Developing competences on the Internet of Things through digital fabrication laboratories.

Co-funded by the Erasmus+ Programme of the European Union

Guidelines for IoT FabLab development

Blended Learning Needs and Opportunities for IoT-FabLabs: A Cross-European Survey of Students, Teachers, and Trainers

Executive Summary

This report presents the findings of Task 2.2 within WP2 of the Erasmus+ project FabLabs, which aims to establish a solid foundation for the development of innovative educational materials for IoT-oriented FabLabs. The objective of this task was to assess the needs, expectations, and readiness of key stakeholders — university students, secondary school students, educators, trainers, technical staff, and industry representatives — in order to define pedagogical and technical requirements for future IoT-FabLab learning environments.

A survey was conducted across six partner countries (Germany, Italy, Portugal, Slovenia, and Spain), reaching 187 participants, of which 92 completed the questionnaire. Respondents represented a balanced mix of teachers (53%), students (25%), and technical staff (22%). Gender representation was 42% female and 58% male, with ages ranging from 16 to 65 years.

The analysis of responses reveals several important insights:

Digital Competence: Most participants rated their technical digital skills as intermediate to advanced, while pedagogical and learner-related competences were reported at basic to intermediate levels. This highlights a need for structured teacher training in digital pedagogy.

Learning Preferences: Both educators and learners expressed strong preferences for blended learning models (eLearning combined with workshops) and hands-on approaches such as project work and FabLab workshops. Face-to-face teaching and group learning also remain highly valued. Remote laboratories were perceived as less effective.

Technology Priorities: IoT, robotics, AI/machine learning, general electronics, additive manufacturing (3D printing), and CAD/CAE software were consistently identified as critical technologies for FabLabs in the near future. These reflect broader digitalisation trends in industry and education.

Assessment and Infrastructure: A majority of participants emphasised the importance of pre-knowledge assessment before training. For distance learning, desktop PCs and laptops were the dominant devices expected to be used. Despite growing interest in FabLabs, awareness of FabLab initiatives remains limited, pointing to a need for stronger promotion and visibility strategies.

The findings of this survey provide a valuable evidence base for the project's next steps. They inform the development of WP2 guidelines for IoT FabLab design, underpin the creation of high-quality digital and blended learning materials in WP3, and support the planning of continuing professional development courses for teachers in WP4.

By highlighting stakeholder needs and preferences, this report contributes to a more learner-centred, inclusive, and future-oriented vision of IoT-FabLabs. Ultimately, the results will guide the consortium in designing learning environments that combine technical excellence with pedagogical innovation, thereby enhancing Europe's capacity to train the next generation of digital professionals.

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1. Introduction and Theoretical Framework

The increasing digitalisation of society and industry requires new educational models that bridge theory and practice in emerging technologies. FabLabs (fabrication laboratories) have become a central element of this shift, providing open spaces where learners can experiment with digital fabrication, electronics, and Internet of Things (IoT) systems. Within higher education, FabLabs are increasingly seen as catalysts for innovation, interdisciplinarity, and experiential learning [1][2].

The Erasmus+ project addresses this transformation by focusing on IoT-oriented FabLabs as environments that combine technical infrastructures with learner-centred pedagogies. The objective of work package 2 is to establish the basis for developing educational materials that reflect the real needs of stakeholders. This requires a thorough understanding of target groups such as:

1. University students, including efforts to engage underrepresented groups such as women in STEM;
2. Secondary school students, preparing for entry into higher education;
3. University professors and trainers, who design and deliver curricula;
4. Companies and technical staff, who bridge academia and the labour market.

The pedagogical orientation of this work is grounded in blended learning and experiential models. Blended learning approaches — combining digital content delivery with face-to-face interaction — have been shown to improve learning outcomes, engagement, and flexibility [3][4]. FabLabs, by enabling “learning by making”, align closely with constructivist theories, where knowledge is constructed through hands-on activities and problem-solving [5].

This report (Task 2.2) therefore investigates the current state of teaching and learning in IoT FabLabs across five European countries. Its findings are intended to guide the pedagogical design of digital materials (WP3) and professional training courses (WP4).

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2. Methodology

The research employed a survey-based approach to capture the needs, expectations, and experiences of different stakeholder groups across partner institutions. The survey was designed collaboratively by project partners, building on previous FabLab-related studies [6][7], and translated into six languages (English, German, Italian, Portuguese, Slovenian, Spanish).

2.1. Survey Design and Participants

- The survey contained both closed (Likert-scale) and open-ended questions.
- It targeted three main profiles: teachers/trainers, students/participants, and technical staff.
- Topics included digital competences, preferred teaching/learning formats, experiences with FabLabs, technology priorities, and infrastructure needs.

A total of 187 responses were collected, of which 92 were complete and thus included in the analysis. Respondents represented:

- Educators/teachers: 53%
- Students: 25%
- Technical staff: 22%

The gender distribution was 42% female and 58% male. Participants ranged in age from 16 to 65 years.

2.2. Data Analysis

Responses were analysed quantitatively (descriptive statistics, frequency distributions) and qualitatively (content analysis of open responses). The data were categorised according to participant profiles and then compared across groups and countries. This mixed-methods approach ensured both breadth and depth in the interpretation of stakeholder needs [8].

2.3. Limitations

The sample size was modest and not representative of all FabLab stakeholders in Europe. Responses were unevenly distributed across countries, which may reflect differences in FabLab maturity or project partner networks. Despite these limitations, the dataset provides robust indications of trends and needs relevant to WP2 objectives.

3. Survey Results and Analysis

The survey results are structured around four key dimensions: digital competences, learning preferences, technology priorities, and infrastructural challenges.

3.1. Digital Competences

Teachers and technical staff: Majority rated themselves at intermediate to advanced levels in technical digital competences (professional collaboration, reflective practice, communication).
Students: Mostly intermediate competence.
Across all groups, pedagogical competences (managing digital resources, assessment, empowering learners) and learner-related competences were lower, indicating a need for teacher professional development.
This aligns with findings in digital education research, which stress the importance of strengthening digital pedagogy for effective integration of technology [9][10].

3.2. Learning Preferences

Respondents strongly favoured blended learning models, combining eLearning with workshops and project work.
- Workshops and project-based learning were rated highest across groups.
- Group learning and face-to-face lectures remained relevant, especially for initial engagement.
- Remote laboratories received weaker preference, suggesting that fully virtual solutions may not adequately replace hands-on experiences.

This preference supports existing evidence that blended and project-based approaches enhance engagement and skill acquisition in STEM education [11][12].

3.3. Technology Priorities for FabLabs

The technologies identified as most important for future FabLabs include:

- *IoT (Internet of Things)*
- *Robotics and general electronics*
- *Artificial intelligence / machine learning*
- *Additive manufacturing (3D printing)*
- *CAD/CAE design and analysis software*
- *Big Data and Blockchain (emerging, but less prioritised)*

These findings confirm wider trends in Industry 4.0 and digital education, where connectivity, automation, and data-driven intelligence are central [13][14].

3.4. Assessment and Infrastructure

A majority of respondents emphasised the importance of pre-knowledge assessment before training, consistent with principles of adaptive and personalised learning [15].
For distance learning, desktop PCs and laptops were the dominant devices expected.
Many participants were unaware of FabLab facilities at their institutions, indicating a lack of promotion and visibility. This calls for stronger communication strategies, outreach activities, and institutional integration to increase FabLab usage.

4. Implications & Recommendations for WP2–WP4

The analysis of survey data (Task 2.2) has revealed distinct patterns in learner preferences, educator competences, and technological priorities. Across all partner countries, the results underline a strong demand for blended learning formats, hands-on workshops, project-based activities, and practical integration of IoT-related technologies into FabLab contexts.

This chapter translates those survey findings into **concrete implications** and **actionable recommendations** for the FabLabs courses. Each planned unit is considered individually, followed by a section of cross-cutting recommendations that apply across the entire curriculum and link directly to the project's subsequent work packages (WP2 guidelines, WP3 learning materials, WP4 professional development).

4.1. Unit 1 – Digital Innovation & DIY Design Thinking

Implications

- Survey participants strongly favoured *project-based and workshop-style learning formats*. This aligns with design thinking approaches, which are inherently iterative and hands-on.
- The relatively lower digital pedagogical competence among educators indicates a need for structured guidance when implementing design thinking in blended and online settings.
- Students expressed high motivation for collaborative group learning, which fits well with design sprints and co-creation methods in innovation contexts.

Recommendations

1. **Embed project-based tasks** in each module [11], e.g., design challenges where learners apply innovation frameworks to IoT or sustainability scenarios.
2. **Use blended delivery**: Introduce concepts online (videos, case studies) but prioritise *in-person workshops* in FabLabs for prototyping (Garrison & Vaughan, 2008).
3. **Promote inclusivity**: Integrate strategies to involve underrepresented groups (especially women in STEM) in collaborative innovation projects [16].
4. **Develop teacher toolkits**: Provide structured lesson plans and facilitation guides for design thinking workshops to reduce dependence on individual pedagogical skills [17].

4.2. Unit 2 – IoT Product Development

Implications

- IoT, robotics, electronics, and CAD/CAE were among the *most prioritised technologies* in the survey, confirming their central role in FabLabs.
- Respondents highlighted **blended learning with strong hands-on components** as essential for mastering IoT development.

- Technical staff rated their competence high, but students and teachers often showed intermediate levels — signaling a need for **structured capacity building**.

Recommendations

1. **Hands-on prototyping** should be central: workshops on Arduino, Raspberry Pi, or microcontrollers should form the backbone of the unit [1].
2. **Pre-knowledge assessment** (endorsed by >80% of survey respondents) should be implemented before IoT courses, ensuring learners are matched with the correct difficulty level [18].
3. **Cross-disciplinary approach**: Encourage collaboration between mechanical, software, and electronics learners within FabLab settings [7].
4. **Bridge academia and industry**: Integrate case studies from companies to connect FabLab IoT projects to real-world innovation ecosystems [14].

4.3. Unit 3 – Blockchain and IoT

Implications

- Survey results indicate that while blockchain was not the top-priority technology, it was recognised as an **emerging skill area** in industrial IoT (IIoT).
- Teachers and students alike rated their **digital competences as intermediate**, suggesting blockchain will require additional scaffolding and introductory materials.
- Learners prefer **interactive tutorials and webinars** for abstract/complex topics — an ideal fit for blockchain basics.

Recommendations

1. **Layer the curriculum**: Begin with blockchain basics (interactive online content), then move to FabLab workshops where learners build simple IoT-blockchain integrations [19].
2. **Highlight practical applications** in IIoT (e.g., supply chain transparency, predictive maintenance) to ensure relevance [20].
3. **Encourage collaborative projects** where multidisciplinary teams explore blockchain-enabled IoT prototypes.
4. **Ethics and trust**: Incorporate modules on cybersecurity and ethical implications, addressing the survey’s call for competence in ICT problem-solving and security [21].

4.4. Unit 4 – AI and Big Data

Implications

- AI and machine learning were highlighted as **key technologies** for future FabLabs, alongside IoT and robotics.
- Learners and teachers expressed strong preferences for **interactive eLearning** and **blended workshops**, which fit well with AI labs and data challenges.
- Survey data shows **lower confidence in pedagogical competence** for teaching advanced digital skills, requiring scaffolded teaching models.

Recommendations

1. **Adopt tiered learning paths**: Provide beginner, intermediate, and advanced tracks (e.g., data tools → machine learning → deep learning) [24].
2. **Blended model delivery**: Use online tutorials for coding basics and ML theory; reinforce through hands-on FabLab workshops (e.g., training IoT devices with AI) [22].
3. **Project-based assignments**: Encourage learners to apply AI to real FabLab-generated data (e.g., sensor data from IoT prototypes).
4. **Ethics and responsibility**: Ensure all modules integrate discussion on ethical AI, data privacy, and bias, reflecting both EU policy frameworks and survey emphasis on ICT security competences [23].

4.5. Cross-cutting Recommendations

- **Blended Learning First**: Across all units, combine online delivery with FabLab workshops and project-based learning.
- **Pre-knowledge Assessment**: Introduce diagnostic quizzes to personalise learner pathways.
- **Teacher Support**: Develop teaching guides and CPD courses that strengthen digital pedagogy, addressing competence gaps highlighted in the survey [9].
- **Promotion & Visibility**: Survey findings showed many students are unaware of FabLab availability. Each unit should include outreach and showcase activities (hackathons, open days).
- **Inclusion & Diversity**: Pay special attention to engaging female students and underrepresented groups in FabLab innovation projects [16].

5. Pedagogical Design Framework for Unit Development

The FabLabs course units (Digital Innovation, IoT Product Development, Blockchain & IoT, and AI & Big Data) are being developed by different institutions across partner countries. To ensure coherence, interoperability, and high-quality pedagogy, this chapter provides a **reference structure** for unit creation. The framework builds on:

- **Survey insights (T2.2)**: learner preference for blended learning, workshops, and project-based formats.
- **Implications & Recommendations**: thematic requirements for each unit.
- **Educational frameworks**: Bloom's Taxonomy [25], DigCompEdu [9], and Constructive Alignment [26].

This chapter provides a pedagogical design framework to guide the development of the FabLabs course units — *Digital Innovation, IoT Product Development, Blockchain & IoT, and AI & Big Data*. Its purpose is to ensure that all units, though created by different institutions across partner countries, follow a coherent, comparable, and high-quality format. At the same time, the framework allows for local adaptation to each FabLab's context, resources, and strengths.

The chapter is structured in eleven sections (5.1–5.11), each addressing a key dimension of unit design:

1. Learning Objectives
2. Levels of Complexity
3. Unit Structure Template
4. Teaching Guide
5. Assessment Strategy
6. Resource Requirements
7. Soft Skills Integration
8. Inclusivity & Accessibility
9. Prerequisites & Dependencies
10. Application Domains & Ethical Considerations
11. Unit Design Canvas

How to Use the Framework in Practice:

- As a checklist: Before developing a unit, partners should review all eleven framework sections to ensure no pedagogical element is overlooked.
- As a guide for structure: Each unit should follow the suggested modular structure, while adapting timing, examples, and tools to local FabLab conditions.
- As a design support: The Teaching Guide, Soft Skills Integration, and Assessment Strategy sections provide direct strategies and prompts that educators can embed in lesson planning.
- As a planning tool: The Unit Design Canvas should be filled in by each institution, serving both as a planning document and as a comparable reference across units.
- As a quality standard: The framework ensures interoperability and coherence, while respecting the diversity of institutional strengths and FabLab setups.

By following this framework, partner institutions (and even others beyond the projects scope) will create course units that are consistent in quality and format, while still leaving room for innovation, flexibility, and FabLab-specific adaptation.

5.1. Learning Objectives

Each unit should combine **cognitive, technical, and soft skill objectives**:

- **Cognitive**: Understanding core concepts and theoretical frameworks.
- **Technical**: Applying tools, methods, and FabLab equipment in practice.
- **Soft skills**: Communication, collaboration, adaptability, critical thinking.

Example (Unit 2: IoT Product Development)

- Cognitive: Explain IoT system architecture and product development lifecycle.
- Technical: Prototype a simple IoT device (e.g., Smart Badge) using microcontrollers and CAD.
- Soft skills: Collaborate in interdisciplinary teams, practice project management, and present outcomes.

5.2. Levels of Complexity

The survey results emphasized differentiated learning. Each unit should therefore offer:

- **Basic level**: introductory concepts and simple exercises accessible to all learners.
- **Advanced level**: deeper analysis, extended projects, or complex problem-solving.

Example – Unit 4 (AI & Big Data)

- Basic: Use Pandas for simple data analysis.
- Advanced: Build and evaluate a neural network with TensorFlow.

5.3. Unit Structure Template

Each unit should follow a modular, blended learning format, ensuring consistency across all course units:

1. **Introduction** (context, objectives, learning outcomes).
2. **(Interactive) Diagnostic Quiz** (assess pre-knowledge, adapt learner pathways).
3. **Theoretical Input** (short lectures, online videos, case studies).
4. **Hands-on Practical Application** (FabLab workshops, simulations, prototypes).
5. **Soft Skills Integration** (group work, peer feedback, reflective prompts).
6. **Assessment** (formative quizzes, project presentation, reflective assignments).
7. **Conclusion & Reflection** (summarise insights, encourage transfer to new contexts).
8. **Time Allocation** (per module/session: lecture vs. hands-on).

Example (Unit 2: IoT Product Development)

- Each module begins with a **quiz** → then introduces concepts (e.g., IoT architecture) → followed by **hands-on prototyping** (Smart Badge) → ends with **peer review** and a **mini-presentation**.

- Time frames:
    - Lecture (30 min): fundamentals of blockchain.
    - Exercise (90 min): deploy smart contracts with IoT devices.

5.4. Teaching Guide

To address the survey's finding that many educators lack confidence in digital pedagogy, each unit should be accompanied by a **teacher's guide**, including:

- Lesson outlines (suggested timings, Notes and tips for lesson delivery).
- Visual aids and interactive teaching techniques.
- Reflection prompts (e.g., "What trade-offs did your team face when balancing usability vs. technical complexity?").
- Alternative teaching paths (e.g., using online simulations if lab tools are unavailable).

Example (Unit 2: IoT Product Development)

- **If programming skills are lacking**: use Arduino Blocks or Tinkercad Circuits.
- **If FabLab access is limited**: use CAD simulators and online PCB ordering instead of in-house PCB production.

5.5. Assessment Strategy

Assessment should be **continuous, formative, and reflective**:

- **Pre-knowledge assessment**: entry quiz per module.
- **Formative assessment**: peer feedback, group discussions, interim project checkpoints.
- **Summative assessment**: final project prototype (e.g., IoT Smart Badge) and group presentation.
- **Soft skills assessment**: evaluated through peer review, group reflections, and role assignments.
- **Evaluation methods**: quizzes, coding notebooks, group projects, case studies, oral presentations.

Example – Unit 4 (AI & Big Data)

- Formative: Jupyter notebook tasks.
- Summative: final project applying machine learning to a real dataset.

5.6. Resource Requirements

Each unit should specify:

- **Hardware**: IoT kits, microcontrollers, 3D printers, sensors (specific **FabLab equipment**: e.g., soldering stations, laser cutters.).
- **Software**: CAD tools (Fusion 360, Tinkercad), Arduino IDE, LMS.
- **FabLab equipment**: soldering stations, laser cutters, 3D printers.

- **Online tools**: collaborative platforms (Miro, GitHub, Moodle).
- **Learning environments**: e.g., Jupyter/Colab notebooks, interactive videos.
- **Optional/nice-to-have tools**: e.g., RFID/NFC modules, cloud blockchain services.

5.7. Soft Skills Integration

Beyond technical competence, the survey results and unit drafts underline that soft skills are essential for preparing learners to succeed in interdisciplinary and innovation-driven contexts. FabLabs, by their collaborative and project-based nature, are particularly well-suited to foster these competences. Each unit should therefore explicitly integrate soft skill development alongside technical and cognitive objectives.

Key Soft Skills to Address

- **Collaboration & Teamwork**: Working effectively in interdisciplinary groups, distributing roles, and engaging in peer review.
- **Communication**: Presenting project outcomes clearly (orally, visually, and in writing), giving and receiving constructive feedback.
- **Critical & Strategic Thinking**: Evaluating trade-offs in design choices, identifying strengths/weaknesses of approaches, and making informed decisions.
- **Adaptability & Flexibility**: Adjusting prototypes, learning from trial and error, responding to constraints or unexpected results.
- **Creativity & Problem-Solving**: Generating innovative ideas, applying design thinking, and approaching problems with an open mindset.
- **Time & Project Management**: Planning deliverables, using tools such as Kanban boards, and meeting deadlines.
- **Ethical Awareness**: Reflecting on social, environmental, and ethical dimensions of innovation (particularly relevant in AI, blockchain, and IoT contexts).

Implementation Strategies in Units

1. **Design activities that require teamwork**: Group projects, collaborative prototyping, and peer feedback sessions.
2. **Embed reflection prompts**: Encourage learners to articulate their decisions, challenges, and lessons learned (e.g., “What trade-offs did your team face between usability and technical complexity?”).
3. **Assign rotating roles within teams**: Such as facilitator, documenter, designer, tester — to build versatility and leadership.
4. **Integrate communication tasks**: Presentations, poster sessions, demo days, or pitches to simulate real-world dissemination of ideas.
5. **Use problem-based learning scenarios**: Pose open-ended challenges requiring creativity and adaptability, especially in interdisciplinary teams.
6. **Evaluate soft skills explicitly**: Incorporate peer/self-assessment rubrics for teamwork, communication, and critical reflection into the assessment strategy.

7. **Link to real-world practice**: Highlight how soft skills underpin success in professional environments (e.g., interdisciplinary collaboration in IoT product development or ethical decision-making in AI projects).

Example Applications in Units

- **Unit 1 (Digital Innovation & Design Thinking)**: Encourage empathy and creativity through user-centered design sprints.
- **Unit 2 (IoT Product Development)**: Foster project management and teamwork via group prototyping of IoT devices.
- **Unit 3 (Blockchain & IoT)**: Promote critical thinking through debates on decentralisation and security trade-offs.
- **Unit 4 (AI & Big Data)**: Support communication and ethical awareness through presentations of AI projects, including reflection on fairness and bias.

5.8. Inclusivity & Accessibility

The survey revealed that many learners were unaware of FabLab facilities, and female students remain underrepresented. Therefore:

- Use **inclusive examples** (applications in healthcare, sustainability, social impact).
- Ensure **accessibility** of digital resources (captions, alternative formats).
- Encourage **diverse participation** in project teams and leadership roles.

5.9. Prerequisites & Dependencies

Each unit should define:

- **General prerequisites**: e.g., basic programming or electronics knowledge.
- **Module-specific prerequisites**: indicated at the start of each module (e.g., Python basics before ML models).

Example – Unit 4 (AI & Big Data)

- Prerequisite: familiarity with Python before entering Module 2 (ML).

5.10. Application Domains & Ethical Considerations

Survey feedback and EU policy frameworks highlight the importance of connecting FabLab learning with real-world impact. Each unit should therefore include:

- **Application domains**: e.g., smart cities, supply chains, healthcare, education.
- **Ethical and sustainability aspects**: e.g., data privacy in AI, energy consumption in blockchain, equity in access to IoT.

Example – Unit 3 (Blockchain & IoT)

- Application: tracking supply chain transparency.
- Ethical issue: energy consumption of blockchain systems.

5.11. Unit Design Canvas

To operationalise this framework, a **Unit Design Canvas** has been developed. It consolidates all the sections above into a single, fillable template table that each partner institution can complete when designing their unit.

SECTION	SUBSECTION	DESCRIPTION / TO BE FILLED IN
GENERAL INFORMATION	Unit Title	______________
	Institution Responsible	______________
	Target Learners	
1. LEARNING OBJECTIVES	Cognitive Goals	______________
	Technical Goals	______________
	Soft Skill Goals	______________
2. LEVELS OF COMPLEXITY	Basic	______________
	Advanced	______________
3. UNIT STRUCTURE	Introduction	______________
	Theoretical Input	______________
	Practical Activity	______________
	Soft Skills Integration	______________
	Assessment	______________
	Conclusion & Reflection	______________
4. TEACHING GUIDE NOTES	Suggested Teaching Methods	______________
	Reflection Prompts	______________
	Alternative Teaching Paths (if resources limited)	______________
5. ASSESSMENT STRATEGY	Pre-knowledge Check	______________
	Formative Tasks	______________
	Summative Assessment	______________
	Soft Skills Evaluation	______________
6. RESOURCE REQUIREMENTS	Hardware	______________
	Software	______________
	FabLab Equipment	______________
	Online Tools	______________
7. INCLUSIVITY & ACCESSIBILITY	Involving Underrepresented Groups	______________
	Accessibility Features	______________

6. Conclusion (summary and strategic takeaways)

This report has presented the findings of Task 2.2 within Work Package 2 of the Erasmus+ FabLabs project. Drawing on survey data collected from multiple stakeholder groups across partner countries, it has analysed current competences, expectations, and needs in relation to IoT-driven FabLab education. The results have informed both the pedagogical framework for unit development and the recommendations for course content, ensuring alignment with real learner and teacher contexts.

Key insights can be summarised as follows:

Blended learning and hands-on approaches dominate learner preferences: Participants consistently emphasised workshops, project-based tasks, and group collaboration as the most effective formats for learning complex digital technologies.

Digital competences are unevenly distributed. While technical competences are relatively advanced among staff, pedagogical and learner-oriented competences remain moderate, highlighting the need for targeted professional development.

IoT, AI, robotics, and digital fabrication are core technologies. These were identified as top priorities for FabLab integration, validating the consortium's chosen unit structure. Blockchain and Big Data were recognised as emerging fields requiring scaffolding and accessible entry points.

Soft skills are central to success. Communication, collaboration, adaptability, and critical thinking were seen as essential for applying technical knowledge effectively in FabLab environments.

Awareness and inclusivity remain challenges. Many learners are unaware of FabLab facilities at their institutions, and women and underrepresented groups remain under-engaged, calling for active outreach and diversity strategies.

Strategic takeaways for the consortium when developing the individual units:

Design for blended learning by default. Each unit should integrate online preparatory content with FabLab-based workshops and project work.

Strengthen teacher support. Comprehensive teaching guides, toolkits, and CPD courses are necessary to raise confidence in digital pedagogy.

Adopt modular, tiered pathways. Units should offer basic and advanced levels with clear prerequisites, enabling learners with diverse backgrounds to engage effectively.

Integrate ethics and application domains. Each unit must connect technical content to real-world use cases and address ethical, social, and sustainability implications.

Ensure visibility and inclusivity. Outreach, open events, and inclusive teaching strategies are crucial to maximise FabLab usage and diversify participation.

By implementing these strategic directions, the project will not only deliver a coherent and innovative FabLab curriculum but also contribute to the wider goals of digital transformation, sustainable innovation, and capacity building in European education. This report thus provides the evidence base and pedagogical roadmap for the successful creation of FabLab course units in the next stages of the project.

References

[1] Blikstein, P. (2013). Digital fabrication and 'making' in education: The democratization of invention. FabLabs: Of machines, makers and inventors. Transcript.

[2] García-Peñalvo, F. J., et al. (2021). Educational innovation with makerspaces and FabLabs. Education in the Knowledge Society, 22, e25612.

[3] Garrison, D. R., & Vaughan, N. D. (2008). Blended learning in higher education. Jossey-Bass.

[4] Hrastinski, S. (2019). What do we mean by blended learning? TechTrends, 63(5), 564–569.

[5] Papert, S. (1993). Mindstorms: Children, computers, and powerful ideas. Basic Books.

[6] Smith, R. C., Hielscher, S., Dickel, S., Söderberg, J., & van Oost, E. (2020). Making as pedagogy: FabLabs and makerspaces for learning. Cogent Education, 7(1).

[7] Troxler, P., & Wolf, P. (2017). Digital fabrication in education: A review of FabLabs and makerspaces in higher education. Procedia CIRP, 62, 626–631.

[8] Creswell, J. W., & Plano Clark, V. L. (2017). Designing and conducting mixed methods research. Sage.

[9] Redecker, C., & Punie, Y. (2017). European Framework for the Digital Competence of Educators (DigCompEdu). JRC Science for Policy Report.

[10] Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. Teachers College Record, 108(6), 1017–1054.

[11] Prince, M. (2004). Does active learning work? A review of the research. Journal of Engineering Education, 93(3), 223–231.

[12] Bernard, R. M., Borokhovski, E., Schmid, R. F., Tamim, R. M., & Abrami, P. C. (2014). A meta-analysis of blended learning and technology use in higher education. Educational Research Review, 9, 17–34.

[13] Kagermann, H., Wahlster, W., & Helbig, J. (2013). Recommendations for implementing the strategic initiative INDUSTRIE 4.0. National Academy of Science and Engineering.

[14] Xu, L. D., Xu, E. L., & Li, L. (2018). Industry 4.0: State of the art and future trends. International Journal of Production Research, 56(8), 2941–2962.

[15] Brusilovsky, P., & Millán, E. (2007). User models for adaptive hypermedia and adaptive educational systems. The Adaptive Web. Springer.

[16] European Commission (2020). A Union of Equality: Gender Equality Strategy 2020–2025.

[17] Razzouk, R., & Shute, V. (2012). What is design thinking and why is it important? Review of Educational Research, 82(3), 330–348.

[18] Brusilovsky, P., & Millán, E. (2007). User models for adaptive hypermedia and adaptive educational systems. The Adaptive Web. Springer.

[19] Christidis, K., & Devetsikiotis, M. (2016). Blockchains and smart contracts for the Internet of Things. IEEE Access, 4, 2292–2303.

[20] Casino, F., Dasaklis, T. K., & Patsakis, C. (2019). A systematic literature review of blockchain-based applications: Current status, classification and open issues. Telematics and Informatics, 36, 55–81.

[21] Kshetri, N. (2017). Can blockchain strengthen the Internet of Things? IT Professional, 19(4), 68–72.

[22] Bernard, R. M., Borokhovski, E., Schmid, R. F., Tamim, R. M., & Abrami, P. C. (2014). A meta-analysis of blended learning and technology use in higher education. Educational Research Review, 9, 17–34.

[23] Floridi, L., Cowls, J., Beltrametti, M., et al. (2018). AI4People—An ethical framework for a good AI society. Minds and Machines, 28(4), 689–707.

[24] Jordan, M., & Mitchell, T. (2015). Machine learning: Trends, perspectives, and prospects. Science, 349(6245), 255–260.

[25] Anderson, L. W., & Krathwohl, D. R. (2001). A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives: complete edition. Addison Wesley Longman, Inc.

[26] Biggs, J. & Tang, C. (2011). Teaching for Quality Learning at University, What the students does, 4th edition. The Society for Research into Higher Education and Open University Press (McGraw Hill Education): Maidenhead, Berks.