DIGITAL FIRST

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Digital Tech as the First Language:

Informatics for Digital Natives

D4.5 Continuous and informal teacher training for informatics teachers

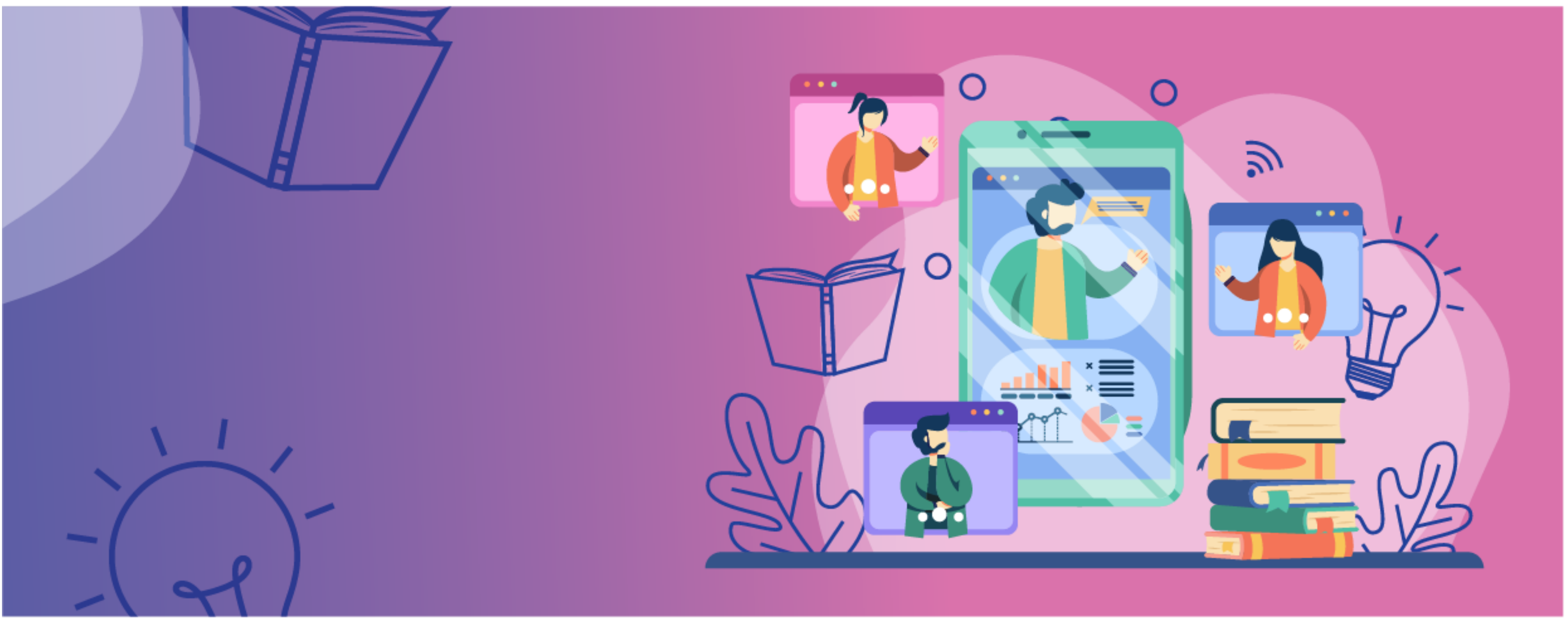

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TABLE OF CONTENTS

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LIST OF FIGURES

LIST OF TABLES

1 Introduction: Why This Framework Matters for Teachers

This deliverable is produced within the Digital First project, which brings together partners from ten countries — Bulgaria, Croatia, Cyprus, Finland, Greece, Italy, Lithuania, Portugal, Slovenia and Spain — whose education systems, teacher qualification pathways and continuous professional development (CPD) arrangements differ considerably. The purpose of this output is to provide a common, evidence-informed framework for the continuous and informal professional development of informatics teachers: one that each partner country can adapt to its own system while working towards the same competence goals. It defines what informatics teachers need to be able to do, where the main competence gaps lie, which resources and methods support professional growth, and how continuous and informal learning can be organised, recognised, and quality assured.

Informatics education in Europe is developing quickly, but not uniformly. Digital First deliverable *D2.2 Transnational research report: What and how we teach/learn in informatics and how happy we are with the results* shows that foundational areas such as Data and Information, Programming, and Privacy, Safety and Security are more widely covered than areas such as Human-Computer Interaction, Responsibility and Empowerment, and Modelling and Simulation (Digital First Consortium, 2024a). It also shows that teaching approaches vary: practical tasks, explanation, demonstration, individual work, teamwork, reflection, simulations, modelling, AI-supported methods and unplugged activities are present, but not equally developed across countries (Digital First Consortium, 2024a). These findings point to clear improvement directions: content alignment, interdisciplinary integration, critical problem-solving in practice, wider involvement of parents and external stakeholders, teachers' professional growth, student-centred transition, collaborative learning, multimodality, personalisation, assessment of learning progress, motivation and awareness, policy enhancement, teacher empowerment and inclusive environments. Many of these directions are directly relevant to continuous teacher training because they describe what teachers must be able to do, not only what students should learn.

Deliverable *D4.1 Informatics teacher education and training in the EU today – research* adds the teacher education perspective. It documents diverse qualification pathways across the ten partner countries, differences between primary, lower secondary and upper secondary contexts, uneven balance between informatics content and pedagogy, varied classroom-practice requirements, and fragmented CPD systems (Digital First Consortium, 2025a). It also shows that teachers often rely on self-study, peer networks, national programmes, MOOCs, conferences and European projects to stay current (Digital First Consortium, 2025a). The conclusion is clear: teachers need a coherent, flexible and evidence-informed CPD structure that recognises both formal and informal professional learning.

A further conceptual anchor of this framework is the functional approach developed throughout Digital First, which describes the seven functions that digital technology serves in teaching and learning. These functions provide a shared lens for translating competences into classroom practice: they clarify not only what informatics teachers should know, but how teachers and students purposefully use digital technology to reach learning goals. The competence architecture in D4.2 and D4.3 Competencies Maps is already articulated in relation to this functional approach, mapping subject-specific, pedagogical and transversal competences to the seven functions (Digital First Consortium, 2024b, 2025b). D4.5 builds directly on that mapping: it associates the proposed CPD themes with the same functions, so that each area of professional growth can be linked to a concrete function of digital technology in practice, and to the types of continuous and informal learning that support its development. In this way, teachers can move from an abstract list of competences towards a functional understanding of how they and their students meaningfully employ digital technology in the classroom.

The core message for teachers is simple: professional growth in informatics education is not only about learning the newest tool. It is about connecting robust informatics concepts with classroom practice, student diversity, ethical responsibility, emerging technologies and evidence of learning.

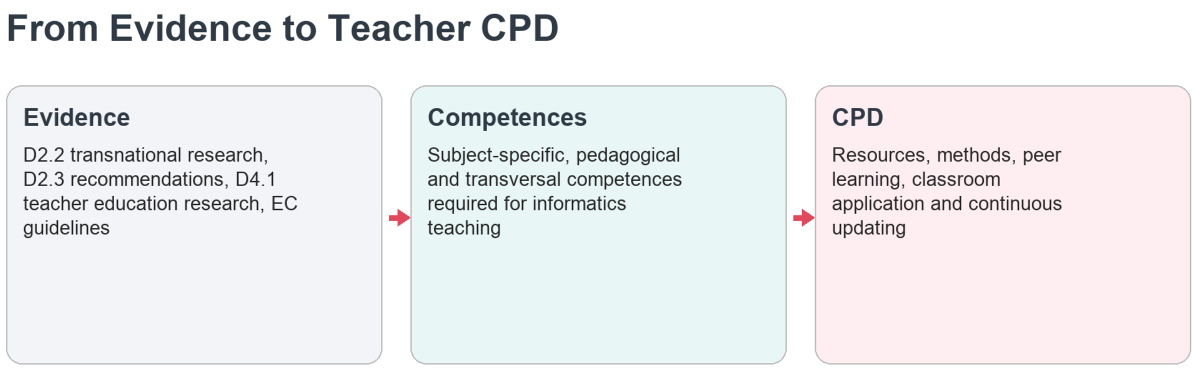

Figure 1. Evidence base and logic of the D4.5 teacher-oriented framework.

Table 1. Main evidence sources used in this deliverable.

Source	What it contributes to D4.5
D2.2 Research methodology	Shows what is currently taught, how informatics is taught and where coverage/methods remain uneven across countries and levels.
D2.3 Transnational research report: What and how we teach/learn in informatics and how happy we are with the results	Defines improvement directions: content alignment, interdisciplinarity, problem-solving, student-centred methods, collaboration, assessment, empowerment and inclusion.
D4.1 Informatics teacher education and training in the EU today – research	Documents current teacher profiles, qualifications, CPD systems, gaps in pedagogy/content balance, and teachers' stated needs for practical support.
D4.2 and D4.3 Competencies Maps	Provide the validated competence architecture: subject-specific, pedagogical and transversal competences for primary and secondary teachers.
EC Guidelines for Teaching Informatics	Reinforce classroom-facing guidance: strong foundations, success for all learners, high-quality teaching, assessment and professional learning.
T4.5 Structuring the continuous and informal teacher training for informatics teachers in primary and secondary schools (workshops)	Confirm partner priorities: AI, data literacy, cybersecurity, inclusion, hands-on workshops, peer learning, mentoring and flexible annual CPD.

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Competence Framework for Informatics Teachers

Within the Digital First project, a comprehensive competence framework for informatics teachers was developed through two complementary deliverables. D4.2 Competencies Map for Informatics Teachers in Primary School defines the competences required for teachers at the primary level (ISCED 1), while D4.3 Competencies Map for Informatics Teachers in Secondary School defines the competences required for teachers at the lower and upper secondary levels (ISCED 24 and ISCED 34). Together, these deliverables establish a coherent competence framework organised into three complementary domains that provide the foundation for effective informatics teaching: subject-specific, pedagogical, and transversal/professional competences (Digital First Consortium, 2025b; Digital First Consortium, 2025c). Together, these three domains reflect the understanding that high-quality informatics teaching depends on the integration of disciplinary expertise, pedagogical knowledge and broader professional competences, rather than excellence in any single domain.

These domains are consistent with the Informatics Reference Framework for School (Informatics4All) (Caspersen et al., 2022), the Combined Knowledge and Competency (CKC) model (Kumar et al., 2023), and DigCompEdu (Redecker & Punie, 2017), while also reflecting the international recommendations on informatics competences for all teachers (Brinda et al., 2025). The competence maps also build on the conceptual perspective developed through the Dialogue Clubs (WP3), where Halliday's seven functions of language (Halliday 1973, 1975) informed the understanding of informatics as a language for describing, exploring and shaping the digital world. This perspective emphasises that informatics education extends beyond the acquisition of technical knowledge to foster communication, creativity, inquiry, collaboration and responsible participation through digital technologies.

Competences of Informatics Teachers

Effective informatics teaching requires far more than technical proficiency with digital technologies. Teachers need a solid understanding of informatics as a scientific discipline and the pedagogical expertise to translate its core concepts into meaningful learning experiences. They should be able to explain fundamental informatics principles, select developmentally appropriate examples, design engaging learning activities, and help students understand how digital systems function, how they are created, and how they influence individuals and society. Although the core competence domains remain consistent across educational levels, the expected depth of understanding, learner autonomy, and conceptual complexity increase progressively from ISCED 1 to ISCED 3. Consequently, teachers at different educational stages require distinct professional competences. Primary school teachers need strong foundational knowledge and confidence in introducing informatics concepts through age-appropriate, exploratory activities. Lower-secondary teachers require broader disciplinary knowledge and the pedagogical expertise to support students' transition towards more formal computational concepts. Upper-secondary teachers, in turn, need advanced conceptual understanding, technical expertise, and the capacity to teach specialised informatics topics while fostering critical reflection on emerging digital technologies and their societal implications.

General-purpose productivity and content-creation tools — spreadsheets, word processors, presentation software, image, audio and video editing, and collaborative documents — remain relevant to informatics teachers' competences, particularly at primary and lower-secondary levels. Teaching these tools may be the informatics teacher's task, but not always — in some education systems other teachers cover it. Within the Digital First functional approach, such tools are not learning goals in themselves but meaningful contexts through which students develop durable informatics concepts and digital competences. The aim is proficiency with these classes of tools, not with any specific commercial product.

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The competence areas in Tables 2–4 are derived from the informatics teacher competence maps developed and validated by project partners in D4.2 (primary) and D4.3 (secondary) (Digital First Consortium, 2025b; Digital First Consortium, 2025c). These maps are grounded in the Informatics for All Reference Framework (I4All) and the CKC model for disciplinary content, and in DigCompEdu for the pedagogical and professional dimensions, and are cross-referenced with the CSTA Standards for Computer Science Teachers (CSTA, 2020) and the K-12 Computer Science Framework (ACM et al., 2016). They were consolidated into a single, level-independent overview by the WP4 team and reviewed by partners during the D4.5 review process.

Table 2 provides an overview of the subject-specific competences for informatics teachers.

Table 2. Subject-specific competences informatics teachers need to have.

Competence area	Teacher should be able to...
Data and Information	Collect, structure, clean, represent, interpret and critically evaluate data; address data quality, bias, privacy and meaningful visualisation.
Algorithms and Computational Thinking	Use decomposition, abstraction, pattern recognition and algorithmic reasoning; plan and structure solutions before coding (for example, with algorithms, pseudocode or flowcharts); support iteration, debugging and evaluation of solutions.
Programming	Move from unplugged and block-based environments to text-based programming where appropriate; support testing, documentation, debugging and collaboration; and use AI-based coding assistants responsibly, as a support and research tool.
Computing Systems and Networks	Understand, configure and explain hardware, software, operating systems, networks, communication and how computing systems process, store and transmit information, while fostering safe, efficient and responsible use of digital infrastructures.
Human-Computer Interaction	Guide students in analysing user needs, usability, accessibility, interface design; support user-centred design and usability testing; and encourage critical reflection on how digital technologies, including augmented and virtual reality, influence individuals, communication, participation and society.
Digital Creativity, Design and Development	Support students in designing and creating digital artefacts, prototypes, multimedia, websites, apps, games and interactive products.
Modelling and Simulation	Guide students in using models, simulations and variables to represent systems, test hypotheses and analyse complex phenomena across disciplines.
Robotics and Physical Computing	. Integrate programming with sensors, actuators, microcontrollers, robotics platforms, Internet of Things (IoT) technologies, and hands-on problem-solving in real-world contexts.
Privacy, Safety and Security	Teach secure behaviour, digital identity, threats, encryption, data protection, copyright, misinformation and responsible participation.
Artificial Intelligence	Design learning experiences that help students understand the principles of AI, machine learning and how algorithms use data to support decision-making and generate recommendations; guide the responsible use of AI tools; and support critical evaluation of their reliability, fairness, limitations, bias and societal impact.

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Competence area	Teacher should be able to...
Generative Artificial Intelligence	Help students understand how generative AI models work — how they are trained on data, generate outputs and why they hallucinate — and support informed, responsible use, including prompt design, critical evaluation of outputs, authorship, academic integrity and ethical considerations.

Note: The competence areas in Table 2 synthesise the more detailed, ISCED-level-specific areas defined in D4.2 and D4.3 into a single, level-independent overview — for example, Algorithms and Computational Thinking combines two separate areas, and Computing Systems and Networks combines Computing Systems with Networks and Communication (ISCED 34). Artificial Intelligence and Generative Artificial Intelligence are listed separately, in line with partner feedback from the D4.3 validation.

Table 3 provides an overview of the pedagogical competences for informatics teachers.

Table 3. Pedagogical competences informatics teachers need to have.

Competence area	Teacher should be able to...
Teaching and learning design	Plan lessons and sequences that connect informatics concepts with meaningful problems, learner interests and real-world contexts.
Pedagogical content knowledge (PCK)	Recognise misconceptions, use analogies and representations, scaffold abstraction, and explain technical language in accessible ways.
Technological pedagogical content knowledge (TPACK)	Choose digital, unplugged, automated, AI-supported or physical-computing tools because they serve learning goals, not because they are new.
Assessment and evaluation	Use formative and summative assessment, projects, portfolios, peer-/self-assessment, rubrics, diagnostics and responsible automated feedback.
Differentiation and inclusion	Adapt tasks, tools, pace, support and assessment so that all students, including underrepresented, struggling and advanced learners, can participate.
Classroom orchestration	Manage practical work, teamwork, debugging, pair programming, exploration, discussion, safety and student reflection.

Table 4 provides an overview of the transversal competences for informatics teachers.

Table 4. Transversal competences informatics teachers need to have.

Competence area	Teacher should be able to...
Professional growth	Identify learning needs, update knowledge, use evidence, engage in CPD and maintain a professional portfolio.
Collaboration and cross-disciplinary integration	Work with colleagues, mentors, families, universities, NGOs, companies and European partners on meaningful informatics learning.

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Competence area	Teacher should be able to...
Ethical and inclusive practice	Address privacy, safety, equity, stereotypes, accessibility, AI ethics, sustainability and the social consequences of digital technologies.
Innovation and adaptability	Respond to curriculum change, emerging technologies and different school contexts without losing focus on durable concepts.
Effective and responsible communication	Communicate informatics concepts clearly to students, colleagues, parents, and other stakeholders; share educational resources and good practices; and promote understanding, engagement, and the value of informatics education.
Leadership and mentoring	Mentor colleagues, share teaching practices and resources, facilitate professional learning communities, and coordinate school-level informatics projects and quality-assurance activities.

Together, these three competence domains provide a coherent framework for describing the knowledge, skills and professional capacities that informatics teachers should develop throughout their careers. They also provide the reference point for analysing current provision across European education systems. The following chapter examines the extent to which these competences are currently supported and identifies priority areas for continuous professional development.

1.1 Competence Expectations by Teacher Profile

Findings from Deliverable D4.1 (Digital First Consortium, 2025a), building on the broad primary/secondary distinction in D2.2 (Digital First Consortium, 2024a), showed that participating countries employ different profiles of teachers to teach informatics, ranging from generalist primary teachers to specialist informatics educators. Each profile is mapped to the ISCED level(s) used consistently across D4.1–D4.4 (ISCED 1 — primary; ISCED 24 — lower secondary; ISCED 34 — upper secondary), so that the profiles remain traceable to the level-specific competence maps in D4.2 and D4.3 (Digital First Consortium, 2025a, 2025b, 2025c, 2025d). All profiles share a common foundation in computational thinking, digital literacy, safe and ethical use of technology, and sound pedagogy, but the expected depth and breadth of disciplinary knowledge grow with the level of specialisation and the age of learners. Primary generalists establish foundational concepts through age-appropriate, inclusive approaches; specialist and upper-secondary informatics teachers build progressively deeper disciplinary expertise; vocational and interdisciplinary teachers apply informatics to authentic, workplace-oriented problems; and mentors and CPD leaders add coaching, quality assurance and professional leadership to a full command of the core domains.

This progression follows the competence-based approach of the Digital First project, grounded in the Informatics for All Reference Framework, the CKC model and DigCompEdu, and reflects the WP2 and WP4 findings that teacher roles, educational pathways and responsibilities differ substantially across European education systems. It is also fully consistent with the European Commission Guidelines for Teaching Informatics: Practical Strategies for European Classrooms (2026), which advocate high-quality, inclusive informatics education from the beginning of compulsory schooling, recognise progression in both learner and teacher expertise, and emphasise that teachers require different combinations of subject knowledge, pedagogical competence and professional learning depending on their educational context and responsibilities. Rather than defining separate competence frameworks for different teacher groups, the Digital First approach establishes a common European reference framework that can be interpreted progressively according to teachers' professional roles, educational levels and national contexts.

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Table 5. How competence expectations vary by teacher profile.

Teacher profile	Expected competences
Primary generalist or integrated-subject teacher (ISCED 1)	Secure foundations in computational thinking, digital creativity, data, safety and age-appropriate unplugged/block-based activities; strong inclusion and confidence-building.
Primary or lower-secondary informatics teacher (ISCED 1/24)	Broader subject knowledge, transition from visual to text-based programming, project work, assessment, digital citizenship, and classroom implementation.
Upper-secondary informatics teacher (ISCED 34)	Advanced programming, algorithms, data, systems, networks, AI/GAI, cybersecurity, modelling, HCI, software practices and deeper ethical/social analysis.
Informatics graduate or professional teaching without a full teaching qualification (ISCED 24/34)	Strong disciplinary knowledge, but developing pedagogical competence: PCK and TPACK, lesson and assessment design, differentiation and inclusion, classroom orchestration and age-appropriate approaches; typically supported by mentoring and induction.
Vocational or interdisciplinary informatics teacher (ISCED 34)	Applied systems, simulations, physical computing, industry-linked problems, interdisciplinary projects and workplace-relevant digital practices.
Mentor / CPD leader (all ISCED levels)	Full command of the core informatics domains, plus mentoring of informatics teachers, leading CPD on informatics topics (programming didactics, computational thinking, AI, data, cybersecurity), curating teaching resources, and supporting quality assurance and communities of practice in informatics.

Note: Table 5 combines teacher profiles identified in D4.1 — expressed using the ISCED levels applied across D4.1–D4.4 — with competences derived from the level-specific maps in D4.2 (primary) and D4.3 (secondary), grounded in I4All, the CKC model and DigCompEdu and aligned with the EC Guidelines for Teaching Informatics (2026).

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2 Current State and Competence Gaps

Across Europe, informatics education is expanding rapidly, but teacher preparation and continuous professional development (CPD) remain uneven. The findings of the Digital First project are consistent with the European Commission Guidelines for Teaching Informatics: Practical Strategies for European Classrooms (2026), which highlight persistent differences in curriculum implementation, teacher education, access to professional learning and classroom practice across education systems. Within this broader European context, D2.2 identifies uneven student access to the full breadth of informatics (Digital First Consortium, 2024a), D4.1 highlights significant variation in teacher preparation and CPD provision (Digital First Consortium, 2025a), and the competence validation carried out in D4.2 and D4.3 shows that desired competence levels consistently exceed current levels, particularly in emerging technologies and pedagogically demanding areas (Digital First Consortium, 2025b; Digital First Consortium, 2025c). Together, these findings provide the evidence base for identifying the competences that teachers need to acquire or further strengthen through continuous and informal professional learning.

2.1 State of Play: What the Evidence Shows

Across different stages of the project, it became evident that informatics teachers need to keep up with new developments in all three competence areas: subject-specific, pedagogical, and transversal. Implications of what teachers need to learn at CPDs are presented in Table 6.

Table 6. State of play from D2.2, D2.3 and D4.1.

Area	Evidence	Implication for teacher CPD
Curriculum and content coverage	D2.2 finds stronger coverage of data and information, programming, and safety than of human-computer interaction (HCI), responsibility and empowerment, and modelling and simulation.	Teachers need a broader, more balanced view of informatics beyond programming and the use of tools.
Teacher education pathways	D4.1 shows major differences between countries and levels; primary often relies on generalist teachers, while secondary more often uses specialists.	CPD must be differentiated by teacher profile and starting point.
Content-pedagogy balance	D4.1 identifies gaps between technical preparation and the application of informatics didactics in classroom practice.	CPD must combine subject knowledge with PCK, TPACK and practical implementation.
Professional development	D4.1 shows CPD is available but unevenly structured, often voluntary, decentralised or dependent on personal initiative.	Teachers need accessible, recognised and sustained professional-learning pathways.
Emerging technologies	D4.1 and T4.5 identify AI, GAI, cybersecurity, robotics, VR/AR, 3D printing and IoT as fast-growing areas that are becoming increasingly relevant in education.	Teachers need regular evidence-informed updates on emerging technologies and their classroom application.
Pedagogy and inclusion	D2.3 recommends student-centred transition, collaboration, multimodality,	Teachers need methods that help all learners engage with informatics and demonstrate competence.

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Area	Evidence	Implication for teacher CPD
	personalisation, assessment and inclusive environments.	
Networks and resources	D4.1 highlights teacher networks, online communities, MOOCs, national programmes, international development and research projects and peer collaboration.	CPD should treat communities and resource sharing as core infrastructure.

The main challenge is not the absence of professional learning opportunities, but the lack of coherence, consistency and balanced competence development across teacher profiles and education systems. While considerable progress has been made in strengthening programming and digital technologies, other essential areas of informatics—including modelling, human-computer interaction, responsible digital participation and inclusive pedagogy—receive less systematic attention. These findings align with the European Commission Guidelines for Teaching Informatics (2026), which emphasise that effective CPD should combine disciplinary knowledge, pedagogical expertise, collaboration and continuous updating in response to technological and societal change. Consequently, future CPD should be competence-based, differentiated and closely connected to classroom practice.

However, designing a competence-based CPD framework is only the first step. As technologies, educational practices and competence requirements continue to evolve, the framework also requires a structured mechanism for ongoing monitoring and revision. The monitoring process ensures that the CPD framework can evolve in a structured and evidence-informed way. Rather than responding to every technological trend, it provides a transparent basis for deciding when new topics should be incorporated into the common CPD offer, when they should remain optional areas of specialisation, and when additional evidence or classroom experience is needed before wider adoption. This approach helps maintain a balance between innovation, quality of education and the long-term stability of the competence framework.

2.2 Competences Teachers Need to Acquire or Strengthen

From data gathered during the Digital First project we identified a set of contemporary competences that informatics teachers need to acquire or strengthen to keep pace with recent developments. Table 7 presents these competences, describes what they include and explains why they are needed.

Table 7. Contemporary competences that informatics teachers need to acquire or strengthen.

Contemporary competence	What the competence includes	Why it is needed
AI and Generative AI literacy	Understanding AI concepts, generative systems, prompt design, output evaluation, bias, hallucination, authorship, academic integrity and responsible classroom use.	AI/GAI were among the lowest current and highest desired areas in competence validation; D4.1 reports fast-changing demands.
Data literacy and learning analytics	Using data ethically, interpreting visualisations, identifying misleading data, protecting data and using learning analytics proportionately.	D2.2 and D2.3 emphasise data as a key digital-society competence.

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Contemporary competence	What the competence includes	Why it is needed
Cybersecurity and digital citizenship	Privacy, identity, threats, encryption, copyright, misinformation, responsible online behaviour and school-level safety practices.	D2.3 recommends stronger attention to privacy, security, fraud prevention and responsible behaviour.
Modelling, simulation and systems thinking	Representing systems, testing variables, using simulations and connecting models to scientific, social and vocational contexts.	D2.2 identifies modelling and simulation as less consistently taught.
Human-computer interaction and accessibility	Understanding users, interface design, accessibility, usability, inclusive design and technology impact.	HCI and responsibility/empowerment are less consistently covered in D2.2.
Inclusive digital pedagogy	Differentiating tasks, using Universal Design for Learning, supporting diverse learners, addressing stereotypes and enabling multiple ways to show learning.	D4.2/D4.3 show that competence in differentiation and inclusion is below the desired level.
Assessment for informatics	Assessing concepts, processes, artefacts, collaboration, creativity and reflection with rubrics, portfolios, diagnostics and cautious automated feedback.	D2.3 and EC guidelines emphasise the importance of assessment, learner progress and learner agency.
Interdisciplinary and functional teaching	Connecting informatics to mathematics, science, arts, humanities, social issues and real-life problem solving while keeping informatics concepts visible.	D2.3 recommends interdisciplinary integration and critical problem-solving in practice.
Professional collaboration and leadership	Participating in professional learning communities, mentoring, peer review, cross-institutional learning and school-level leadership, including practical support from school leaders such as protecting time for CPD, enabling peer observation and recognising teachers' classroom-based innovations.	D4.1 highlights the importance of professional networks; D4.2/D4.3 identify professional growth and cross-disciplinary integration as areas for further development.

Note: The contemporary competences in Table 7 were derived by triangulating evidence across the project: the curriculum and teaching findings of D2.2 and the improvement directions of D2.3; the teacher-education and CPD gaps documented in D4.1; the competence-validation results from D4.2 and D4.3, where desired levels exceeded current levels (notably in emerging technologies and inclusion); and the partner priorities expressed in the T4.5 workshops. The resulting priorities are aligned with the European Commission Guidelines for Teaching Informatics (2026). Each competence is linked to its evidence source in the "Why it is needed" column.

Building on the evidence presented above, the competences in Table 7 represent priority areas for continuous professional development rather than an additional set of isolated skills. They combine emerging technological knowledge with pedagogical, ethical and professional capabilities that enable teachers to translate informatics concepts into meaningful classroom practice. Together, these competences support progression from technology use towards informed educational decision-making, inclusive teaching and lifelong professional growth, in line with the Digital First competence maps and the European Commission Guidelines for Teaching Informatics (2026).

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2.3 Contemporary CPD Themes

The competences identified in the previous section can be translated into contemporary CPD themes that reflect current and emerging priorities in informatics teacher professional development. Rather than attempting to address all topics simultaneously, CPD should combine a common core for all informatics teachers with opportunities for specialisation, pedagogical innovation and participation in professional learning communities. Table 8 organises these themes into CPD categories that support flexible, modular and sustainable professional learning pathways, consistent with the competence-based approach promoted by the European Commission Guidelines for Teaching Informatics (2026).

Table 8. Contemporary CPD themes derived from the state of play.

CPD category	CPD themes
Common core (mandatory)	AI and data literacy; privacy, safety and cybersecurity; inclusive pedagogy; assessment; curriculum/competence updates; ethical and responsible digital practice.
Specialisation (optional)	Advanced programming, software engineering, data science, robotics, physical computing, IoT, VR/AR, 3D design/printing, game development, NLP, quantum computing.
Pedagogical innovation	Problem-based learning, project work, collaborative learning, multimodality, personalised pathways, unplugged activities, reflection, student agency and formative assessment.
Professional ecosystem	Mentoring, professional learning communities, school-based inquiry, European mobility, teacher exchanges, resource creation and peer-reviewed lesson scenarios.

Note: The CPD themes in Table 8 were developed by the WP4 team from the project's own evidence (D2.2, D2.3, D4.1, the D4.2/D4.3 competence validation and the T4.5 workshops) and grouped into four categories. They are consistent with the competence-based approach of the EC Guidelines for Teaching Informatics (2026), while the themes and their organisation are the project's own contribution.

The proposed CPD themes and their organisation should not be regarded as fixed. To remain relevant, CPD priorities need to be reviewed regularly considering emerging technologies, educational research and evolving curriculum expectations.

2.4 Technology and Evidence Monitoring

The CPD priorities presented in this framework should not be regarded as static. Informatics is a rapidly evolving discipline, requiring continuous professional development to respond to technological innovation while maintaining a strong focus on enduring informatics concepts, sound pedagogy and educational value. As emphasised in the European Commission *Guidelines for Teaching Informatics: Practical Strategies for European Classrooms* (2026), professional learning should evolve in response to research evidence, curriculum developments and classroom needs, rather than following technological trends alone. A monitoring mechanism is therefore an integral part of this framework: because informatics changes quickly, a competence framework without a means of keeping it current would soon become outdated, so the framework specifies not only the competences and CPD themes but also how they are to be reviewed and updated over time.

To support the continuous evolution of CPD, the framework incorporates a transparent technology-and-evidence monitoring process. This process is intended to be carried out by the bodies responsible for CPD in each national context — such as teacher-education institutions, CPD providers and national or regional coordinators — working together with informatics teacher communities and, where relevant, subject associations and researchers. Rather than promoting the adoption of every emerging technology, this process supports evidence-informed decisions about which developments should become part of the common core, which should remain optional areas of specialisation, which require classroom piloting, and which should continue to be monitored until stronger educational evidence becomes available.

The monitoring process consists of four complementary stages:

- **Evidence gathering** – Collect evidence from research, curriculum developments, professional standards, teacher communities, learner practices and credible technology providers.
- **Assessment** – Evaluate educational value, technological maturity, inclusion, accessibility, privacy, risks, infrastructure requirements and potential implications for teaching and learning.
- **Design and piloting** – Co-design classroom-oriented CPD activities with teachers and experts, incorporating appropriate safeguards, implementation strategies and evaluation criteria.
- **Review and refinement** – Analyse teacher feedback, classroom evidence, learner outcomes, implementation costs and emerging research before scaling, revising or retiring CPD content.

This continuous monitoring process enables transparent and evidence-informed decisions about the evolution of the CPD framework. It helps distinguish essential competences that should become part of the common core—such as AI and data literacy, privacy, safety, and cybersecurity, inclusive pedagogy and assessment—from themes that are better suited to optional specialisation or future monitoring, including robotics, IoT, virtual and augmented reality, advanced AI, quantum computing and other domain-specific applications. In this way, the framework remains responsive to innovation while preserving coherence, educational quality and long-term relevance.

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3 Resources for Continuous Professional Development

Teachers need reliable resources that support both subject knowledge and classroom application. The resources listed below are not intended as a closed list; they are examples of resource types and recognised European and international entry points that can be used for self-directed learning, CPD modules, peer learning and school-based development. Resource selection should remain aligned with the evidence base from D2.2, D2.3 and D4.1, the D4.2 and D4.3 competence maps, and recognised frameworks such as Informatics for All, CKC and DigCompEdu (Digital First Consortium, 2024a; Digital First Consortium, 2024b; Digital First Consortium, 2025a; Caspersen et al., 2022; Kumar et al., 2023; Redecker & Punie, 2017).

Table 9. Resource map for informatics teachers' continuous learning.

Resource type	Examples	Best used for
Project and framework documents	D2.2; D2.3; D4.1; D4.2; D4.3; D4.4; Informatics for All / Informatics Reference Framework (Caspersen et al., 2022); CKC model (Kumar et al., 2023); DigCompEdu (Redecker & Punie, 2017); AI literacy frameworks (e.g., UNESCO, 2024).	Understanding project evidence, competence domains, progression and policy alignment.
European Commission guidelines and policy resources	European Commission Guidelines for Teaching Informatics: Practical Strategies for European Classrooms (European Commission, 2026), UNESCO AI Competency Framework for Teachers, European Commission Guidelines on the ethical use of AI and data in teaching and learning.	Classroom-facing strategies for foundations, inclusion, teaching quality, assessment, ethical AI and data use, and professional learning.
Open course platforms	European School Education Platform, European Schoolnet Academy, Code.org, FutureLearn, edX and Coursera.	Flexible foundational and specialist knowledge; useful for self-study and blended CPD.
Teacher resource hubs	Raspberry Pi Foundation resources and Hello World, Code.org, Teach Computing, BJC – Beauty and Joy of Computing, CS Unplugged, IT2School, micro:bit Educational Foundation, Scratch Educators and MIT App Inventor.	Ready-to-adapt lesson ideas, examples, assessment materials and unplugged/plugged activities.
Assessment and reflection resources	Dr. Scratch, LitterBox, Project Quantum, Bebras tasks, SELFIEforTEACHERS, COMATH and validated K–12 CS assessment instruments, where available.	Formative feedback, rubrics, computational thinking assessment and diagnostics.
AI and data literacy resources	AI4T, GAIRDIN, Machine Learning for Kids and selected classroom-ready AI/data literacy resources.	Understanding AI concepts, classroom applications, ethical use, bias, data practices and responsible AI pedagogy.

Resource type	Examples	Best used for
Cybersecurity, safety and digital citizenship resources	ENISA CyberEducation Platform, Better Internet for Kids and national Safer Internet Centres.	Teaching privacy, safety, cybersecurity, digital identity, responsible participation and online risks.
Professional communities	EU Code Week, eTwinning, Informatics for All, European Digital Education Hub, ALL DIGITAL communities, Bebras Challenge communities and national informatics associations.	Peer learning, mentoring, dissemination, collaboration and visibility.
National and regional providers	KATIS and Study Meetings (Študijska srečanja) in Slovenia; ANPRI/CFAEs in Portugal; CodeINTEF and regional centres in Spain; other ministry or agency programmes.	Contextualised CPD aligned with national curricula and recognition systems.
Mobility and project-based learning	International development and research projects (e.g. Erasmus+ Teacher Academies and mobility actions), school exchanges, study visits, selected course providers such as Europass Teacher Academy, university-school partnerships, and industry and research seminars.	Exposure to new practice, international collaboration, applied projects and resource sharing.

3.1 Resource Ecosystem and Practice Examples

The evidence presented in this report and the European Commission Guidelines both emphasise that high-quality CPD works best as an ecosystem rather than as isolated one-off courses. Useful ecosystems combine curated resources, hands-on modules, mentoring, professional communities, recognised learning pathways and classroom application. At the heart of such ecosystems are school-based communities of practice and peer-learning networks. Much of teachers' most sustained professional growth happens locally — through shared lesson planning, peer observation, co-teaching, joint problem-solving and the exchange of classroom-tested materials among colleagues within and across schools. These communities turn one-off training into continuous, job-embedded learning, and they are especially valuable for informatics teachers, who are often few within a single school and benefit from wider subject networks. CPD provision should therefore actively support and connect these networks, rather than treating courses and resources as stand-alone offers.

Practice examples illustrate how such ecosystems can be organised in different ways. The National Centre for Computing Education in England combines courses, school hubs, curriculum resources, equipment support, communities and accreditation. Spanish initiatives such as CodeINTEF and Programamos combine institutional and grassroots provision, while Code.org connects curriculum, teacher training, assessment resources and teacher forums. These examples should be treated as models for design, not as templates to copy without adaptation to national context.

Teachers can also use diagnostic and reflective tools such as SELFIEforTEACHERS, based on DigCompEdu, to identify professional-learning needs and connect them with suitable resources, portfolios or micro-credentials.

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3.2 Selecting High-Quality Resources

When selecting resources for CPD, teachers should consider both the quality of the resource and its relevance to their own competence-development needs. The following criteria can support informed selection:

- **Alignment with competence needs.** Resources should be aligned with the subject-specific, pedagogical or transversal competence area that teachers want to strengthen. D4.2/D4.3, Informatics for All and the CKC model can be used as alignment anchors (Digital First Consortium, 2025b; Digital First Consortium, 2025c; Caspersen et al., 2022; Kumar et al., 2023).
- **Classroom applicability.** Preference should be given to resources that include classroom examples, age-level guidance, assessment ideas and adaptation notes, as recommended by D2.3 and the European Commission Guidelines for Teaching Informatics (Digital First Consortium, 2024b; European Commission, 2026).
- **Balance between durable concepts and specific tools.** Technology-neutral resources are particularly useful when learning durable concepts, while tool-specific resources should be selected only when they serve a clear teaching purpose. This helps keep CPD anchored in informatics concepts rather than in short-lived tools (Caspersen et al., 2022; Digital First Consortium, 2025a).
- **Inclusion, safety and ethical dimensions.** Resources should address inclusion, accessibility, data protection, safety and ethical use where relevant.
- **Peer review before wider adoption.** Teachers should discuss resources in a professional community before adopting them widely, especially through teacher networks, professional learning communities and European exchange platforms highlighted in D4.1 (Digital First Consortium, 2025a).
- **Documentation of use and impact.** Teachers should document the selected resource, the classroom trial and the evidence of student learning in their professional portfolio.

4 Methods for Implementing Competence-Based Professional Learning

The methods presented in this chapter operationalise the evidence-based framework. At its core is a continuous competence development cycle illustrated in Figure 2, which guides teachers in identifying professional learning needs, engaging in targeted learning, applying new knowledge in practice, evaluating its impact and sharing experiences within professional communities. The remaining methods complement this cycle by providing practical guidance for designing and implementing competence-based professional learning, including balanced learning pathways, flexible learning loads, diverse learning formats, evidence-informed recognition, and collaboration through mobility and professional networks. Together, these methods support lifelong professional growth while preserving the key principles of the D4.5 framework: lifelong learning, modularity, school-embedded practice, quality assurance and continuous improvement.

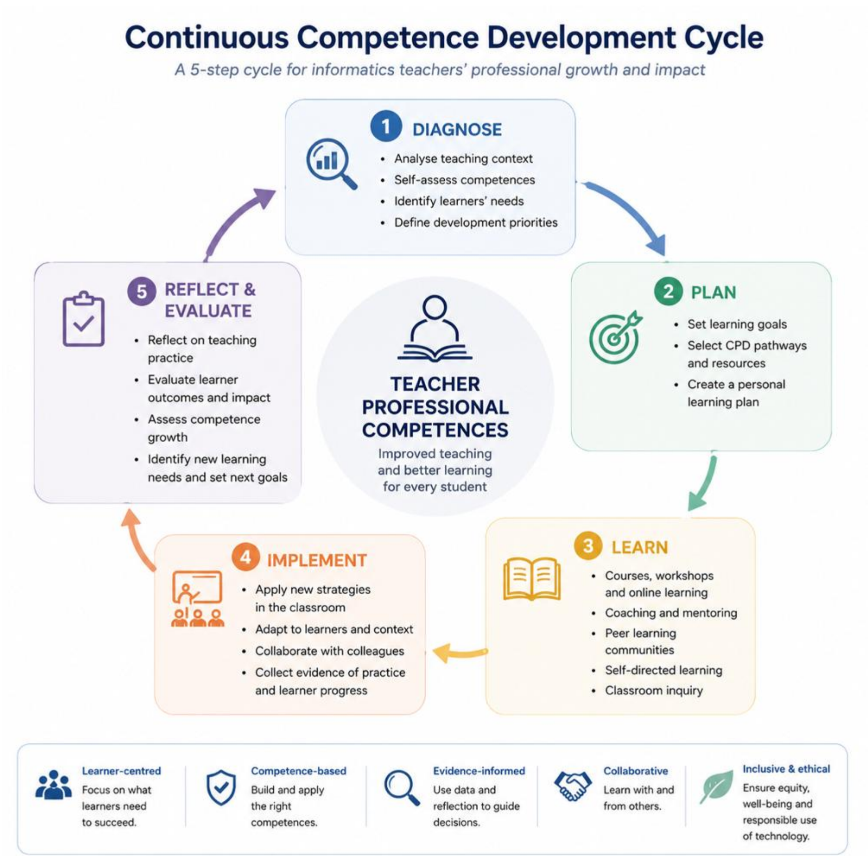

Figure 2. Continuous competence development cycle for informatics teachers.

Note: This five-stage cycle (Diagnose – Plan – Learn – Implement – Reflect & Evaluate) is an original contribution developed by the WP4 team. It synthesises well-established models of professional learning — the experiential learning cycle (Kolb, 1984), reflective practice (Schön, 1983) and continuous-improvement (plan–do–study–act) cycles (Deming, 1986) — and adopts the self-assessment logic of DigCompEdu and SELFIEforTEACHERS (Redecker, 2017) in its diagnostic stage. Its five guiding principles — learner-centred, competence-based, evidence-informed, collaborative, and inclusive and ethical — align the cycle with the Digital First framework and the EC Guidelines for Teaching Informatics (2026).

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4.1 Competence Development as a Continuous Learning Cycle

Professional development is most effective when it is understood as a continuous process rather than a series of isolated training events. The competence development cycle presented in Figure 2 provides a practical structure for planning, implementing and reflecting on professional learning. It encourages teachers to identify their own development needs, select meaningful learning opportunities, apply new knowledge in authentic classroom contexts and evaluate its impact on teaching and student learning. The cycle also promotes evidence-informed reflection and professional collaboration, ensuring that learning contributes not only to individual competence development but also to the collective capacity of schools and professional communities.

In practice, teachers can follow the five stages of the cycle through the following activities:

- **Diagnose** – use the competence domains and state-of-play tables to identify current strengths, development needs and learner needs.
- **Plan** – select one or two competence goals that are most relevant to the classroom, school or curriculum context, and choose suitable CPD pathways and resources.
- **Learn** – engage in professional learning through a module, workshop, mentor, professional community, self-directed learning or other recognised activity.
- **Implement** – apply the new knowledge by designing or adapting classroom activities, assessments or interdisciplinary projects, and collect evidence through student work, classroom observation, peer feedback, reflective notes or assessment results.
- **Reflect and evaluate** – assess the impact on teaching and student learning, document professional growth, and share resources or reflections with professional learning communities.

4.2 Balance Common Core and Professional Specialisation

Professional learning cannot rely on a single, uniform offer for all informatics teachers. WP2 findings show substantial variation in what is currently taught and how teachers are prepared to teach it across countries and school levels (Digital First Consortium, 2024a, 2024b), while the WP4 competence catalogues describe expectations that progress from a shared foundation towards profile-specific depth in subject knowledge, pedagogy and transversal competences (Digital First Consortium, 2025b, 2025c). Taken together, this evidence points to one principle: CPD must ensure a common, regularly updated set of competences for every teacher while leaving room for specialisation aligned with professional role, experience and career stage. Table 10 translates this principle into a balanced CPD structure built around a common core, differentiated professional pathways, optional specialisation and continuous informal learning. Figure 3 illustrates how these components combine to support teachers' professional growth throughout their careers.

Teachers should select their professional pathway based on their current competence profile, teaching role, classroom needs and career stage, and should be able to revise this choice as their expertise develops.

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Table 10. Balanced CPD structure for informatics teachers.

CPD component	Recommended content	Evidence of learning and application
Common CPD core	Annual updates on curriculum, AI/data, cybersecurity, inclusion, assessment and learner wellbeing.	Short portfolio entry or adapted learning scenario.
Selected professional pathway	Foundation, development, advanced/specialist or mentor/leadership pathway.	Lesson sequence, project, assessment design or mentoring plan.
Optional specialisation	Robotics, data science, GAI, HCI, VR/AR, modelling, simulations, physical computing, cybersecurity labs.	Prototype, classroom trial or resource contribution.
Informal professional learning	Reading, peer observation, online communities, self-study, professional networks.	Documented reflection and evidence of use.

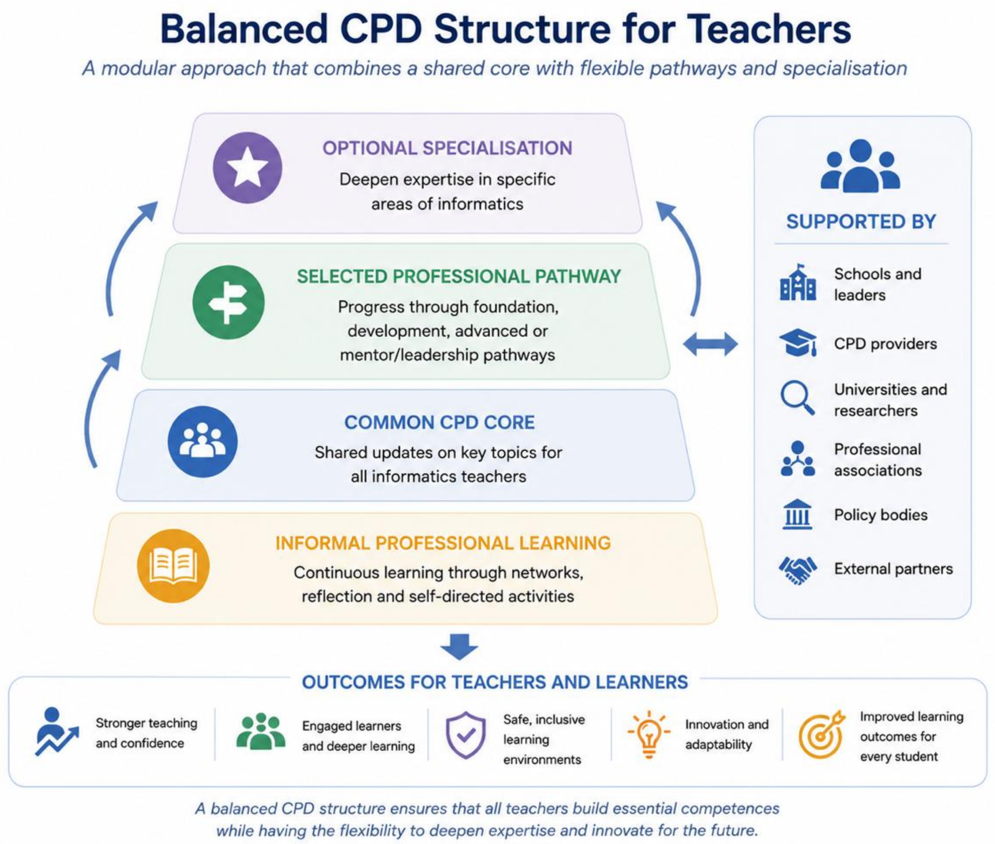

Figure 3. Balanced Structure of Continuous Professional Development for Informatics Teachers.

Note: Table 10 and Figure 3 were developed by the WP4 team from WP2 findings (D2.2, D2.3) and the WP4 competence catalogues (D4.2, D4.3), organising CPD into four layers — informal learning, a common core, differentiated pathways and optional specialisation — aligned with the EC Guidelines for Teaching Informatics (2026).

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4.3 Maintain a Flexible Annual Learning Path

The balanced CPD structure presented in Figure 3 provides the overall architecture for teachers' professional learning, while the annual learning pathway translates this structure into manageable professional-development activities. An annual learning target supports professional growth only if it can adapt to the working conditions, prior preparation and access to protected time that WP2 and WP4 evidence show varying widely across schools and countries.

The framework therefore proposes an indicative annual model of approximately **15–32 hours** of recognised or documented professional learning per year, or an equivalent multi-year accumulation, combining a compact **6–10-hour common core** with pathway-specific learning, classroom inquiry, mentoring, collaboration, mobility and documented informal learning. Treating these values as indicative rather than mandatory enables schools and education systems to adapt CPD to local priorities while ensuring that every teacher engages in regular, competence-based professional learning. Annex 1 (Table 17) provides worked examples of how these components can be combined into annual pathways for each teacher profile.

Table 11. Indicative annual CPD model.

Component	Indicative hours per year	Examples
Common core updates	6-10 hours	Curriculum, AI/data, safety, ethics, learner impact, policy changes.
Selected development pathway	4-10 hours	Hands-on workshop, module, micro-credential, specialist seminar.
Classroom application and reflection	3-6 hours	Trial, observation, evidence review, portfolio entry.
Collaboration or contribution	2-6 hours	Mentoring, community meeting, resource sharing, mobility preparation.

Note: The components derive from the balanced structure in Table 10; the indicative hours are the WP4 team's proposal, informed by partner CPD practices reported in D4.1 and the T4.5 workshops, and are deliberately presented as indicative rather than mandatory given the cross-country variation documented in D4.1.

4.4 Select Professional Learning Formats That Support Classroom Transfer

No single professional learning format meets every need: hands-on workshops, webinars, mentoring, accredited programmes and self-study each serve different purposes. The choice of format should therefore start from the learning goal and teachers' contexts, rather than from convenience or availability alone. Regardless of format, professional learning is more likely to transfer into practice when it is followed by conditions such as a classroom trial, structured discussion or documented application. Table 12 therefore links each format with its recommended use and the conditions needed for classroom impact.

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Table 12. CPD formats and conditions for success.

Format	Recommended use	Condition for impact
In-person hands-on workshops	Best for equipment, practical design, peer problem-solving and immediate feedback.	Include a classroom trial afterwards.
Blended modules	Best for sustained learning with flexibility and interaction.	Combine asynchronous learning with synchronous discussion and applied work.
Online webinars and meetings	Best for horizon scanning, expert updates and quick access.	Connect to deeper resources or follow-up tasks.
Mentoring and coaching	Best for novice teachers, isolated teachers and implementation support.	Use clear goals, manageable frequency and recognition.
Professional learning communities	Best for ongoing dialogue, peer review, resource exchange and reflection.	Facilitate regularly and keep resources searchable.
Projects and mobility	Best for innovation, cross-border exchange and real-world contexts.	Require preparation, dissemination and local transfer.
Self-paced online courses	Best for foundational knowledge, flexible upskilling and access to quality-assured platforms.	Select accredited or curated courses and pair them with classroom application.
Accredited programmes and micro-credentials	Best for formal recognition, career progression and in-depth specialisation.	Link certification to demonstrated competence and proportionate evidence.
Self-study and professional reading	Best for staying current, personal inquiry and preparing for other learning formats.	Document reflections and share relevant insights with peers.

Note: Compiled from the CPD formats teachers report using in D4.1 and the priorities expressed in the T4.5 workshops; the "condition for impact" column applies the classroom-transfer principle set out above (that learning transfers into practice when followed by a trial, structured discussion or documented application).

4.5 Recognise Professional Learning Through Evidence

Recognition should not reflect attendance alone. Teachers should be able to demonstrate what they learned, how they applied it, what evidence they collected and how the learning influenced their classroom practice or professional community. This is particularly important because D4.1 shows that CPD is often voluntary, decentralised and dependent on personal initiative (Digital First Consortium, 2025a); without documented evidence, valuable informal learning can remain invisible and unrecognised, which is also addressed as a risk in Table 16.

Evidence should be proportionate, ethically collected and anonymised where it includes student work, feedback or classroom observation. Evidence of professional learning may include:

- **Portfolio artefacts**: lesson plans, projects, code, assessment rubrics, student work samples or adapted scenarios.
- **Reflection**: what worked, what did not, what students found difficult, what should be changed next time.
- **Peer evidence**: observation notes, mentoring logs, community feedback or co-created resources.

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- **Student evidence**: improved understanding, engagement, participation, safer practice, better explanations or stronger artefacts.
- **School or system evidence**: resources shared, teachers mentored, school practice improved, partnerships formed.

4.6 Recognise Formal, Non-formal and Informal Learning

Professional learning takes many forms, and recognition should value all of them rather than privileging formal courses alone. While Section 5.5 focuses on the evidence needed for recognition, this section clarifies that recognition should apply across formal, non-formal and informal learning. D4.1 shows that informatics teachers already rely heavily on self-study, peer networks, national programmes, MOOCs, conferences and European projects to stay current (Digital First Consortium, 2025a), so distinguishing formal, non-formal and informal learning helps schools, providers and policy bodies design recognition that matches how teachers actually learn. Recognition should therefore rest on demonstrated competence, classroom application and professional contribution rather than attendance alone: certificates, credits, micro-credentials, digital badges and career-progression points are meaningful only when linked to the clear outcomes and evidence described in Section 5.5.

For this purpose, the following types of learning and evidence should be recognised:

- **Formal learning**: accredited courses, postgraduate modules, recognised national programmes and certified micro-credentials.
- **Non-formal learning**: workshops, webinars, summer schools, Erasmus+ activities, competitions, provider courses and structured professional learning communities.
- **Informal learning**: peer observation, mentoring, professional reading, online communities, self-study, classroom experimentation, resource creation and reflective inquiry.
- **Evidence**: portfolio artefacts, lesson designs, student work samples, assessment rubrics, reflective notes, peer feedback, presentations, mentoring logs or demonstrated competence.

4.7 Strengthen Professional Learning Through Mobility and Collaboration

Mobility and collaboration should not be treated as optional add-ons; they are core professional-learning methods that enable teachers to encounter different practices, access expertise, compare approaches, build confidence and bring new ideas and practices back to their schools. D4.1 highlights teacher networks, MOOCs, national programmes, Erasmus+ and peer collaboration as resources teachers already use to stay current (Digital First Consortium, 2025a), confirming that cross-border and cross-institutional exchange should be recognised alongside more formal CPD formats. This can take many forms: teacher exchanges, Erasmus+ mobility, job shadowing, study visits, joint online classroom projects, eTwinning projects, university-school partnerships, industry or research seminars and cross-border resource development. To generate real professional value, however, mobility and collaboration need structured preparation, participation and transfer, as outlined in Table 13.

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Table 13. Mobility and collaboration as professional-learning methods.

Phase	Teacher action	Evidence of learning and transfer
Preparation	Define competence goal, classroom question and evidence to collect.	Short learning plan.
Participation	Observe, co-design, discuss, collect examples and compare practice.	Notes, resources, contacts, prototype activity.
Transfer	Adapt and test one idea locally; share with colleagues.	Classroom trial, dissemination session, portfolio evidence.

Note: Based on the collaboration and mobility practices identified in D4.1, structured into three phases (preparation, participation, transfer) to link each activity to evidence of learning and classroom transfer.

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5 Implementation and Quality Assurance

For the framework to work, responsibility must be shared across the professional-learning ecosystem, rather than resting solely with individual teachers. D4.1 documents fragmented CPD systems across the ten partner countries, with support split unevenly between ministries, schools, universities and providers (Digital First Consortium, 2025a). Schools, ministries, teacher training centres, universities, professional associations, European projects and external partners all have roles. Quality assurance should focus on relevance, accuracy, accessibility, classroom transfer and evidence of professional growth.

Table 14. Stakeholder roles in supporting teacher competence development.

Stakeholder	Main responsibilities
Teachers	Diagnose needs, engage in CPD, apply learning, reflect, share and maintain a portfolio.
School leaders	Protect time, support infrastructure, enable collaboration and value CPD outputs.
Training providers	Offer practical, differentiated, evidence-informed CPD with follow-up support.
Universities and researchers	Provide disciplinary and pedagogical expertise, mentoring and evaluation support.
Professional associations and networks	Sustain communities, enable resource sharing, peer support and visibility.
Policy bodies	Establish recognition rules, funding mechanisms, quality criteria and equitable access.
External partners	Provide authentic contexts, specialised expertise and equipment under clear educational governance.

Note: Derived from the fragmented CPD systems documented in D4.1, which distribute responsibility across ministries, schools, universities and providers; the roles are aligned with the shared-responsibility principle of the EC Guidelines (2026).

Turning these responsibilities into practice requires shared and checkable quality standards. Table 15 translates the quality-assurance criteria above into concrete questions that training providers, schools and reviewers can apply when judging whether a specific CPD module is fit for purpose. Annex 2 (Table 18) turns this checklist into a module design template that CPD providers, schools and professional communities can complete when planning a new module.

Table 15. Quality checklist for CPD modules.

Quality criterion	What to check
Competence alignment	The module clearly states which subject-specific, pedagogical and transversal competences it addresses.
Classroom relevance	It includes realistic teaching examples, classroom tasks and adaptation options.
Balance	It combines technical knowledge with pedagogy, assessment, inclusion and ethical considerations.

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Differentiation	It is suitable for different teacher profiles and starting points.
Evidence	It requires evidence of application, such as a product, classroom trial, reflection, portfolio entry or other evidence beyond attendance.
Follow-up	It provides mentoring, peer exchange, a discussion forum, and community support.
Accessibility and ethics	It addresses access, privacy, safety, bias, commercial influence and sustainability.
Review and update	It has an owner, an update cycle and a mechanism for improvement.

Note: Operationalises the quality-assurance criteria set out above in this section, drawing on the competence domains (Tables 2–4) and the evidence-of-application principle established in Section 5.5; it forms the basis of the module design template in Annex 2 (Table 18).

5.1 Alignment and Continuous Improvement

The proposed framework is closely aligned with the European Commission *Guidelines for Teaching Informatics* (2026), particularly through its emphasis on strong disciplinary foundations, inclusive teaching, effective pedagogy, assessment for learning and continuous professional development. These principles are reflected throughout the competence framework, including its integration of pedagogical content knowledge and technology-related pedagogical knowledge, reflected in PCK/TPACK approaches, differentiated professional learning pathways, mentoring, professional learning communities and recognition of classroom-based evidence.

Continuous quality assurance should operate at multiple levels. Individual CPD activities should be evaluated immediately after participation to assess relevance and participant satisfaction, followed by evaluation after classroom implementation to examine how newly acquired competences have been transferred into teaching practice. At the system level, regular monitoring should identify emerging competence needs, inequalities in access, and priorities for future professional development. Annual reviews can update thematic priorities, while more comprehensive reviews every two to three years should evaluate the overall competence framework, delivery formats, recognition mechanisms and evidence of educational impact.

As informatics evolves rapidly, collaboration with external organisations, industry and technology providers can strengthen professional learning by providing authentic contexts and specialised expertise. Such collaboration should remain educationally driven and governed by transparent quality criteria that safeguard privacy, accessibility, interoperability, sustainability, commercial influence and pedagogical independence. These principles help ensure that CPD remains focused on durable informatics competences rather than short-lived technologies or commercial products.

5.2 National implementation contexts

The organisation and requirements for continuous professional development differ considerably across the participating countries. Finland, Lithuania and Portugal require teachers to complete a defined number of recognised professional-development hours within a set timeframe, while in Italy, professional development is mandatory, particularly for newly appointed teachers. In Cyprus and Greece, mandatory professional development is linked to career progression or certification. In contrast, participation in Croatia is largely voluntary, driven by teachers' motivation and institutional encouragement. In Spain, CPD is legally established as both a right and a duty of teachers. Participation in specific CPD activities is generally teacher-initiated, while provision, certification and recognition are substantially decentralised and organised by the Autonomous Communities. Consequently, CPD structures and incentives vary across regions. Slovenia promotes participation through publicly funded programmes without making it mandatory (Digital First Consortium, 2025a). These differences reinforce the central design principle of this framework: a common European competence framework can succeed only if each education system is able to adapt its professional-learning pathways, recognition mechanisms and provider landscape to its own institutional context.

5.3 Sustaining the Framework Beyond the Project

The long-term value of this framework lies not in the project deliverable itself, but in its adoption by the institutions that will continue to shape informatics teachers' professional learning after the end of the Digital First project. Building on the national implementation contexts described in Section 6.2, the framework is designed as a flexible reference model that can be adopted or adapted by a range of actors within the professional-learning ecosystem described in Table 14, each taking ownership of the elements most relevant to its mandate.

- **Universities and teacher-education faculties**: can integrate the competence domains (Tables 2–4) and the module design template (Table 18) into initial teacher education, postgraduate programmes and micro-credentials, and use the framework as a shared reference for mentoring and practicum supervision.
- **Ministries and national education authorities**: can adopt the stakeholder responsibilities (Table 14) and quality checklist (Table 15) as a basis for national CPD policy, recognition rules and funding criteria, adapting the indicative annual model (Table 11) to existing requirements such as mandatory CPD hours or career-progression schemes.
- **Teacher training centres and national CPD providers**: can use the framework as a curriculum backbone for their course catalogues, apply the quality checklist (Table 15) when designing or reviewing modules, and maintain the technology-and-evidence monitoring cycle described in Section 3.4 to keep their offer current.
- **Erasmus+ Teacher Academies and other EU-funded teacher-education alliances**: can embed the framework into joint training offers as a shared competence reference across partner countries, sustaining transnational mobility, collaboration and peer learning beyond the project's funding period.
- **Professional associations and networks**: can maintain communities of practice, support informal recognition of learning, and continue disseminating updated resources and evidence so the framework remains current and responsive to teachers' evolving needs.

Because the framework is designed for adoption and adaptation rather than replication, each actor can adjust the balance between subject-specific, pedagogical and transversal competences, the annual hours model or the recognition mechanisms to its own institutional context, while preserving the underlying competence structure that enables comparability and mobility across the ten partner countries and beyond. This distributed ownership, consistent with the shared-responsibility principle set out in Table 14, is intended to give the framework a life beyond the Digital First project itself.

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6 Risks and Mitigation Strategies

Even a well-designed professional learning framework can fail in implementation if predictable risks are left unmanaged. The WP2 evidence shows that informatics teachers already face heavy workloads, uneven access to professional learning and constant pressure from rapidly changing tools. A framework that ignored these realities would risk widening rather than closing existing gaps. Most of these risks, from unprotected time and overly generic training to invisible informal learning and provider-driven content, can be anticipated through the design choices described in the previous chapters, including differentiated pathways, recognition of applied evidence and quality assurance of external offers. Table 16 summarises the main risks identified during the development of this framework and pairs each with a practical mitigation strategy that schools, providers and policy makers can apply.

Table 16. Main risks and mitigation strategies.

Risk	Mitigation
CPD adds workload without protected time.	Schedule learning within working time where possible and recognise classroom application, mentoring and collaboration.
CPD is too generic or too basic.	Use diagnostics, differentiated pathways and advanced specialist modules.
Novel tools displace durable concepts.	Anchor all CPD in informatics concepts, competence maps and functional learning goals.
Learning does not transfer to the classroom.	Require application, follow-up, peer reflection and evidence of student learning.
Access depends on geography or school resources.	Use blended formats, open resources, regional hubs, equipment lending and targeted funding.
Informal learning remains invisible.	Recognise portfolios, peer validation, mentoring logs, resource creation and micro-credentials.
External CPD offers may become product centred.	Require transparency, privacy safeguards, tool-neutral outcomes and independent educational review.

Note: The risks were identified during the development of this framework, drawing on the WP2 evidence of heavy teacher workloads, uneven access to professional learning and pressure from rapidly changing tools (D2.2, D2.3), and on D4.1's finding that CPD is often voluntary and decentralised, leaving informal learning unrecognised. Each mitigation applies a design choice from the previous chapters — differentiated pathways, recognition of applied evidence and quality assurance of external offers.

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7 Conclusion

Teachers play a central role in strengthening informatics education. D2.2 and D2.3 show the direction in which teaching and learning need to develop towards stronger content alignment, interdisciplinarity, problem-solving, student-centred methods, collaboration, multimodality, personalisation, assessment, motivation, policy support, empowerment and inclusion (Digital First Consortium, 2024a; Digital First Consortium, 2024b). D4.1 shows that teachers cannot be expected to make this transition alone: teacher education and CPD systems are diverse, uneven and often dependent on personal initiative (Digital First Consortium, 2025a). A sustainable D4.5 framework must therefore help teachers diagnose their own needs, select reliable resources, learn with colleagues, experiment in the classroom and document professional growth.

This teacher-oriented D4.5 framework therefore defines the competences teachers need, the contemporary competences they need to acquire, the resources that can support them and the methods through which they can develop these competences. The framework is flexible rather than prescriptive, but it is not vague: it expects CPD to be competence-based, practical, classroom-connected, inclusive, evidence-informed, collaborative and continuously updated.

Looking across the deliverable, the chapters form one coherent professional-learning pathway. Chapter 2 defines the subject-specific, pedagogical and transversal competences that informatics teachers need and shows how expectations grow across teacher profiles, from primary generalists to upper-secondary specialists, vocational teachers and mentors (Digital First Consortium, 2025b; Digital First Consortium, 2025c). Chapter 3 compares these expectations with the current state of play and identifies the competences that teachers most need to acquire or strengthen — AI and generative AI literacy, data literacy, cybersecurity and digital citizenship, modelling and simulation, human-computer interaction, inclusive pedagogy, assessment and interdisciplinary teaching — and translates them into contemporary CPD themes supported by a transparent technology-and-evidence monitoring process.

Chapter 4 maps the resource ecosystem that teachers can draw on — European guidelines and policy resources, open course platforms, teacher resource hubs, assessment tools, professional communities and national providers — together with criteria for selecting high-quality resources. Chapter 5 turns the framework into practice through a continuous competence-development cycle, a balanced structure that combines a regularly updated common core with professional specialisation, an indicative annual learning path of approximately 15–32 hours, learning formats chosen for classroom transfer, and recognition of formal, non-formal and informal learning through proportionate evidence. Chapters 6 and 7 complete the framework by distributing responsibility across the professional-learning ecosystem, aligning quality assurance with the European Commission Guidelines for Teaching Informatics (European Commission, 2026) and pairing predictable implementation risks with practical mitigation strategies.

The framework will, however, be implemented in ten education systems that organise informatics teacher education very differently. D4.1 shows that in-service education, development and training for informatics teachers are provided by a varied mix of governmental bodies, universities, specialised teacher associations and regional training centres (Digital First Consortium, 2025a). This diversity is visible in the national examples reported in D4.1. In Bulgaria, training is offered by institutions such as Sofia University's Faculty of Mathematics and Informatics and Junior Achievement Bulgaria; in Croatia, by the Ministry of Science, Education and Youth in collaboration with CARNET, alongside Algebra University and the University of Zagreb faculties; in Cyprus, through joint initiatives of the Cyprus Computer Society and the Ministry of Education; in Finland, mainly by universities funded by the national agency of education, though without regular annual programmes; in Greece, by the Institute of Educational Policy,

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Peripheral Training Centres and the Computer Technology Institute "Diophantus"; in Italy, by the "Team Digitale" and emerging Ministry of Education initiatives; in Lithuania, by the Lithuanian Informatics Teacher Association (LInMA) and the Lithuanian Computer Society (LIKS); in Portugal, by Portuguese National Association of Informatics Teachers (ANPRI) and the Teacher Training Centres (CFAE); in Slovenia, by university faculties such as those of the Universities of Ljubljana and Maribor, together with ACM Slovenia and projects such as NAPOJ; and in Spain, by regional informatics teacher associations such as AAPRI in Andalusia and APICV in Valencia, supported by organisations like Programamos and regional centres such as Galicia's CFRs.

What all systems share, however, is more important than what separates them. Regardless of qualification pathway, teacher profile or national CPD arrangements, informatics teachers cannot rely on initial education alone: informatics is a rapidly evolving discipline that increasingly shapes other disciplines, and all partner countries recognise the importance of continuous professional development to keep teachers up to date (Digital First Consortium, 2025a).

In line with the European Commission Guidelines for Teaching Informatics, this means engaging in professional learning every year: maintaining integrated technological, pedagogical and content knowledge (TPACK) — knowing what to teach, how to teach it and which tools to use; collaborating with fellow informatics teachers; seeking coaching and school-based support; participating in active professional learning communities; and complementing formal courses with self-directed, lifelong learning through online courses, MOOCs and professional publications (European Commission, 2026). Because standalone courses have only limited impact on their own, this learning is most effective as an ecosystem blending formal, non-formal and informal opportunities, recognised through evidence of classroom application rather than attendance alone.

By working annually towards the competence set defined in this framework, informatics teachers — whatever their background — can remain confident professionals in a discipline that changes rapidly and strongly influences all others.

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Annex 1 - Example Annual CPD Pathways

The pathways in Table 17 are worked examples showing how the teacher profiles described in Table 5 can combine the common core, a selected professional pathway and classroom application into an annual plan, following the balanced CPD structure (Table 10) and the indicative annual model of 15–32 hours (Table 11). All hours are indicative: components may be rebalanced within the overall envelope — for example, an advanced micro-credential may extend the selected pathway beyond its typical range — and the total may be accumulated over more than one year.

Table 17. Example annual CPD pathways for different teacher profiles.

Teacher profile	Common core	Selected pathway	Application and contribution	Indicative total
Primary generalist or integrated-subject teacher	AI/data foundations; privacy and safety (8 h)	Computational thinking and inclusive block-based activities (8 h)	Trial two scenarios; mentor reflection; share adaptation (6 h)	22 h
Primary or lower-secondary specialist	AI, cybersecurity, curriculum update (8 h)	Assessment and interdisciplinary physical-computing project (10 h)	Classroom inquiry and peer lesson review (6 h)	24 h
Upper-secondary informatics teacher	Emerging-tech and learner-impact update (6 h)	Advanced AI/data/cybersecurity micro-credential (14 h)	Develop and peer-review a resource; mentor colleague (8 h)	28 h
Vocational or interdisciplinary teacher	AI, cybersecurity and workplace digitalisation update (8 h)	Physical computing, simulations and industry-linked project design (10 h)	Implement an interdisciplinary project; document learner impact (6 h)	24 h
Mentor / CPD leader	System priorities and responsible innovation (6 h)	Mentoring, facilitation and quality assurance (10 h)	Lead community cycle and evaluate transfer (10 h)	26 h

Note: Worked examples applying the teacher profiles (Table 5), the balanced CPD structure (Table 10) and the indicative 15–32-hour annual model (Table 11). All hours are indicative and may be rebalanced or accumulated over more than one year.

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Annex 2 - CPD Module Design Template for Informatics Teacher Training

This template can be used by CPD providers, teacher educators, schools or professional communities when designing a continuous or informal training module for informatics teachers. It translates the D4.5 framework into a practical planning tool: each module should be competence-based, classroom-connected, inclusive, evidence-informed and suitable for recognition.

The template is intentionally flexible. It can be used for a short workshop, an online module, a mentoring cycle, a micro-credential, a mobility activity or a school-based professional learning community. Not every module needs to be large, but every module should make clear what teachers will learn, how they will apply it and what evidence will show that professional learning took place. The template elements mirror the quality checklist in Table 15, so a completed template can be reviewed directly against those criteria. A quick quality check (A2.1) and a short worked example (A2.2) follow the template at the end of this annex.

Table 18. CPD module design template for informatics teacher training.

Template element	Guiding questions	Expected output / evidence
1. Module title and target group	What is the module called? Who is it for: primary generalist, primary or lower-secondary specialist, upper-secondary informatics teacher, vocational or interdisciplinary teacher, mentor / CPD leader or a mixed group (see Table 5)? What prior knowledge is expected?	Clear title, target group, ISCED level, prerequisites and pathway level: foundation, development, advanced/specialist or mentor/leadership.
2. Rationale and evidence base	Which teacher or classroom need does the module address? Which evidence supports this need: D2.2, D2.3, D4.1, D4.2/D4.3, EC Guidelines, local curriculum or school priorities?	Short justification that links the module to documented gaps, curriculum changes, learner needs or emerging technologies.
3. Competence alignment	Which subject-specific, pedagogical and transversal competences are addressed? Which contemporary competence is strengthened: AI, data, cybersecurity, inclusion, assessment, HCI, modelling, robotics or another area?	List of 2-4 competences with the expected development level and connection to the competence maps.
4. Functional dimension(s) addressed	Which function(s) of digital technology does the module enable teachers to develop through informatics: personal, representational/informative, interactional, instrumental, imaginative, heuristic and/or regulatory?	The selected function(s), with a brief note on how the module's informatics content develops each.
5. Learning outcomes	What will teachers know, understand, design, evaluate or apply by the end of the module? Are outcomes observable and realistic for the duration?	3-5 measurable learning outcomes, written from the teacher perspective.

Template element	Guiding questions	Expected output / evidence
6. Learning sequence	How will the module combine conceptual input, hands-on activity, discussion, collaboration, reflection and feedback? What is synchronous, asynchronous or classroom-based?	Short sequence of activities with approximate timing and format.
7. Classroom application	How will teachers transfer the learning into practice? Will they adapt a lesson, test an assessment, run a project, observe students, co-teach or pilot a resource?	Defined classroom task, professional task or implementation challenge.
8. Inclusion and safeguards	How does the module address accessibility, differentiation, equity, language, infrastructure, data protection, privacy, safety, bias, wellbeing and ethical use?	Safeguards and adaptation notes for different learners, schools and teaching contexts.
9. Evidence and recognition	What evidence will show professional learning beyond attendance? How can formal, non-formal or informal learning be recognised?	Portfolio artefact, lesson design, student work sample, rubric, reflection, peer feedback, mentoring log, badge, certificate or micro-credential evidence.
10. Follow-up and community	What happens after the session? Is there mentoring, peer discussion, a professional learning community, resource sharing, observation or later feedback?	Follow-up plan with responsible person/group and expected contribution to a community or resource hub.
11. Review information	Who authored or provided the module? Which tools, platforms or external providers are involved? When should the module be reviewed or retired?	Authorship, provider interests, sources, tools, costs, last review date, next review date and technology/evidence monitoring status.

Note: This template operationalises the D4.5 framework as a planning tool; its eleven elements mirror the quality checklist in Table 15, and it draws on the teacher profiles (Table 5), the competence domains (Tables 2–4) and the evidence sources (D2.2, D2.3, D4.1, D4.2/D4.3, EC Guidelines). A completed template can therefore be reviewed directly against the criteria in Table 15.

A2.1 Quick quality check before implementation

The module names the competences it develops and connects them to D4.2/D4.3 Competencies maps for informatics teachers (Digital First project, 2025b, 2025c) or another recognised framework.
The module identifies which function(s) of digital technology it develops (personal, representational/informative, interactional, instrumental, imaginative, heuristic, regulatory), where applicable.
The module includes a classroom application task, not only input or presentation.
The module addresses inclusion, accessibility, privacy, safety and ethical implications.
The module gives teachers resources they can adapt, not only theory or tool demonstration.

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The module includes evidence of learning suitable for a portfolio, certificate, badge, micro-credential or local recognition.
The module has follow-up support through mentoring, peer feedback, community discussion or later review.
The module records sources, provider interests, tool costs and a review date so it can be updated as technology and evidence change.

A2.2 Optional short module example

Example: Responsible use of generative AI in lower-secondary informatics.

Target group: lower-secondary teachers with basic informatics teaching experience.

Competence focus: AI/GAI literacy, assessment, ethics and classroom safeguards.

Learning sequence: short conceptual input, comparison of AI outputs, discussion of bias and hallucination, design of a classroom task, peer review of safeguards.

Classroom application: teachers pilot one AI-output evaluation activity and collect student reflections.

Evidence: adapted lesson plan, rubric, student examples and teacher reflection.

Recognition: portfolio entry or micro-credential evidence where available.

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