D2.4 Problem-Based Learning Implementation Guide

5G-DiGITs

Cross-sectorial education and talent development for beyond 5G Digital and Green Industrial Technologies.

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Reviewer 1:	Giuseppe Caso (KAU)
Reviewer 2:	Vasileios Mavrikakis (Infolysis)
Contributors:	Dionysia Triantafyllopoulou (TUC)

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Abbreviations

B5G: Beyond 5G

ECTS: European Credit Transfer and Accumulation System

EQF: European Qualification Framework

IoT: Internet of Things

ITU-T: International Telecommunication Union Telecommunication Standardization Sector

KSA: Knowledge, Skills and Abilities

LMS: Learning Management System

MVP: Minimum Viable Product

PBL: Problem Based Learning

PLCs: Professional Learning Communities

QA: Quality Assurance

WP: Work Package

3GPP: 3rd Generation Partnership Project

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Executive Summary

This deliverable builds upon the work of deliverable D2.3, "Real-World Problems and Case Studies", under Task T2.3, which designed and developed real problem-based teaching and learning methods within the 5G-DiGITs project. It translates those foundations into a framework for educators, trainers, and mentors, aiming to support the implementation, facilitation, and continuous improvement of Problem-Based Learning (PBL) activities across the 5G-DiGITs curriculum.

PBL is a learner-centred methodology grounded in constructivist and experiential learning principles. It develops knowledge, skills, and abilities (KSA) through engagement with authentic, open-ended problems that reflect real professional contexts. Within 5G-DiGITs, PBL acts as a core pedagogical approach promoting interdisciplinary competence, industry relevance, and innovation capacity. Students become active problem solvers and collaborators, guided by educators and industry mentors who facilitate inquiry rather than deliver content.

The deliverable presents a PBL Implementation Framework that provides a roadmap for embedding PBL into higher education and professional training. It introduces a Case Study Template, created in D2.3, to ensure consistency and quality across problem scenarios. Practical guidance is offered for adapting these case studies to different institutional contexts, aligning them with curriculum structures, workload, and European Credit Transfer and Accumulation System (ECTS) requirements.

Recognizing the pivotal role of educators and mentors, the guide defines essential facilitation and mentoring competences. It provides tools for guiding inquiry, managing group processes, supporting student autonomy, and fostering collaboration with industry experts. These practices ensure that learning remains engaging, inclusive, and professionally meaningful.

To maintain quality and sustainability, the guide also proposes a Quality Assurance and Continuous Improvement Framework. This includes data collection tools (surveys, feedback, and observation), metrics for evaluating PBL effectiveness, and iterative improvement strategies. These mechanisms establish a feedback-driven system that supports pedagogical excellence and adaptation to technological and educational change.

The deliverable puts PBL into action within the 5G-DiGITs educational model. It equips educators and institutions with the tools to deliver learning experiences that prepare students for future careers. By embedding PBL into teaching and curriculum design, the project advances its broader goal: enhancing Europe's capacity to develop digitally skilled, innovative, and industry-ready professionals capable of driving sustainable technological transformation.

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1 Introduction

The purpose of this deliverable is to provide a comprehensive guide for educators, trainers, and mentors on implementing the Problem-Based Learning (PBL) approach within the 5G-DiGITs curriculum. Building upon the pedagogical foundations and case studies developed in deliverable D2.3 [1], this document translates the conceptual framework into guidance for teaching practice. It provides methodologies, facilitation techniques, and assessment strategies to ensure that PBL is effectively integrated into formal learning environments.

The deliverable also supports the broader 5G-DiGITs mission to modernize digital education and enhance the alignment between higher education, research, and industry in the rapidly evolving 5G and beyond-5G (B5G) landscape. By focusing on real-world challenges and competence-based learning, this guide allows educators to promote innovation-driven, problem-solving mindsets among students and lifelong learners.

This deliverable is a direct outcome of the activities of task T2.3, which focuses on designing and implementing real problem-based teaching and learning methods. T2.3 resulted in the identification and development of a set of seven real-world case studies representing key domains of 5G application, such as smart cities, eHealth, edge computing, and sustainable agriculture.

While D2.3 concentrated on defining the PBL methodology and producing authentic case studies aligned with the 5G-DiGITs competence framework, the focus of this deliverable is on implementation. Therefore, it provides the necessary tools for educators to embed these case studies into their courses. It puts the methodology in use by describing facilitation approaches, educator training guidelines, assessment models, and mechanisms for quality assurance and continuous improvement.

The primary audience of this guide includes educators, trainers, curriculum designers, and industry mentors involved in the 5G-DiGITs consortium and partner institutions. It is also intended for academic leaders and quality assurance officers responsible for curriculum design and pedagogical innovation. Beyond the consortium, the deliverable serves as a resource for the broader education and training community seeking to adopt PBL in digital technology disciplines. By offering adaptable tools, templates, and examples, it supports replication and scalability across different institutional, national, and disciplinary contexts.

The document is organized as follows:

Section 2 provides an overview of the principles of PBL and their placement within the context of the 5G-DiGITs vision and competence framework.

Section 3 provides a detailed implementation framework and step-by-step guide for integrating PBL into courses and curricula.

Section 4 focuses on the role and training of educators and mentors, presenting facilitation techniques and collaborative practices.

Section 5 concludes with recommendations for quality assurance, monitoring, and continuous improvement to ensure sustainability.

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Through this structure, the deliverable functions as both a pedagogical reference and a practical manual, supporting the systematic adoption of PBL across 5G-DiGITs educational activities.

2 Overview of Problem-Based Learning (PBL) in the 5G-DiGITs context

2.1 PBL Methodology and Principles

PBL is an instructional approach that positions learners at the centre of the educational process by engaging them with authentic, real-world challenges that require the application of critical thinking, collaboration, and domain-specific knowledge. Originating in medical education, PBL has evolved into a widely adopted methodology in engineering, technology, and business disciplines due to its capacity to simulate complex professional environments and promote active, deep learning.

In a PBL environment, students are presented with an open-ended or ill-structured problem that mirrors a realistic situation. They work collaboratively or individually to define the problem, identify what knowledge and skills they already possess, and determine what additional information they must acquire. Through inquiry, investigation, and iterative reflection, learners construct new knowledge and develop solutions that integrate technical, analytical, and interpersonal competences.

PBL is grounded in constructivist learning theory **Error! Reference source not found.**, which emphasizes that individuals build new understanding based on prior experiences and active engagement. Learning is contextualized in meaningful scenarios, promoting cognitive engagement and long-term retention. Furthermore, the collaborative nature of PBL allows students to negotiate meaning, challenge assumptions, and articulate reasoning, thereby developing metacognitive and communication skills.

The educational benefits of PBL are well-documented, and include enhanced problem-solving and analytical abilities, improved teamwork and communication, and greater intrinsic motivation [3]. By requiring learners to take responsibility for their own inquiry process, i.e., setting goals, monitoring progress, and reflecting on outcomes, PBL also fosters self-regulation and lifelong learning habits. These outcomes align closely with modern competence-based education, where the acquisition of knowledge, skills, and abilities (KSA) is prioritized over rote learning. Consequently, PBL is particularly suited for preparing learners for emerging 5G and digital transformation sectors, which demand adaptability, interdisciplinary collaboration, and innovation-driven thinking.

2.2 PBL within the 5G-DiGITs Vision and Competence Framework

The 5G-DiGITs project seeks to develop and implement an advanced educational ecosystem that bridges the gap between academic training and the evolving demands of the 5G and beyond-5G industries. Within this vision, PBL functions as a cornerstone pedagogical approach that connects theoretical knowledge with real-world practice. By embedding authentic technological and business challenges into the curriculum, PBL directly supports the project’s mission to

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cultivate a highly skilled, innovation-oriented workforce capable of driving Europe's digital transformation.

The conceptual framework developed under Work Package 2 (WP2) identifies a combination of technical, digital, and transversal skills as essential for professionals in the 5G domain. These include expertise in network architecture, edge computing, cybersecurity, data analytics, and sustainability, complemented by critical thinking, creativity, teamwork, and entrepreneurial mindsets. PBL provides structured yet flexible means to develop these competences simultaneously. Each problem scenario or case study exposes learners to interdisciplinary challenges that require integrating multiple domains—technical design, policy, business models, and ethical considerations—reflecting the holistic skill set demanded by industry.

Furthermore, PBL promotes collaboration between academia and industry partners by using authentic use cases derived from real 5G applications (e.g., smart cities, eHealth, precision agriculture). These industry-driven problems ensure that learning activities are relevant, updated, and aligned with future workforce needs. In this way, PBL puts the 5G-DiGITs vision of experiential, competence-based education in operation, bridging innovation ecosystems, research, and practical application.

2.3 The Role of Educators and Facilitators in PBL

A fundamental shift in pedagogy occurs when implementing PBL. Educators experience the transition from being transmitters of knowledge to facilitators of learning. Their role is not to provide solutions but to create conditions under which learners can explore, question, and construct understanding collaboratively. This role requires educators to design meaningful problem scenarios, guide group processes, monitor progress, and prompt reflection without dictating outcomes.

Effective facilitation involves several core competences. Educators must be skilled in *scaffolding learning* i.e., providing strategic support early in the inquiry process and gradually reducing it as students gain confidence and autonomy. They also need to manage group dynamics, ensuring equitable participation and constructive dialogue. Moreover, facilitators must help students articulate their reasoning, connect theory to practice, and reflect critically on both the process and outcomes of their work.

In 5G-DiGITs, the facilitation process is enhanced by close collaboration with industry professionals, who provide authentic insights and feedback from professional contexts. This model strengthens the bridge between academic and industrial learning, ensuring that learners develop both technical expertise and professional behaviours. By adopting this role, educators become catalysts for innovation-oriented, self-directed, and collaborative learning cultures that are essential to the 5G era.

2.4 Integration of PBL into the 5G-DiGITs Curriculum and Learning Outcomes

PBL is systematically embedded into the 5G-DiGITs curriculum to account for approximately 40% of the overall learning experience, ensuring that experiential, problem-oriented activities are a core component rather than an adjunct to traditional teaching. The integration process involves

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aligning PBL case studies and problem scenarios with the programme's learning outcomes and competence framework, guaranteeing that each activity contributes directly to targeted knowledge and skills acquisition.

Each PBL case study developed under T2.3 serves as a modular learning unit that can be implemented across different courses and disciplines. The design of these scenarios ensures progressive complexity, encouraging students to apply prior learning to increasingly sophisticated real-world problems. For example, early cases may focus on system design and simulation, while advanced ones may engage learners in strategic decision-making, sustainability assessment, or business model innovation.

Assessment in the PBL-integrated curriculum emphasizes competence demonstration rather than content recall. Evaluation criteria include the quality of problem analysis, creativity in proposed solutions, teamwork effectiveness, and reflection on learning. This competence-based assessment ensures alignment with both academic standards and industry expectations.

To sum up, the integration of PBL within the 5G-DiGITs curriculum realises the project's pedagogical vision by transforming abstract knowledge into actionable expertise. It strengthens technical and transversal competences and cultivates learners who are capable of innovation, collaboration, and critical thinking; skills essential to sustaining Europe's leadership in the digital and 5G-driven economy.

3 PBL Implementation Framework and Guidelines

This section provides a comprehensive framework for the implementation of the PBL approach within the 5G-DiGITs curriculum. It is intended as a practical guide for educators, trainers, and professionals who will put PBL-based learning in use within their teaching practices. Building on the foundations established in [1], it translates the pedagogical rationale and case study design principles into a set of actionable guidelines for classroom and laboratory implementation.

The framework outlined here ensures that PBL activities are systematically embedded in the 5G-DiGITs educational model, representing approximately 40% of the total learning workload. It also guarantees that the learning process remains competency-driven, interdisciplinary, and aligned with both academic and industrial expectations.

3.1 Step-by-Step Guide to Introducing PBL in Courses

The integration of PBL into existing or newly designed courses requires a structured and iterative process. Based on the pedagogical principles described D2.3, the following roadmap outlines the essential phases for implementing PBL effectively in 5G-DiGITs programmes.

Step 1: Define Learning Outcomes and Competence Targets

The process begins with a clear definition of the intended learning outcomes and associated competence areas, as established in the 5G-DiGITs Competence Framework (T2.2). Educators should specify which KSA items are to be developed through PBL, whether these relate to technical domains such as 5G infrastructure design, network management, and edge computing, or transversal competences such as teamwork, communication, and innovation management.

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Learning outcomes must be measurable, achievable within the course duration, and aligned with the European Qualification Framework (EQF) and European Credit Transfer and Accumulation System (ECTS) credit workload.

Step 2: Select or Develop a Real-World Problem Scenario

Each PBL cycle should revolve around a realistic, ill-structured problem. Educators may:

- Select one of the seven 5G-DiGITs case studies identified in D2.3, or
- Develop a new problem scenario using the official case study template (see Section 3.2 below).

In both cases, the problem must reflect an authentic challenge faced by the 5G ecosystem, e.g., as sustainable urban mobility, immersive eHealth, smart agriculture, or network energy efficiency, and should require interdisciplinary analysis and collaboration.

Step 3: Map the Problem to Course Content and Curriculum Objectives

The selected problem must be explicitly linked to course-level objectives and to the overarching programme learning outcomes. This ensures that each activity directly contributes to the intended competences rather than functioning as an isolated exercise.

Educators should identify where the PBL activity fits within the course structure (e.g., replacing traditional laboratory work or project assignments) and document this alignment within the course syllabus.

Step 4: Design the PBL Learning Cycle

PBL activities should be structured into a sequence of stages that reflect the learning process described in D2.3:

1. Problem presentation and clarification: Students are introduced to the real-world context and asked to define the problem in their own words.
2. Inquiry and research: Learners identify knowledge gaps, gather data, and consult relevant technical and academic sources.
3. Formation of ideas and solution design: Teams develop potential solutions or prototypes, applying theoretical concepts to practical challenges.
4. Presentation and reflection: Students present their outcomes, receive feedback, and reflect on their learning process.

This structure may be completed within a single module or extended over multiple courses, depending on the scope and complexity of the case.

Step 5: Facilitate Collaborative and Guided Learning

Educators act as facilitators, guiding inquiry rather than delivering content. Facilitation involves supporting group dynamics, prompting critical questioning, and providing strategic guidance while allowing autonomy.

Where possible, industry mentors should participate to ensure that the problems and feedback reflect current technological and professional realities.

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Step 6: Assess Learning Through Competence Demonstration

Assessment in PBL is both formative and summative, focusing on process as well as outcomes. Rubrics should evaluate:

- Analytical and problem-solving abilities
- Creativity and innovation
- Team collaboration and communication, and
- Professional and ethical awareness.

The evaluation criteria must be transparent and directly linked to the competences outlined in the course learning outcomes.

Step 7: Reflect, Document, and Improve

At the conclusion of each PBL cycle, educators should conduct debriefing sessions with students and mentors. Reflection is central to metacognitive development and continuous improvement. Documentation of challenges, outcomes, and feedback enables the refinement of both pedagogical approaches and case study design for future iterations.

The different phases of PBL Implementation are depicted in Figure 1.

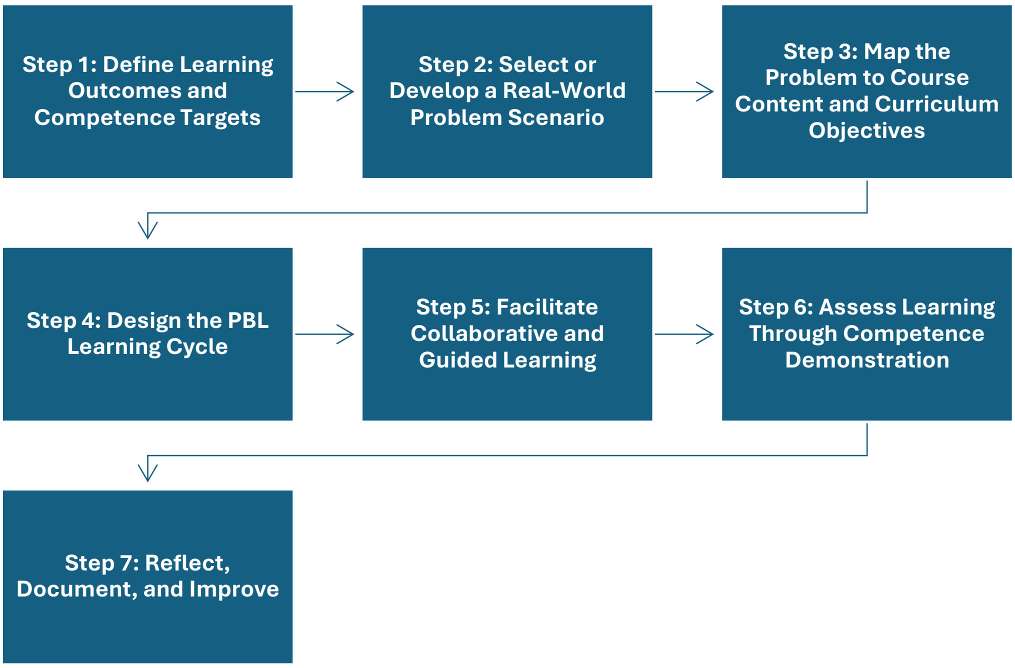

Figure 1. PBL Implementation Phases

3.2 Using the Case Study Template for Problem Scenarios

The Case Study Template developed under T2.3 provides a structured format for designing, documenting, and implementing PBL scenarios within 5G-DiGITs. Its purpose is to ensure consistency across courses and partners while maintaining flexibility for contextual adaptation.

The template's structure, detailed in D2.3, supports educators in systematically describing each problem, its pedagogical goals, and its practical requirements.

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3.2.1 Core Components of the Template

Each case study includes the following elements:

- **General Information:** Case title, thematic focus, duration, target learner level, and required prerequisites.
- **Introduction and Context:** A concise narrative describing the real-world background, including industry relevance, societal importance, and technological focus.
- **Detailed Description of the Problem:** A clearly defined yet open-ended problem statement outlining stakeholders, constraints, and objectives.
- **Learning and Training Tasks:** Specific learning activities, assignments, and roles for individuals and teams.
- **Usage Guidelines:** Recommendations for implementation, including group size, timeline, assessment strategy, and facilitation techniques.
- **Resources and Materials:** Links to technical tools, datasets, simulation environments, standards, e.g., 3rd Generation Partnership Project (3GPP), International Telecommunication Union Telecommunication Standardization Sector (ITU-T), and literature.
- **Mapping to Courses:** Explicit correspondence between the case study and 5G-DiGITs modules, learning outcomes, and competences.

3.2.2 Design Principles

Educators designing new cases using this template should ensure that:

1. Problems are authentic, relevant, and complex enough to stimulate inquiry.
2. Learning activities integrate theoretical and practical dimensions.
3. Scenarios encourage collaboration, reflection, and creativity.
4. Assessment methods are competence-based and transparent.

Using a standardized format also facilitates cross-institutional collaboration, as educators can easily share, compare, and adapt case studies across partner universities and training centres.

3.3 Customizing and Adapting the 5G-DiGITs Case Studies

The seven case studies developed in D2.3 represent diverse real-world applications of advanced 5G technologies, ranging from smart cities and eHealth to edge computing and sustainable agriculture. Each case has been designed to be modular, adaptable, and scalable to various learning environments and educational levels.

Adapting for Contextual Relevance

Educators are encouraged to tailor these cases to their local, institutional, or disciplinary contexts while retaining the integrity of the PBL structure. Adaptation may involve:

- Adjusting the technical depth to match student backgrounds (e.g., bachelor’s vs. master’s level).
- Incorporating region-specific data, regulations, or infrastructure constraints.
- Aligning with national or institutional sustainability, innovation, or digitalization priorities.

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- Integrating institutionally available resources (labs, simulation platforms, or local 5G testbeds).

Integrating Industry and Research Contexts

Customization should also consider opportunities for collaboration with industry partners and ongoing research projects. For example, a case study on smart mobility may incorporate data from a local 5G pilot city or involve a telecom partner in mentoring student teams. Such integration strengthens the authenticity of the learning experience and provides students with first-hand exposure to professional practice.

Ensuring Pedagogical Coherence

While customizing case studies, educators should maintain consistency with the 5G-DiGITs pedagogical framework. This includes adherence to the PBL learning cycle, active facilitation methods, and competence-based assessment. Modifications should be documented within the case study template to preserve traceability and facilitate quality assurance.

3.4 Integrating PBL Activities into the Curriculum (≈40% Learning Workload)

The 5G-DiGITs curriculum integrates PBL as a core component representing approximately 40% of the total learning workload across courses. This proportional integration ensures that experiential, problem-driven learning complements rather than replaces theoretical instruction. It also aligns with European higher educational frameworks emphasizing learning outcomes and workload-based credit systems.

Curricular Integration Strategies

1. Modular Integration:

   PBL can be embedded as a dedicated module or project unit within existing courses. For instance, a 6 ECTS course may allocate 2-3 ECTS to PBL activities linked to real-world 5G challenges.

2. Cross-Course Implementation:

   Some PBL cases may span multiple courses, enabling interdisciplinary collaboration, e.g., combining network design, Internet of Things (IoT) security, and digital entrepreneurship modules.

3. Capstone or Project-Based Integration:

   Advanced PBL cases, such as the “Edge-Enabled Urban Mobility Minimum Viable Product (MVP)”, can serve as final capstone projects, encouraging synthesis of knowledge acquired throughout the programme.

Workload and Credit Alignment

To ensure transparency and comparability across partners, workload calculations for PBL activities should follow the standard ECTS convention of 25-30 hours per credit. Educators should document:

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- Expected student workload for each task (in-class, self-study, and teamwork).
- The contribution of each PBL activity to assessed competences.
- The distribution of formative and summative assessments.

Institutional Support and Sustainability

Successful integration of PBL into curricula requires institutional commitment. This includes providing faculty training in facilitation techniques, establishing supportive digital environments (e.g., collaborative platforms, simulation tools), and recognizing PBL facilitation in academic workload models. Moreover, alignment with quality assurance systems—through feedback loops and periodic evaluation—ensures sustainability and scalability of PBL practices within and beyond 5G-DiGITs.

The PBL Implementation Framework and Guidelines presented in this section translate the pedagogical philosophy and case study design principles of D2.3 into a practical roadmap for educators. By following the step-by-step implementation process, using the standardized case study template, customizing scenarios for local contexts, and ensuring proportional curricular integration, educators can effectively embed real-world problem solving into the 5G-DiGITs learning ecosystem. This structured approach supports not only the development of technical expertise but also the cultivation of transversal skills, creativity, collaboration, and innovation, that are essential for a sustainable, digitally empowered European workforce.

4 Role and Training of Educators and Mentors

The successful implementation of PBL within the 5G-DiGITs curriculum relies heavily on the effectiveness of educators and mentors in facilitating active, student-centred learning. As highlighted in D2.3, PBL requires a fundamental shift in the role of the educator, from the traditional transmitter of knowledge to a facilitator of learning processes and co-constructor of knowledge. This section provides practical guidance on facilitation techniques, group management, fostering learner autonomy, and collaboration between academic staff and industry mentors. It also emphasizes the training and professional development required to ensure educators and mentors are well equipped to sustain high-quality PBL practices in the 5G-DiGITs ecosystem.

4.1 Facilitation Techniques for PBL Sessions

Effective facilitation is crucial to the success of any PBL activity. As described in D2.3, the facilitator’s role is not to provide direct answers or predetermined solutions, but to guide inquiry, encourage critical thinking, and support collaborative problem solving. Facilitators help students navigate uncertainty, clarify their understanding, and connect theory to practice.

Several key facilitation techniques are recommended:

1. Socratic Questioning:

   Use open-ended, probing questions that stimulate analysis, synthesis, and evaluation. For example: “What evidence supports this assumption?” or “How does this concept relate to your proposed solution?”

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This approach encourages students to justify their reasoning and recognize alternative perspectives.

2. Scaffolding Learning:

   Provide structured support at the beginning of the problem-solving process, gradually reducing it as learners gain confidence. This “fading” of guidance mirrors the constructivist principle of supporting the learner’s zone of proximal development thus helping them to move from dependence to autonomy.

3. Encouraging Peer Interaction:

   Facilitate dialogue among students rather than between students and teacher. Group discussion, peer explanation, and debate enhance conceptual understanding and foster ownership of the learning process.

4. Managing the Learning Environment:

   Establish clear expectations, timelines, and collaborative norms at the start of the PBL cycle. A structured yet flexible environment ensures that inquiry remains focused and purposeful.

5. Promoting Reflective Practice:

   Incorporate reflection checkpoints throughout the activity. Ask learners to articulate what they have learned, what challenges remain, and how their understanding has evolved. Reflection reinforces metacognitive awareness and consolidates learning.

Educators implementing these facilitation strategies must remain adaptable, responsive, and empathetic, balancing guidance with autonomy to sustain learner engagement and motivation.

The PBL facilitation techniques are summarised in Figure 2.

Figure 2. PBL Facilitation Techniques

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4.2 Guiding Inquiry and Managing Group Processes

As PBL relies on teamwork and collective inquiry, educators must also act as process managers, ensuring that group interactions are effective, inclusive, and aligned with learning objectives. Learning through collaboration mirrors real-world professional contexts, where multidisciplinary teams solve complex technological problems.

Key strategies for guiding inquiry and managing group dynamics include:

Structuring Group Work:

Form small, diverse teams (typically 4-6 members) to maximize knowledge exchange and balance individual strengths. Assign roles such as coordinator, recorder, research lead, and presenter to promote accountability.

Establishing Inquiry Pathways:

Encourage students to define what they know, need to know, and plan to learn. This self-directed inquiry map helps maintain focus and transparency throughout the PBL cycle.

Facilitating Effective Communication:

Use group debriefing sessions, progress checkpoints, and peer feedback to maintain momentum and prevent communication breakdowns. The facilitator's role is to model constructive dialogue and mediate conflicts when necessary.

Supporting Equitable Participation:

Monitor group interactions to ensure all members contribute meaningfully. If certain students dominate or disengage, use targeted interventions (e.g., rotating roles, reflective feedback) to rebalance participation.

Monitoring Progress and Providing Feedback:

Adopt formative assessment approaches, such as brief check-ins, feedback logs, or mentor comments, to track progress and address emerging difficulties. Feedback should focus on the reasoning process rather than the final answer.

By managing group processes thoughtfully, educators create psychologically safe spaces where students can take intellectual risks, challenge assumptions, and co-create knowledge; key outcomes of effective PBL practice.

4.3 Supporting Student Autonomy and Reflection

A defining characteristic of PBL is the cultivation of learner autonomy. Students are expected to take ownership of their learning by identifying what they need to learn, planning how to acquire it, and evaluating the results. The educator's role is to scaffold this process and encourage habits of self-directed, reflective inquiry.

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Practical approaches to foster autonomy and reflection include:

1. **Goal Setting and Learning Contracts:**

   Encourage students to set personal and team learning goals at the beginning of each project. Documenting these in a learning contract fosters accountability and direction.

2. **Guided Reflection Activities:**

   Integrate short reflection exercises at key stages of the PBL cycle. For example, reflection journals, "muddiest point" discussions, or group retrospectives help learners articulate challenges and achievements.

3. **Metacognitive Prompts:**

   Ask questions such as "What strategies worked well for your team?" or "How has your understanding of the problem evolved?" to help learners think about their own thinking.

4. **Feedback Loops:**

   Encourage two-way feedback between educators and learners. Constructive feedback not only supports learning but models reflective professional practice.

5. **Gradual Release of Responsibility:**

   As students demonstrate competence, reduce instructor intervention. This empowers learners to independently navigate uncertainty and ambiguity, core features of real-world problem solving.

By supporting autonomy and reflection, educators enable learners to perform the transition from dependent recipients of information to self-regulated professionals capable of continuous learning, an essential attribute in the rapidly evolving 5G and digital innovation sectors.

4.4 Collaboration between Academia and Industry Mentors

The 5G-DiGITs project emphasizes collaboration between students, academic staff, and industry professionals. Industry mentors play a pivotal role in ensuring that learning remains grounded in real-world challenges, technologies, and professional expectations. Their participation transforms PBL activities into valid learning experiences that bridge the gap between theory and practice.

Mechanisms for effective academia–industry collaboration include:

- **Co-Design of Problem Scenarios:**

  Industry partners can contribute directly to the creation or refinement of PBL case studies by providing real datasets, operational challenges, or system design constraints. This ensures authenticity and relevance to current technological developments.

- **Mentorship during PBL Cycles:**

  Industry experts can serve as co-facilitators or guest mentors during problem-solving sessions, offering feedback, insights, and professional guidance. Their presence reinforces the application of academic concepts to practical contexts.

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- **Joint Evaluation and Feedback:**

  Inviting industry mentors to participate in final presentations or evaluations adds professional rigor to assessment. Students benefit from external perspectives and exposure to industry expectations.

- **Internship and Project Continuity Opportunities:**

  Successful PBL projects can evolve into internships, thesis projects, or collaborative research initiatives, fostering long-term partnerships between academia and industry.

To ensure consistency and quality, mentor involvement should be supported by clear guidelines outlining roles, expected time commitment, communication channels, and confidentiality agreements where necessary.

Regular coordination meetings between educators and mentors help align educational and professional objectives and ensure that feedback provided to students remains coherent and constructive.

The implementation of PBL within the 5G-DiGITs curriculum transforms the educator's role from lecturer to facilitator, guide, and mentor. Effective facilitation, thoughtful management of group processes, and support for student autonomy are essential to realizing the full pedagogical potential of PBL. Moreover, structured collaboration between academia and industry enriches the learning process by embedding authenticity, professional relevance, and innovation-oriented perspectives into education.

Through continuous training and reflective practice, educators and mentors become central actors in cultivating the next generation of digital professionals: creative, adaptive, and capable of solving complex problems in the evolving 5G and beyond-5G landscape.

5 Quality Assurance, Monitoring, and Continuous Improvement

Ensuring the quality and effectiveness of the PBL approach within the 5G-DiGITs curriculum requires a structured system of monitoring, evaluation, and feedback. As emphasized in D2.3, PBL introduces dynamic, student-centred learning processes that must be continuously observed and refined to maintain educational relevance, alignment with competence goals, and responsiveness to industry needs.

The quality assurance (QA) framework presented below integrates data-driven evaluation methods, clearly defined performance indicators, and iterative improvement mechanisms. Together, these ensure that PBL remains an evolving, evidence-informed practice capable of supporting the long-term objectives of the 5G-DiGITs project and the broader European digital education agenda.

5.1 Data Collection Tools (Surveys, Feedback, Observation)

To monitor the impact and effectiveness of PBL implementation, a combination of qualitative and quantitative data collection tools should be systematically applied. These instruments

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enable continuous feedback from all stakeholders—students, educators, and industry mentors—and provide the empirical basis for evaluation and decision-making.

1. Student and Educator Surveys

   Structured online surveys are used to gather perceptions on PBL effectiveness, workload, facilitation quality, and skill development. Pre- and post-course surveys help measure learning progression and satisfaction. Standardized Likert-scale questions may cover areas such as problem relevance, collaboration, and perceived competence gain.

2. Focus Groups and Interviews

   Small group discussions and semi-structured interviews allow for in-depth exploration of participant experiences. These qualitative insights help contextualize survey results and identify barriers or success factors not captured by quantitative tools.

3. Peer and Mentor Feedback

   Peer evaluation and mentor reflections are valuable for assessing teamwork, professional engagement, and authenticity of problem-solving processes. Feedback logs and mentor observation notes can highlight areas where guidance or industry involvement could be strengthened.

4. Classroom and Online Observation

   Educators and quality coordinators can use structured observation checklists to record evidence of learner engagement, inquiry depth, and group dynamics during PBL sessions. Digital learning platforms, e.g., Learning Management System (LMS) analytics, can also track student participation, collaboration frequency, and resource usage.

5. Performance Artifacts and Portfolios

   Student deliverables, including reports, prototypes, or presentations, serve as direct evidence of learning outcomes. When archived systematically, these artifacts support longitudinal analysis of learning quality and innovation capacity.

These complementary tools form a comprehensive feedback ecosystem that ensures continuous insight into how PBL is functioning across contexts and partners, see Figure 3.

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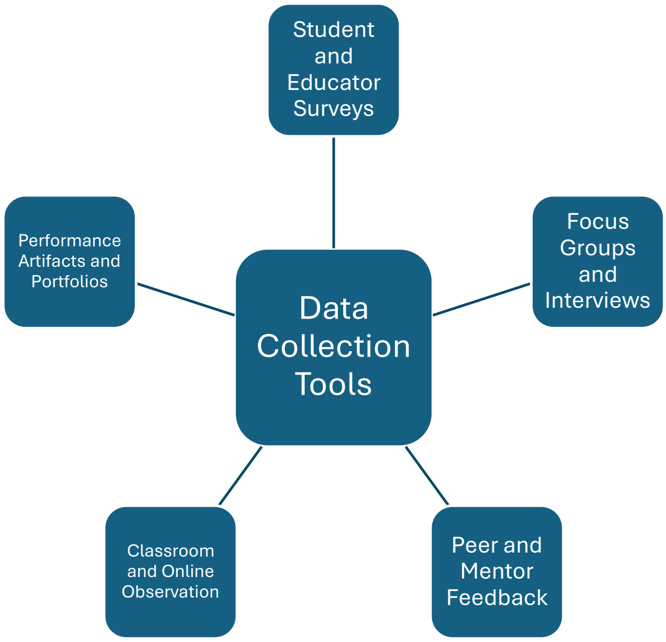

Figure 3. 5G-DiGITs Feedback Ecosystem

5.2 Evaluation Metrics for PBL Effectiveness

To ensure comparability and accountability across institutions, 5G-DiGITs adopts a set of standardized indicators for evaluating PBL effectiveness at both the learning and institutional levels.

These metrics build upon the competence-based education principles described in D2.3 and align with the project's learning outcome framework.

Student Learning Metrics:

- Achievement of targeted KSAs through problem-solving tasks.
- Improvement in critical thinking, creativity, and communication skills, as assessed through rubrics.
- Student engagement and motivation, measured through attendance, participation, and reflection activities.
- Quality of teamwork, peer collaboration, and interdisciplinary integration.
- Application of theoretical knowledge to real-world contexts (evaluated through project outputs).

Institutional and Programmatic Metrics:

- Degree of PBL integration within course curricula (percentage of workload aligned with PBL, as targeted at ~40%).
- Educator readiness and professional development in PBL facilitation (training completion rates, self-assessment).
- Industry participation levels (number of mentors involved, frequency of engagement).
- Student satisfaction and employability outcomes (career readiness indicators, internships, project spin-offs).

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- Evidence of curricular innovation, resource sharing, and dissemination across partner institutions.

These indicators provide a structured foundation for periodic review and reporting, ensuring that both educational and strategic objectives of PBL integration are being achieved.

5.3 Strategies for Continuous Improvement and Sustainability

PBL quality assurance is not a static process but an iterative cycle of design, implementation, evaluation, and enhancement. Building on the reflective principles of PBL itself, continuous improvement requires systematic feedback analysis and institutional learning.

1. **Iterative Review Cycles**

   After each academic term or PBL cycle, educators, mentors, and quality coordinators should jointly review collected data and identify lessons learned. Findings are then translated into targeted actions—such as revising case studies, improving facilitation training, or adjusting workload distribution.

2. **Professional Learning Communities (PLCs)**

   Cross-institutional educator networks foster shared learning and peer support. Regular workshops, webinars, and experience-sharing sessions encourage reflection on best practices and promote methodological consistency across the 5G-DiGITs consortium.

3. **Integration with Institutional Quality Systems**

   PBL evaluation results should feed into existing institutional QA mechanisms (course reviews, accreditation processes, curriculum committees). Embedding PBL monitoring within established governance structures ensures long-term sustainability.

4. **Continuous Industry Engagement**

   Regular feedback from industry mentors and partners guarantees that PBL problems remain aligned with technological developments and labour market trends. Updating case studies based on this input maintains the authenticity and relevance of learning.

5. **Dissemination and Knowledge Transfer**

   The documentation of successful PBL practices, templates, and evaluation results should be shared through the 5G-DiGITs knowledge base and open educational resources. This facilitates replication and scalability beyond the project’s lifetime.

A robust system of quality assurance, monitoring, and continuous improvement ensures that PBL within 5G-DiGITs remains adaptive, impactful, and sustainable. Through systematic data collection, well-defined evaluation metrics, and iterative enhancement processes, educators and institutions can maintain pedagogical excellence while continuously aligning learning experiences with the evolving realities of the 5G and beyond-5G ecosystem.

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6 Conclusion

This deliverable consolidates the work initiated in D2.3, “Real-World Problems and Case Studies” by operationalizing the PBL methodology within the 5G-DiGITs educational model. It provides educators and mentors with practical tools, templates, and quality mechanisms to integrate real-world, competence-driven learning experiences into their courses. By translating pedagogical principles into structured implementation guidelines, the document supports the systematic adoption of PBL as a core teaching strategy for digital and engineering education.

Through the framework presented, PBL becomes not only a pedagogical innovation but also a driver of institutional transformation, promoting interdisciplinary collaboration, learner autonomy, and stronger links between academia and industry. The emphasis on structured facilitation, reflective learning, and iterative quality improvement ensures that PBL remains adaptable to diverse educational contexts and evolving 5G and beyond-5G technologies.

7 References

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