic Effects in H₂ Systems (Joule-Thomson & Adiabatic Compression)
6. Hydrogen Value Chain

4.2 Reaction Mechanisms & Thermochemistry

Covers the chemical and thermodynamic principles governing hydrogen reactions, including chemical equilibrium, energy transformations, and kinetics. It establishes the foundational knowledge needed to understand the behaviour of hydrogen in energy conversion systems.

7. Chemistry of H₂ Reactions
8. Chemical Reactions and Thermochemistry
9. Chemical Equilibrium
10. Reaction Kinetics

4.3 Electrochemical Processes

Explores the core principles and system configurations of electrolysis and fuel cells. Learners are introduced to galvanic and electrolytic cells, electrochemical modelling, and the operational features of various electrochemical technologies.

11. Basic Electrochemical Principles
12. Galvanic and Electrolytic Cells
13. Fuel Cell Operation and Types
14. Types of Water Electrolysis
15. Modelling of Fuel Cells
16. Modelling of Water Electrolysis

4.4 Hydrogen Storage & Distribution

Learners are introduced to the methods, challenges, and technologies associated with storing and distributing hydrogen in its various physical and chemical forms. Topics include compression, liquefaction, solid-state storage, blending, and infrastructure compatibility.

17. Compression of Hydrogen
18. Liquefaction of Hydrogen
19. Gaseous Hydrogen Storage
20. Liquid Hydrogen Storage
21. Hydrogen Storage in Solid Materials
22. Storage in Chemical Carriers
23. Other Hydrogen Storage Methods

- 24. Hydrogen Blending/Deblending
- 25. Compatibility of Materials
- 26. Hydrogen Transportation/Conditioning

4.5 Hydrogen Production Technologies

This section presents an overview of hydrogen production processes, including electrochemical, thermochemical, biological, and renewable-based methods. It addresses key integration challenges and compares different technologies based on performance and application.

- 27. Overview of H₂ Production Methods
- 28. Resources – Biomass – Biofuels – Bioenergy
- 29. Thermochemical Hydrogen Production
- 30. Alkaline Electrolysis
- 31. PEM Electrolysis
- 32. SOEC
- 33. AEM Electrolysis
- 34. Water Treatment for Electrolysis Units
- 35. Integration of Water Electrolysis Systems
- 36. Other Hydrogen Production Methods
- 37. Comparison of Electrolysis Technologies

4.6 Hydrogen Combustion for Heat & Power

Focuses on the application of hydrogen in combustion systems, including its behaviour in flames, emissions control, and use in gas turbines and combined cycles for thermal and electrical energy generation.

- 38. Combustion of Fuels
- 39. Types and Properties of Flames
- 40. Emission Formation and Pollution Control
- 41. Combustion of Hydrogen
- 42. H₂ Gas Turbines
- 43. H₂ in Combined Steam/Gas Cycles

4.7 Fuel Cell Technologies & Applications

Provides an in-depth examination of fuel cell types, including design, materials, and operational principles. Comparative analysis supports understanding of their respective roles across mobility, stationary, and portable applications.

- 44. Design and Materials for Fuel Cells
- 45. LT-PEMFCs
- 46. DMFCs
- 47. HT-PEMFCs
- 48. PAFCs
- 49. SOFCs
- 50. Comparison of Fuel Cells Technologies

4.8 Hydrogen in Transportation & Mobility

Presents hydrogen-powered transport applications, from internal combustion and fuel cell vehicles to infrastructure components such as refuelling stations. Includes coverage of road, rail, maritime, and aviation applications solutions.

- 51. H₂-to-Mobility
- 52. H₂ ICEs
- 53. H₂ Fuel Cell Electrical Vehicles (Cars, Busses, Trucks, Bicycles, Drones etc)
- 54. H₂ in Trains, Ships and Airplanes
- 55. Hydrogen Refuelling Stations (HRSs)

4.9 Chemical Hydrogen Carriers & Conversion Pathways

Covers the transformation of hydrogen into alternative chemical carriers such as ammonia, methanol, and synthetic methane. Learners explore how these carriers support energy storage, transport, and integration with existing fuel systems.

- 56. H₂-to-Fuel
- 57. Methanation
- 58. Methanol Production and Utilization
- 59. Ammonia Production and Utilization
- 60. Syngas and Methane Production and Utilization

- 61. Dimethyl ether, LOHC & Other Chemical Carriers
- 62. Production and Utilization of Green Fuels

4.10 Hydrogen Industrial Applications

Explores hydrogen's role in key industrial sectors including steel, chemical, refinery, and food processing. Emphasis is placed on decarbonisation, process integration, and hydrogen's contribution to sectoral energy transitions.

- 63. H₂-to-Industry
- 64. Refineries
- 65. Hydrogen Power & Co-Generation Plants
- 66. Steel Industry
- 67. Chemical Industry
- 68. Food Industry

4.11 Hydrogen for Buildings & Energy Systems

Introduces the application of hydrogen technologies in the built environment for heating, electricity supply, and combined heat and power. Includes discussion of energy management, self-sufficiency, and cost considerations.

- 69. H₂-to-Buildings
- 70. Heating
- 71. Electricity
- 72. Cogeneration of Heat & Power
- 73. Energy Management, Self-Sufficiency & Costs

4.12 Hybrid Renewable–Hydrogen Energy Systems

Explores the integration of hydrogen with renewable energy sources in hybrid systems. Topics include plant configurations, control strategies, and digital solutions that support decentralised and flexible energy networks.

- 74. Renewable Energy Sources
- 75. Hybrid H₂– Renewable Energy Plants
- 76. Energy Management & Control in Hybrid Hydrogen Systems
- 77. Smart Systems and Digital Integration in Hydrogen Energy Systems

4.13 Hydrogen Safety & Hazard Prevention

Provides comprehensive training in hydrogen safety, including physical and chemical hazards, risk assessment, emergency response, and maintenance protocols across the hydrogen infrastructure.

- 78. Hydrogen Properties Related to Safety
- 79. History of Hydrogen Accidents
- 80. Physical Hazards
- 81. Chemical Hazards
- 82. Safe Handling of Gaseous H₂
- 83. Safe Handling of Liquid H₂
- 84. Safety Equipment, Measures and Rules
- 85. Safety Related to Material Selection and Use
- 86. Prevention
- 87. Detection
- 88. Reaction
- 89. Safety and Maintenance in Electrolysis Plants
- 90. Safety and Maintenance in Fuel Cell Plants
- 91. Safety and Maintenance in H₂ Mobility
- 92. Safety and Maintenance in HRSS
- 93. Safety Assessment in Industrial and Building Applications
- 94. Maintenance Planning and Procedures for Hydrogen Systems

4.14 Policy, Standards & Regulatory Frameworks

Presents key policy instruments, regulatory frameworks, and standardisation systems at both EU and national levels. Topics include certification schemes, safety regulations, and skills recognition mechanisms relevant to hydrogen deployment.

- 95. EU and National Hydrogen Legislation
- 96. Certification Schemes and Skills Recognition
- 97. Regulatory Frameworks in Hydrogen Valleys
- 98. Standards for Safety, Transport, and Storage

4.15 Hydrogen, Sustainability & Circularity

Addresses sustainability and circularity in hydrogen technologies, including strategies for component reuse, materials recovery, and end-of-life management. Learners are introduced to design for disassembly and regulatory approaches to recycling.

- 99. Sustainability Criteria & Supply Chain
- 100. Life Cycle Thinking & End-of-life strategies (R-strategies)
- 101. Circularity Engineering, Modularity & Design for Disassembly
- 102. Secondary use and service life extension
- 103. Recycling of components (stacks, tanks, etc.)
- 104. Material consumption & cycles (platinum, nickel, etc.)
- 105. Recycling processes
- 106. Policy and Standards for Circular Hydrogen Infrastructure

4.16 Hydrogen Equipment & Exercises

This section supports experiential learning through hands-on activities and familiarisation with hydrogen-related equipment. Includes applied exercises in measurement, thermodynamics, and system analysis.

- 107. H₂ Equipment
- 108. Life Cycle Assessment of Hydrogen Equipment & Use-Cases
- 109. Exercise 1 (Experiment on lab equipment)
- 110. Exercise 2 (Thermodynamic exercises)
- 111. Exercise 3 (Multiple Choice Questions)

4.17 Technical & Economic Case Studies in Hydrogen Ecosystems

Presents real-world hydrogen projects through detailed case studies, techno-economic analyses, and cross-sector integration scenarios. Learners examine investment dynamics, cost structures, and market deployment strategies.

- 112. Hydrogen Valley Case Studies
- 113. CAPEX and OPEX in Hydrogen Projects
- 114. Barriers to Deployment and Market Readiness
- 115. Comparative Assessment of Technology Options

- 116. Financial Modelling Tools and Frameworks
- 117. Stakeholder and Value Chain Dynamics
- 118. Lessons Learned from International Demonstrators

The course lists as presented in this section, are indicative. They serve as a working framework to support curriculum planning and content development under WP5. The final structure of the training modules, including definitive course selection and learner targeting, will be validated through piloting and formally established in Deliverable D5.5.

5. Format and Delivery of Educational Material

The effectiveness of a VET curriculum depends not only on the relevance of its content but also on the clarity of its structure and the flexibility of its delivery. In the context of the H2VE project, where training is intended to serve a diverse range of learners across different educational levels and institutional environments, the format and delivery of the educational material must be both standardized and adaptable.

By establishing a common format and a flexible delivery framework, the H2VE curriculum ensures that learners receive a coherent educational experience regardless of location, institutional setting, or delivery methods. At the same time, it enables trainers and providers to adapt the material to their own contexts while preserving alignment with the EQF and NQFs.

5.1 Learning Unit Structure and Pedagogical Approach

The H2VE training content is structured into modular learning units, each of which is designed to address a specific thematic topic within the hydrogen sector while targeting one or more qualification levels, as defined by the EQF. This modularity ensures pedagogical coherence, facilitates adaptability across partner countries, and supports progressive learning pathways for various target groups identified in Section 2.

Each learning unit is designed as an autonomous, outcome-driven package of instruction. It can be delivered independently or combined with other units to form comprehensive training programs, areas of specialization, or cross-sectoral qualifications. The structure is adapted to both formal and non-formal learning settings and is designed for potential certification at national or transnational levels.

In order to enhance uniformity and quality, each learning section will follow a common teaching pattern. The proposed structure consists of the following key elements:

Unit Title and Scope

Each course will include a concise, descriptive title accompanied by a short summary defining its scope and relevance. This introduction will situate the content within the broader H2VE

curriculum and will provide guidance on the required background knowledge or recommended prerequisite courses.

Target EQF Level(s)

Each course will be mapped to one or more EQF levels, depending on the depth and complexity of the subject. This mapping will ensure that the content is appropriate for the learner's intellectual, technical, and independent working capabilities. For example, basic safety training may correspond to EQF Level 3, while system design and modelling may target EQF Levels 6 or 7.

Intended Learning Outcomes

Clearly formulated statements detailing what learners are expected to achieve by the end of the unit. These outcomes are expressed using EQF-aligned descriptors in the areas of:

- Knowledge (factual and theoretical understanding)
- Skills (intellectual and practical abilities)
- Autonomy and Responsibility (the extent to which the learner can act independently, apply skills without supervision, and be accountable for their performance.)

Learning outcomes will be written in observable and measurable terms, such as “Explain,” “Apply,” “Analyze,” or “Evaluate,” enabling consistent assessment and potential for formal recognition.

Core Content Overview

A breakdown of the thematic material will be provided, structured into subtopics or learning blocks. It will outline both the theoretical and applied aspects of each subject, with an emphasis on sector relevance, technological updates, and real-world applications.

Learning Activities and Methodologies

Each course will include recommendations for engaging learning experiences that promote active participation, critical thinking, and practical application. Examples include:

- Interactive lectures and guided discussions,
- Problem-based learning scenarios,
- Simulation tools or virtual labs,
- Case study analysis (e.g., from Hydrogen Valleys or industry),

- Group work and project-based tasks,
- Hands-on technical demonstrations (where applicable).

These methodologies are intended to be adaptable to classroom-based, online and hybrid environments.

Assessment and Evaluation

The structure will include suggested assessment methods for both formative and summative purposes. These may include quizzes, short-answer questions, or practical exercises. Assessments will be aligned with the intended learning outcomes and will serve as the basis for validation, feedback, and eventual recognition.

Estimated Learning Time

Each unit will include an indicative workload, typically expressed in hours. This estimate will account for both direct instruction and independent learning and may inform future alignment with ECVET/ECTS systems or micro-credentialing initiatives.

Support Materials and Resources

Each module will be accompanied by a comprehensive list of recommended resources, such as readings, videos, datasets, technical manuals, and links to external platforms. Where appropriate, supplementary tools such as glossaries and FAQ sections will be included to support learner understanding and ease of use.

The pedagogical model guiding this structure will be grounded in learner-centered, competence-based, and inclusive principles. Content will be designed to accommodate a variety of learning styles and learner profiles, particularly those engaged in vocational and professional training. Particular attention will be given to accessibility, incorporating strategies such as plain language, visual aids, and adaptive technologies.

Furthermore, the modular nature of the curriculum will support adaptability across multiple levels of complexity, allowing content to be designed for both foundational and advanced learning within a given thematic area (e.g., EQF Level 4 and EQF Level 6 modules on hydrogen safety). It will also enable horizontal integration, allowing training modules from different domains (such as production, safety, and transport) to be combined as needed. This flexibility ensures the curriculum can be implemented in diverse contexts, including formal education programmes, professional upskilling initiatives, and interdisciplinary training environments.

Taken together, the learning unit structure defined in this deliverable offers a robust and adaptable framework for the design, delivery, and future validation of hydrogen-related training content. It ensures that all modules are pedagogically coherent, systematically organised, and compatible with national systems and international standards, supporting the broader objectives of the H2VE project and the development of skilled professionals for the hydrogen economy.

5.2 Delivery Methods and Learning Environments

The delivery of H2VE training content will be designed to accommodate a range of educational environments, learner profiles, and institutional contexts. Rather than prescribing a fixed model, the approach will prioritize adaptability and inclusivity, reflecting the diversity of the Hydrogen Valleys ecosystem and the varying structures of national vocational systems.

To ensure broad accessibility, training materials will be available in the regional languages of the project partners. Delivery formats will follow a blended learning approach, combining in-person sessions with online modules hosted on the project's digital platform. This approach will facilitate engagement through interactive digital tools while preserving the benefits of face-to-face instruction, particularly for technical or hands-on subjects.

A variety of pedagogical techniques will be used across modules to support active learning and practical application. These may include guided discussions, case studies, scenario-based exercises, virtual simulations, and group project work. Content will be structured to accommodate different learning styles and levels of prior knowledge, enabling both foundational instruction and deeper technical training where appropriate.

The modular format will allow individual courses to be delivered independently or combined to support institutional or regional needs. This flexibility will facilitate implementation across formal education systems, professional training programmes, and cross-sectoral initiatives without requiring structural changes to existing national qualifications frameworks.

In addition, selected modules will address transversal competences, such as communication, teamwork, and problem-solving. These skills are essential for working effectively in interdisciplinary and multi-stakeholder environments, such as those found in hydrogen production, distribution, and integration systems.

While the core delivery strategy will focus on blended formats, the project remains open to incorporating innovative tools, such as virtual or augmented reality, in future iterations, where such technologies can add pedagogical value, particularly in simulation-based training.

5.3 Integration with National Training Systems

The curriculum developed under the project is designed to serve as a flexible framework that can be aligned with existing national education and training structures across all partner countries. Rather than acting as a fixed or uniform course package, the content will be adaptable to institutional and regulatory contexts, supporting implementation in formal and non-formal settings.

Each module will be capable of integration into existing programmes at various qualification levels. In EU member states, this may include referencing units through national qualifications frameworks or sectoral skills councils. In Ghana, alignment will follow the GNQF and national regulatory bodies such as CTNET. Institutions may also choose to incorporate modules into recognized VET curricula, higher education pathways, or continuing professional development offers.

While H2VE does not confer certification itself, the structure of the content supports potential validation through national authorities. Where applicable, partners are encouraged to identify the most relevant integration routes, such as qualification registers, local credit systems, or occupational standards.

This approach balances European-level consistency with national-level autonomy, enabling each partner to implement the training according to its institutional mandate, regulatory environment, and strategic workforce needs.

5.4 Supporting Tools and Documentation

The effective implementation of the H2VE curriculum will be reinforced by a set of structured tools designed to support content delivery, learner engagement, and institutional alignment. These resources will ensure that training modules can be applied consistently across diverse educational and national contexts.

Trainer guides will accompany each learning unit, offering practical suggestions for delivery, adaptation, and alignment with intended learning outcomes. Learner-oriented materials such as glossaries, concept summaries, or introductory handbooks will support independent learning and comprehension.

To facilitate evaluation, templates for quizzes, applied tasks, and rubrics will be developed, allowing both formative and summative assessments to be adapted to local requirements.

Mapping sheets will also be provided to help institutions position modules within national qualifications frameworks or training programmes.

General guidance will support the use of H2VE content in recognition processes, including micro-credentialing or RPL, where appropriate. In addition, targeted dissemination materials, such as visual summaries or explainer slides, may be created to assist partners in communicating the training offer to local stakeholders.

All tools will follow principles of accessibility, modularity, and transferability, using open formats and multilingual templates where feasible. They will be essential in ensuring that the curriculum is not only well designed but also readily usable and adaptable across partner contexts.

6. Implementation, Validation and Quality Assurance

The successful development and future deployment of the H2VE training curriculum relies not only on sound pedagogical design but also on an integrated process of validation, testing, and quality assurance. As outlined in the Grant Agreement, this process is not confined to the initial drafting phase but is embedded throughout the project lifecycle to ensure the continuous refinement, relevance, and sustainability of the educational material.

Following the submission of D5.1, which specifies the curriculum structure, EQF alignment, and delivery approach, the training content will enter a structured validation process. This includes internal partner review, consultation with external stakeholders such as VET providers and industry actors, and testing through pilot activities under WP8. These steps will help ensure that the training materials are not only technically sound and pedagogically robust, but also applicable across diverse institutional, regional, and national contexts.

The implementation and validation phases are guided by the overall quality assurance strategy of WP10, which defines the procedures, tools, and benchmarks necessary to monitor the project's performance and support evidence-based improvements. Quality assurance mechanisms will be applied continuously, both through internal peer reviews and external evaluations, enabling the curriculum to remain adaptable to feedback and responsive to evolving hydrogen sector needs.

This section outlines the multi-layered strategy for validating the H2VE curriculum and preparing it for effective deployment. It describes how feedback from partners, educators, learners, and stakeholders will inform refinements, how pilot activities will serve as testing grounds for real-world application, and how quality will be maintained and improved across all phases of development and delivery.

6.1 Curriculum Validation Process

The validation of the H2VE curriculum is conceived as a continuous, multi-stage process that extends throughout the lifecycle of the project. While the curriculum structure and learning unit specification have now been finalised, their effective implementation and long-term relevance depend on sustained consultation, feedback, and quality assurance.

The validation process is embedded within a broader ecosystem of internal review, external engagement, pilot testing, and structured evaluation, as outlined in Work Packages 5, 8, 10, and 11. This ensures that the curriculum is not only pedagogically coherent and technically accurate but also adaptable across different national systems, educational contexts, and sectoral needs.

The first phase of validation focuses on internal review among the project partners involved in WP5. The curriculum was examined for its alignment with national qualification frameworks, consistency with EQF level descriptors, and adaptability to institutional priorities. This review was coordinated by the WP5 leader and supported by contributions from relevant partners. Attention was placed on the modular structure of the curriculum, the clarity and measurability of learning outcomes, and the potential for integration into formal and non-formal training pathways.

Moving forward, the validation process will be further expanded through targeted engagement with VET providers, industry representatives, and regional stakeholders, as described later in Section 6.2. These external actors will contribute practical insights that ensure the curriculum meets real-world training demands and can be adopted in a range of implementation environments. Particular focus will be placed on verifying the technical accuracy, labour market relevance, and pedagogical usability of the training content.

This repeating validation process will continue during the pilot training activities under WP8. Feedback will be collected from trainers, learners, and institutional staff participating in these activities. Their responses will inform further improvements to the curriculum structure, delivery methods, and support materials. Data collection instruments, such as satisfaction surveys and structured interviews, will support this process.

Quality assurance will be overseen by WP10 through the application of the Quality and Evaluation Strategy (QES), the Risk Management Plan, and tools such as the Self-Assessment Tool (SAT). These will support ongoing monitoring of curriculum quality, performance, and alignment with both institutional and regional development goals. In parallel, the Skills Anticipation Wave (SAW) ([Crisonà, 2021](#)) methodology will be used to identify emerging training needs in the hydrogen sector, providing guidance for future updates and refinements.

The validation process will remain active throughout the implementation of the project, extending beyond the submission of D5.5. This ensures that the curriculum retains its adaptability and relevance as the hydrogen sector evolves. Regional coordinators and partners involved in the establishment of the H2VE CoVEs will facilitate local feedback loops, enabling continuous alignment of the training offer with regional labour markets and innovation ecosystems.

Through this comprehensive and dynamic validation strategy, the H2VE curriculum is positioned not as a static deliverable but as a living framework, designed for adaptability, committed to quality, and responsive to the needs of both learners and the wider hydrogen economy.

6.2 Engagement with VET Providers and Industry Stakeholders

Following the internal validation process, the H2VE curriculum will undergo structured consultation with external stakeholders, most notably, VET providers and industry representatives. These actors are essential to ensuring the curriculum's applicability, technical relevance, and long-term impact across the hydrogen sector.

VET institutions represent both key implementation partners and sources of pedagogical expertise. Their involvement is crucial for evaluating how the curriculum can be integrated into national education systems, training offers, and institutional workflows. At the same time, companies and sectoral bodies operating across the hydrogen value chain, offer critical insight into current and emerging skill needs, workplace practices, and qualification requirements.

The engagement process will be initiated and coordinated by project partners responsible for regional outreach, curriculum development, and CoVE formation.

Activities will include:

- **Targeted consultation sessions** with VET institutions, where the structure, content, and learning outcomes of the training material will be discussed in the context of national curricula, training standards, and regulatory frameworks.
- **Collaborative focus groups** involving trainers, curriculum designers, and institutional staff to assess the usability of the proposed learning unit format and delivery methods across different education levels (EQF 3–8).
- **Technical validation meetings** with hydrogen sector stakeholders to confirm the relevance and accuracy of the content, with attention to sectoral specializations such as production, storage, transport, mobility, and safety.
- **Liaison with skills councils and certification bodies**, where applicable, to explore options for national accreditation, modular certification, or micro-credentialing based on the proposed training structure.

This process is not limited to the review of the curriculum as a whole but extends to the thematic sections and individual training units. Stakeholders will be invited to comment on the alignment

of learning outcomes with workplace requirements, the appropriateness of EQF level assignments, and the adaptability of the material to hybrid, digital, or work-based learning settings.

Input collected through these consultations will inform the adaptation of training content prior to pilot implementation and contribute directly to the finalization of D5.5. Moreover, stakeholder engagement will support the creation of a responsive feedback loop, enabling future iterations of the curriculum to evolve in line with labor market dynamics, technological innovation, and pedagogical advances.

Through this coordinated engagement strategy, H2VE ensures that the curriculum is not only educationally robust but also professionally relevant and regionally embedded. This will facilitate widespread adoption, increase stakeholder ownership, and enhance the impact of the curriculum across formal VET programmes, professional development initiatives, and industry-led training schemes.

6.3 Pilot Implementation Strategy and Feedback Mechanisms

The implementation of pilot activities represents a pivotal phase in validating the H2VE curriculum's functionality, relevance, and adaptability across diverse educational and sectoral contexts. It marks the transition from design and stakeholder consultation to practical deployment, enabling the consortium to test the educational material under real-world conditions and gather feedback that will inform ongoing refinement.

Pilot activities will be primarily carried out under WP8, which includes dedicated actions for the training of trainers (T8.1), student engagement through summer schools (T8.2), SME-oriented training (T8.3), school-level hydrogen education (T8.4), and skills development workshops (T8.5). Each of these training formats will be used to evaluate specific aspects of the curriculum, its thematic coherence, level appropriateness, delivery methodology, and responsiveness to learner needs.

The strategy for pilot implementation will involve the following coordinated steps:

1. Selection of Pilot Modules

A representative set of learning units, spanning multiple EQF levels, thematic sections, and learner types, will be selected for piloting across participating institutions. These modules will

include both foundational and advanced content, allowing for the testing of modular progression and cross-thematic integration.

2. Training Delivery in Real Contexts

The selected units will be delivered by trainers from VET institutions, universities, or regional CoVEs, using the delivery methods defined in the curriculum framework. Sessions may include in-person, hybrid, and online components, depending on the institutional and regional context.

3. Feedback Collection from Learners and Trainers

Structured feedback mechanisms will be deployed during and after the training activities. These will include satisfaction surveys, learner self-assessment tools, trainer evaluation forms, and optional interviews or focus groups. Feedback will address content relevance, instructional clarity, learning outcomes, workload, and overall learning experience.

4. Monitoring and Data Collection

Quantitative and qualitative indicators will be used to measure performance. These may include participation rates, completion rates, competency gains, and user satisfaction. All pilot implementations will be documented, with data aggregated across countries and learner groups.

5. Iterative Adaptation and Integration

Based on the evaluation findings, adjustments to content, level allocation, delivery methods, and support materials will be proposed. While Deliverables D5.2, D5.3, D5.4, and D5.5 are scheduled for early submission, they represent initial consolidated versions of the curriculum, trainer guide, and student learning framework. These will serve as foundational references for implementation, but not as static outputs.

The pilot activities conducted under WP8 will serve as a crucial validation stage, allowing the curriculum and associated resources to be tested across diverse contexts. Insights gathered during implementation will guide the continuous enhancement of course content, instructional methods, and supporting tools, ensuring responsiveness to learner needs, institutional realities, and sectoral developments.

Each regional CoVE will also have the opportunity to test and tailor curriculum components to its own priorities, fostering contextual integration while maintaining coherence with the overarching EQF-based framework.

Crucially, the pilot phase is not a closing phase of development but a key mechanism in an ongoing cycle of refinement and quality improvement. Feedback collected will inform revisions to all core training resources - D5.2 through D5.5 - ensuring that both educator capacity-building and learner experience evolve in step with real-world application.

6.4 Continuous Improvement and Quality Assurance

The development of high-quality educational material within the H2VE project does not conclude with the submission of D5.5. Rather, the curriculum will remain a living framework, subject to continuous refinement throughout the project's duration. This approach acknowledges that training needs, pedagogical methods, and sectoral demands will continue to evolve alongside technological advances and the maturing of hydrogen economy.

While D5.5 represents the formalization of the initial curriculum for secondary and tertiary students, it is expected that the materials (once deployed through pilot activities and implemented in various VET contexts), will require iterative adjustment. These refinements may include the recalibration of EQF level allocations, adaptation of course content to better reflect real-world conditions, enhancement of teaching resources, and the integration of new delivery tools or methods.

The feedback generated during the pilot phase, combined with ongoing consultation with VET providers and industry stakeholders, will serve as the primary inputs for this process. In addition, collaboration with the WP10 will ensure that curriculum improvement aligns with the broader project quality framework, while remaining within the scope of WP5's deliverables.

To facilitate this, WP5 partners will establish internal processes to:

- Review partner and stakeholder feedback on a rolling basis
- Track regional variations and implementation challenges across CoVEs
- Evaluate the continued pedagogical soundness of the learning units
- Propose concrete adjustments to the curriculum where needed

Where substantial updates are required, these will be documented and shared across the consortium through established project communication channels. While WP5 concludes in the early phase of the project, the foundations it sets will enable WP8 and WP10 to carry forward the refinement and scaling of the curriculum. This ensures that the shared vision of a responsive, high-quality hydrogen training offer remains central throughout the project's lifetime.

The integration of continuous improvement processes into the broader H2VE framework establishes a forward-looking mechanism for sustaining the quality, relevance, and adaptability of the curriculum. By systematically incorporating insights from validation, piloting, and stakeholder feedback, the training content can remain responsive to technological advancements, pedagogical developments, and evolving regional contexts. This iterative approach strengthens the long-term applicability of the curriculum and supports its progressive integration within institutional frameworks across the H2VE Centres of Vocational Excellence and beyond.

7. Conclusions

Deliverable 5.1 defines the educational and pedagogical framework upon which the H2VE training curriculum will be developed, structured, and validated. It marks a foundational step toward the delivery of a harmonised, flexible, and modular training offer that is aligned with European and national qualifications frameworks, sectoral skill demands, and institutional implementation realities.

Setting out a thematic model structured around EQF levels and learner profiles, D5.1 ensures that the training material can be adapted across diverse contexts. These include vocational schools, higher education institutions, industry-led training programmes, and continuous professional development. The curriculum's design reflects both the complexity of the hydrogen value chain and the scientific knowledge required for its deployment within Hydrogen Valleys. Its modular architecture and alignment with learning outcomes ensure that the material remains transferable, stackable, and scalable.

The deliverable has further established the methodology for structuring learning units, defining their instructional format, and planning delivery across digital, hybrid, and physical learning environments. Through detailed mapping of the national qualifications frameworks of the partner countries and their alignment with the EQF, it ensures transparency and interoperability of the educational offer. This includes the functional compatibility of the Ghana National Qualifications Framework.

Importantly, D5.1 sets the stage for a multi-level validation strategy that integrates partner feedback, stakeholder consultation, and pilot training activities. The mechanisms for refinement, coordinated with WP8 and WP10, will ensure that the curriculum remains pedagogically sound, technically accurate, and regionally adaptable as it moves into the implementation phase. The continuous improvement model built into the process supports long-term quality and relevance.

As the first milestone in WP5, this deliverable does not represent a finalised curriculum. Instead, it provides an agile framework upon which D5.2 through D5.5 will build. It offers a robust and flexible foundation to guide the design of future training modules, support the professional development of trainers, and contribute to skills development for learners across the hydrogen sector. By aligning educational ambition with real-world needs, D5.1 advances the H2VE project's overarching goal of fostering vocational excellence and supporting Europe's transition toward a sustainable hydrogen economy.