S.T.E.P.S.
Robotics and Education

Project Result 7

Recommendations and Guidelines for Higher Education Institutions, Secondary Schools and Education Authorities

Improving the Training of Pre- and In-Service Secondary Teachers in STEM and Robotics through S.T.E.P.S. Results

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UniLaSalle Institut Polytechnique
ΧΑΡΟΚΟΠΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ HAROKOPIO UNIVERSITY
GFOSS Open Technologies Alliance
UNIVERSIDAD DE BURGOS
T.C. MİLLÎ EĞİTİM BAKANLIĞI
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Preamble

This document presents the final recommendations and guidelines developed as Project Result 7 of S.T.E.P.S., an Erasmus+ Cooperation Partnership dedicated to strengthening integrated STEM education through accessible, inclusive and open-source educational robotics.

As the main result of Work Package 5, these recommendations and guidelines bring together the project's research, educational resources and implementation experience and translate them into practical directions for Higher Education Institutions, secondary schools, teachers, school leaders, educational authorities and policymakers.

The document is primarily intended for Higher Education Institutions involved in the initial and continuing education of secondary-school teachers. It also addresses secondary schools, teachers, school leaders, educational authorities and policymakers whose decisions influence the adoption and sustainability of educational robotics. Its purpose is to support these stakeholders in moving beyond the isolated use of robotics as a technical activity and towards its meaningful integration into interdisciplinary, inclusive and learner-centred STEM education.

The document presents 28 recommendations organised around three complementary levels of action: Higher Education Institutions and teacher-education programmes; secondary schools and classroom practitioners; and educational policy and systemic sustainability. The recommendations address teacher confidence, pedagogical and curricular integration, classroom implementation, assessment, inclusion, computational thinking, open-source infrastructure, professional development and long-term institutional support.

Rather than prescribing a single implementation model, PR7 proposes a flexible framework that can be adapted to different educational systems, curricula, learner profiles and levels of available infrastructure. In doing so, it translates the evidence and experience generated through S.T.E.P.S. into practical guidance for the sustainable use of educational robotics in teacher education and secondary-school learning.

The S.T.E.P.S. Consortium
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1. Introduction

1.1. Background

Integrated Science, Technology, Engineering and Mathematics (STEM) education has become one of the main priorities of educational systems worldwide. Rapid technological advances, digital transformation, artificial intelligence, automation and the growing complexity of societal challenges require educational institutions to prepare learners with competences that go far beyond traditional disciplinary knowledge. Contemporary societies increasingly demand citizens who are capable of solving complex problems, collaborating in multidisciplinary environments, thinking critically, analysing data and adapting to continuous technological change.

Within this context, educational robotics has emerged as one of the most promising pedagogical approaches for supporting integrated STEM education. Unlike conventional instructional methods, robotics provides authentic learning environments in which students combine theoretical knowledge with practical experimentation, allowing them to design, construct, programme and evaluate technological solutions to real-world problems. Robotics also promotes creativity, computational thinking, engineering design skills and collaborative learning, while increasing students' motivation and engagement.

Nevertheless, despite the growing interest in educational robotics across Europe, significant challenges remain. Access to robotics education is still uneven between countries and regions, teacher confidence varies considerably, many educational initiatives continue to focus primarily on technological skills while neglecting broader STEM integration, and issues related to inclusion, gender equality and educational equity continue to represent important barriers for many learners.

S.T.E.P.S. was conceived as a response to these challenges. Through the development of an open-source robotics ecosystem centred on the FOSSBot platform, together with teacher-training resources, digital learning materials, pilot experiences and Open Educational Resources, the project seeks to democratise access to high-quality integrated STEM education across Europe and promotes robotics as an educational methodology capable of supporting interdisciplinary learning, creativity, critical thinking, problem-solving and social responsibility.

1.2. The S.T.E.P.S. Project

S.T.E.P.S. (STEM Teaching and Education Platform for Students) is an Erasmus+ Cooperation Partnership that aims to improve the quality, accessibility and

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inclusiveness of integrated STEM education through innovative educational resources based on educational robotics and open technologies. The project brings together Higher Education Institutions, educational organisations, and technology and open-source specialists from several European countries, combining complementary expertise in STEM education, robotics, teacher education, digital technologies and educational research.

A distinctive characteristic of S.T.E.P.S. is its commitment to openness. Instead of relying on proprietary robotics kits, the project is built around FOSSBot, an open-source robotic platform whose hardware, software and educational resources are freely available. This approach reduces implementation costs, facilitates adaptation to different educational contexts and enables both teachers and students to move beyond simply using technology towards understanding, modifying and creating technological solutions.

The project has developed an integrated educational ecosystem composed of several complementary resources. These include the physical FOSSBot robot, a digital twin that enables virtual experimentation, an Instruction Manual, a comprehensive Pedagogical Manual, a School Box containing classroom activities and learning scenarios, and a Massive Open Online Course for teacher professional development. These resources were complemented by testing, pilot implementation and evaluation activities conducted across partner countries.

Together, these components offer several entry points for introducing robotics into integrated STEM education. Depending on their experience, objectives and available infrastructure, users may begin with the digital environment, a learning scenario, the MOOC, the Pedagogical Manual or the physical FOSSBot, before progressively exploring other parts of the ecosystem.

Throughout the project, particular attention has been given to educational inclusion, gender equality, accessibility and sustainability. Rather than considering these dimensions as complementary objectives, S.T.E.P.S. integrates them as fundamental design principles guiding the development of its educational materials and activities. This reflects current European educational priorities and contributes to ensuring that robotics education becomes accessible to a broader and more diverse population of learners.

1.3. Purpose of this Document

The purpose of this document is to provide evidence-informed recommendations for the effective implementation of educational robotics within integrated STEM education at

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both secondary and higher education levels. In addition, it offers policy recommendations to guide policymakers and educational authorities in creating the conditions necessary for the sustainable adoption and scaling of educational robotics across education systems.

The recommendations are based on several complementary results developed throughout the project. PR1 provided the initial evidence base through a review of scientific literature and the identification and expert evaluation of 50 good practices in educational robotics and integrated STEM education across five European countries. This work also formed the basis of the Springer chapter published by Merino-Fernández et al. (2025). PR5 translated the project's findings into pedagogical guidance for pre- and in-service teachers, including approaches to STEAM education, computational thinking, inclusion, differentiated learning and the combined use of physical and virtual robotics. PR6 further operationalised these principles through the S.T.E.P.S. School Box, MOOC and learning scenarios, whose implementation and evaluation provided practical feedback on their clarity, usefulness and applicability in educational settings. All source materials are available on the project's official website: https://S.T.E.P.Sproject.eu/.

Rather than prescribing rigid methodologies, the document proposes a flexible framework that institutions may adapt to their own educational contexts, curricular requirements and available resources. The recommendations recognise the diversity of European educational systems while identifying common principles that contribute to successful integrated STEM education through robotics.

More specifically, the document aims to:

- Provide practical guidance for Higher Education Institutions involved in teacher education and STEM programmes
- Support secondary schools in integrating educational robotics into everyday classroom practice
- Promote inclusive, equitable and gender-sensitive integrated STEM education
- Encourage the adoption of open technologies and Open Educational Resources
- Strengthen teachers' pedagogical and technological competences
- Foster inquiry-based, project-based and challenge-based learning methodologies
- Inform policymakers and educational authorities about strategies, governance and support measures that facilitate the effective and sustainable integration of educational robotics into education systems
- Contribute to the long-term sustainability, scalability and institutionalisation of educational robotics across Europe

Where relevant, the recommendations are illustrated through learning scenarios developed within the S.T.E.P.S. School Box, demonstrating how the project's pedagogical principles may be applied in practice. The complete activities are available through the project's open educational environment.

Ultimately, these recommendations seek to ensure that educational robotics is understood not merely as a technological innovation, but as a pedagogical strategy capable of transforming integrated STEM education into a more engaging, inclusive and socially relevant learning experience.

1.4. Development and Refinement Process

The recommendations were developed collaboratively by the S.T.E.P.S. project partners, drawing on their respective institutional, national and disciplinary perspectives. Structured contributions were prepared by the partners and subsequently brought together and consolidated by the University of Burgos as PR7 leader.

The drafting process was progressive and iterative. An initial update on WP5 and the direction of PR7 was shared during E5, while the recommendations were still under development. A more complete version was subsequently presented during the E2 final online webinar, where the recommendations were linked explicitly to the wider S.T.E.P.S. ecosystem and to the different ways in which learners, teachers, institutions and policymakers may engage with and support its implementation.

These successive presentation and discussion stages contributed to refining the structure, clarity and practical orientation of the document, while ensuring its relevance across diverse educational contexts.

The final version therefore reflects both the collective expertise of the consortium and the progressive refinement of the recommendations throughout the project.

2. Conceptual Framework

Sections 2.1 to 2.6 of this chapter draw primarily on previous work published by members of the S.T.E.P.S. project consortium, particularly Merino-Fernández et al. (2025). This conceptual foundation is then connected to the architecture and practical components of PR7 in Sections 2.7 to 2.9.

2.1. Integrated STEM Education: Towards Transdisciplinary Learning

Integrated Science, Technology, Engineering and Mathematics (STEM) education has emerged as a response to the limitations of traditional disciplinary teaching. Instead of treating these domains as isolated subjects, integrated STEM education promotes a transdisciplinary approach in which knowledge is mobilised to address authentic, real-world problems (Ortiz-Revilla et al., 2020). This perspective reflects the growing consensus that integrated STEM education should foster the development of key competences such as problem-solving, collaboration, creativity and systems thinking, rather than focusing solely on isolated factual knowledge (Portillo-Blanco et al., 2024).

Recent systematic reviews highlight that integrated STEM education is not a fully unified construct, but rather a set of evolving principles that include engineering design processes, contextualised learning and interdisciplinary knowledge integration (Portillo-Blanco et al., 2024). One of the main challenges identified in the literature is the lack of conceptual coherence in the implementation of STEM integration across educational contexts, which can lead to fragmented or superficial connections between disciplines.

Within this framework, STEM learning is increasingly understood as a system of interdependent components, whereby content knowledge, pedagogy, technology and assessment must be aligned to ensure meaningful learning outcomes. Therefore, integrated STEM education requires not only curricular redesign, but also teacher capacity building and appropriate technological infrastructure to support interdisciplinary learning environments.

2.2. Educational Robotics as a Mediator of STEM Learning

Educational robotics has become one of the most powerful tools for implementing integrated STEM education in practice. It provides a tangible and programmable environment in which abstract concepts in mathematics, science and engineering become observable and testable. Research consistently shows that robotics can enhance learner engagement, conceptual understanding and the development of computational thinking skills (Darmawansah et al., 2023; Ouyang & Xu, 2024).

A recent meta-analysis confirms that robotics-based STEM education improves both cognitive and affective learning outcomes, particularly when combined with structured pedagogical approaches such as problem-based or project-based learning (Ouyang & Xu, 2024). Robotics allows learners to engage in iterative cycles of design, programming, testing and debugging that closely resemble authentic engineering practices.

From a theoretical perspective, educational robotics is strongly aligned with constructionist learning theory, which proposes that learners construct knowledge more effectively when they actively build meaningful artefacts. This is consistent with research presenting robotics as a bridge between abstract STEM concepts and real-world applications and as a means of supporting experiential and inquiry-driven learning (Urrea, 2026).

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Furthermore, robotics-based learning environments foster collaboration and communication, as students typically work in teams to design and refine robotic systems. These collaborative dynamics contribute to the development of transversal competences such as teamwork, resilience and problem-solving under constraints (Darmawansah et al., 2023).

2.3. Active Methodologies: Inquiry, Project-Based, and Challenge-Based Learning

Active learning methodologies constitute a central pillar of contemporary integrated STEM education. Inquiry-Based Learning (IBL), Project-Based Learning (PBL) and Challenge-Based Learning (CBL) shift the focus from teacher-centred instruction towards student-centred exploration, enabling learners to construct knowledge through experience and reflection.

Systematic reviews show that PBL is one of the most frequently used pedagogical approaches in robotics-based STEM education because of its capacity to structure extended and interdisciplinary learning experiences (Darmawansah et al., 2023). Within these contexts, students identify problems, design solutions, test prototypes and iteratively refine their ideas.

Active methodologies also align with experiential learning cycles in which concrete experience is followed by reflection, conceptualisation and further experimentation. This cyclical process is particularly relevant in robotics environments, where learners continuously test, debug and optimise their designs (Urrea, 2026).

Importantly, research indicates that active methodologies enhance not only content acquisition, but also higher-order thinking skills such as critical thinking, creativity and innovation. These competences are increasingly recognised as core outcomes of integrated STEM education in the 21st century.

2.4. Open Technologies and Digital Learning Ecosystems

Open technologies play a fundamental role in supporting accessibility and scalability in integrated STEM education. Open-source hardware, including microcontrollers and robotics platforms, Open Educational Resources and freely available software enable schools to implement innovative STEM practices while reducing their dependence on expensive proprietary systems.

Research highlights that open educational ecosystems can reduce barriers to participation and promote greater equity in STEM education by enabling low-cost

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experimentation and the adaptation of learning materials. Open infrastructures also support teacher autonomy by allowing educators to modify, share and co-develop resources within professional communities.

Digital ecosystems integrating robotics platforms, simulation tools and collaborative environments can also extend learning beyond the physical classroom. They support blended approaches and greater continuity between formal, non-formal and informal learning contexts. In particular, virtual environments and simulations can provide an alternative entry point when access to physical equipment is limited or when learners require additional opportunities to practise before working with a physical robot.

The availability of appropriate digital infrastructure, technical support and interoperable resources is therefore an important condition for extending and sustaining educational innovation. Open and adaptable ecosystems can help institutions respond to different levels of infrastructure while maintaining access to shared learning opportunities.

2.5. Teacher Competences for Integrated STEM Education

Teacher competence is a critical determinant of the successful implementation of integrated STEM education. Teachers are no longer merely transmitters of content, but designers of learning environments, facilitators of inquiry and mediators of technology-enhanced learning processes.

The literature identifies several key competence domains required for effective STEM teaching:

- Pedagogical competence in inquiry-based and project-based methodologies
- Disciplinary integration competence across STEM domains
- Digital competence, including robotics, coding, and open technologies
- Assessment competence aligned with formative and process-oriented evaluation
- Facilitation competence for collaborative and student-centred learning

Systematic reviews consistently highlight that many teachers feel underprepared to implement integrated STEM approaches, particularly when robotics or programming are involved (Darmawansah et al., 2023). This gap underscores the need for structured professional development programmes and accessible training resources.

Research also emphasises that teacher professional development should be practice-oriented, collaborative and sustained over time. Effective STEM teacher training should combine theoretical foundations with hands-on experience in designing, implementing and evaluating interdisciplinary learning activities.

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Without adequate teacher preparation, even well-designed STEM curricula and technologies risk having a limited impact in the classroom. Teacher competence development is therefore a central pillar of sustainable integrated STEM education.

2.6. Synthesis of the S.T.E.P.S. Conceptual Foundations

The conceptual foundations of the S.T.E.P.S. project bring together five interdependent dimensions:

1. Integrated STEM education as a transdisciplinary learning paradigm
2. Educational robotics as a mediating and experiential tool
3. Active methodologies as pedagogical drivers
4. Open technologies as enabling infrastructures
5. Teacher competences as the foundation for implementation

These components form a dynamic system in which each dimension reinforces the others. Integrated STEM education defines the epistemological structure. Educational robotics creates opportunities for experiential engagement, while active methodologies structure the learning process. Open technologies support accessibility and adaptability, and teacher competences make effective implementation possible.

Together, these elements support the development of meaningful, inclusive and scalable integrated STEM practices aligned with European priorities for educational innovation. They also provide the conceptual basis for the recommendations and practical guidance presented in the following chapters.

2.7. From Project Evidence to Action: The PR7 Architecture

Based on this conceptual foundation, the purpose of PR7 is not to reproduce every preceding result, but to organise the project evidence and resources into an actionable framework. The document presents 28 recommendations distributed across three complementary levels of action.

28	11	11	6
Recommendations	for Higher Education Institutions	for Secondary Schools and Teachers	for Policy and Education Systems

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Table 1. Evidence base informing the PR7 recommendations

Evidence strand	What it contributed to PR7	Main project sources
European evidence and needs	Feasible practices, recurring barriers, inclusion gaps, curriculum links and transfer conditions	PR1: literature review, 50 practices and expert assessment
Open robotics ecosystem	Technical possibilities, modularity, repairability, physical–digital continuity and open-source principles	FOSSBot design, validation and technical resources developed through PR2–PR4
Teacher preparation	Pedagogical foundations, progression, Universal Design for Learning, classroom strategies and professional learning pathways	PR5 Pedagogical Manual
Classroom implementation	Ready-to-use scenarios, worksheets, assessment tasks, MOOC pathways and implementation feedback	PR6 School Box, 25 learning scenarios, Implementation Form and Teacher's Immediate Reflection Form
Consortium experience	Successes, constraints and partner expertise informing dissemination, sustainability and scaling	Partner contributions, implementation activities, TPM6, E5 and E2

Table 2. Architecture of the 28 recommendations

Target group	Number	Primary purpose	Practical domains
Higher Education Institutions	11	Prepare pre- and in-service teachers to design, facilitate and sustain robotics-based integrated STEM learning	Technical confidence · Pedagogy · Classroom management · Assessment and Inclusion · Institutional innovation · Computational thinking

Secondary schools and teachers	11	Shift classroom robotics from isolated tasks towards inquiry, interdisciplinarity, creativity and inclusive participation	Social relevance · Data literacy · Humanities · Engineering · Computational thinking · Inclusion · Integrated STEM
Policy and system actors	6	Create the structural conditions for equitable, resilient and scalable adoption	Open infrastructure · Curriculum and hybrid ecosystems · Equity · Teacher workforce

How to read the recommendations

Each recommendation follows a common logic: the challenge addressed, the proposed action, the S.T.E.P.S. results that support it, the main implementation conditions, possible indicators of success and considerations for adaptation to different contexts.

This shared structure enables readers to consult individual recommendations independently while retaining a coherent connection between the project evidence, the proposed action and its practical implementation.

2.8. PR6 Learning Scenarios as Didactic Implementation Examples

The 25 learning scenarios developed through PR6 provide practical examples of how the recommendations can be applied in teacher education and classroom practice. Grounded in the PR5 Pedagogical Manual, they cover programming and robotics, environmental applications and sustainability, technology integration, and engineering principles and practices.

Each scenario identifies its target group, learning outcomes, prerequisites, teaching and learning activities, worksheets and assessment elements. PR7 does not reproduce the scenarios in full.

Instead, Table 3 maps seven representative examples to the relevant recommendations and illustrates possible uses in initial teacher education, continuing professional development and secondary-school learning. Reference information and direct access are provided in Annex 1, while the complete collection is available through the S.T.E.P.S. School Box.

Table 3. Selected PR6 scenarios mapped to PR7 uses

Selected PR6 scenario	Main learning areas	Relevant PR7 recommendations	Example use in teacher education or school practice
Draw with Code!	Programming, geometry and computational thinking	R3, R11, R17, R22	Analyse scaffolding from movement commands to loops and adapt the task to curriculum standards and mixed-ability groups
Measuring Velocity	Physics, mathematics, programming and data interpretation	R3, R14, R21, R22	Design an inquiry cycle, identify measurement error and create process-based assessment criteria
Smart Lighting for the Environment and Safety	Sensors, automation and energy awareness	R12, R14, R17, R21	Practise contextualised lesson design and examine how sensor thresholds affect scientific reasoning and sustainability decisions
Discovering Atapuerca / We Are Archaeologists	Social sciences, mathematics, arts, technology and engineering	R15, R16, R21, R22	Explore interdisciplinary planning beyond traditional STEM boundaries and use robotics to support historical inquiry
Solar Oven	Energy, heat transfer, engineering design and data analysis	R12, R14, R16, R21, R22	Plan a project-based sequence, identify safety and classroom-management requirements, and compare design iterations

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Edge Detection and Safe Robot Navigation	Programming logic, sensor use and engineering safety	R4, R17, R21	Rehearse troubleshooting, anticipate misconceptions and compare alternative parameter settings
Sustainable Road Transport Management	Motion, speed, energy use, programming and sustainability	R12, R14, R16, R21, R22	Connect experimental data to environmental decision-making and evaluate the balance between technical and pedagogical complexity

The scenarios were subject to internal quality review and classroom implementation feedback. The student-facing Implementation Form examined the contribution of the School Box materials and FOSSBot to learning across different subject areas, while the Teacher's Immediate Reflection Form captured teachers' observations on disciplinary integration, learner engagement, practical adjustments and implementation conditions. Together, these instruments provided complementary feedback on the pedagogical usefulness of the scenarios and their implementation in practice. Aggregated results are presented in Annexes 2 and 3.

2.9. Contextualising Feasibility and Usefulness

The feasibility and usefulness of S.T.E.P.S. will vary according to the context in which it is implemented. Rather than defining a single implementation model, PR7 encourages institutions and educators to use the recommendations, selected learning scenarios and implementation feedback as reference points when planning and reviewing their own approach.

Before implementation, this contextual review can help identify an appropriate entry point, anticipate practical constraints and determine any adaptations that may be required. Following implementation, it can support reflection on the educational value of the selected resources, the experiences of teachers and learners, possible improvements and the potential for future reuse or wider adoption.

The supporting scenarios and aggregated implementation feedback are provided in Annexes 1 to 3. This review is intended as a flexible planning and reflection process, rather than as a formal audit or accreditation mechanism.

3. Recommendations for Higher Education Institutions

Higher Education Institutions (HEIs) play a central role in preparing pre- and in-service secondary-school teachers to integrate educational robotics meaningfully into STEM teaching. Across Europe, however, the adoption of robotics-based pedagogy within teacher education remains uneven. Although many programmes recognise the importance of digital competence and innovative teaching methodologies, robotics is still frequently confined to optional workshops or technical modules rather than integrated into STEM didactics, curriculum design, assessment and practical teacher preparation.

Building on the conceptual foundations and project evidence presented in Section 2, this chapter sets out 11 recommendations to support HEIs in strengthening teachers' technical confidence, pedagogical preparation and capacity to implement inclusive robotics-based learning. The recommendations also address the institutional conditions needed to connect teacher education with classroom practice and sustainable school-level innovation.

The recommendations are explicitly numbered from 1 to 11 and organised into six categories:

1. Building Technical Confidence and Hardware Fluency
2. Pedagogical Integration and Curriculum Transformation
3. Classroom Implementation and Management Skills
4. Assessment and Inclusive Teaching Strategies
5. Institutional Innovation and School Engagement
6. From Programming Confidence to Computational Thinking

These recommendations may be integrated into initial teacher-education programmes, continuing professional development and other university-led training activities. Their implementation should be adapted to national qualification frameworks, institutional priorities, participant profiles and the resources available in each educational context.

3.1. Building Technical Confidence and Hardware Fluency

A recurring structural issue across Higher Education Institutions is that pre-service teachers approach robotics with both technical distance and limited confidence. ***Recommendation 1. Demystifying the Hardware: Hands-on Assembly and Maintenance of the Open-Source FOSSBot*** therefore addresses not only technical unfamiliarity, but a lack of confidence in handling, adapting, maintaining or repairing

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educational technology. Many student teachers, particularly those from non-engineering backgrounds, perceive hardware as something they might damage rather than manipulate, adapt, or repair, which discourages its future classroom use.

The recommendation proposes integrating a practical Hardware Fluency module into initial or continuing teacher education. Rather than focusing solely on operating the robot, participants should have opportunities to assemble and partially disassemble FOSSBot, practise battery safety and sensor connection, and undertake basic troubleshooting of its electronic and 3D-printed components. This practical approach presents robotics as an open, understandable and modifiable technology rather than as a closed system, thereby encouraging technical agency and a maker mindset.

The recommendation draws directly on FOSSBot and on the Instruction Manual and open-source technical resources developed through PR2–PR4. Implementation could, for example, involve a dedicated two- to three-hour laboratory session in which participants work collaboratively in pairs using basic electronic tools. Troubleshooting situations should be treated as learning opportunities, enabling participants to build confidence through guided experimentation rather than simply following operating instructions.

Success indicators combine quantitative measures, such as improvements in technical self-efficacy and successful completion of troubleshooting tasks, with qualitative evidence gathered from participants' reflections on their confidence when handling electronic components. Finally, this recommendation is particularly relevant in HEI contexts where teacher education has traditionally placed greater emphasis on theoretical knowledge than on practical experience, and where differences in participants' academic backgrounds may result in uneven levels of digital and technical confidence. The depth and pace of the activity should therefore be adapted to participants' prior experience so that these differences do not become barriers to participation.

3.2. Pedagogical Integration and Curriculum Transformation

Building technical confidence is only the first step. For educational robotics to support integrated STEM learning, teachers must also be able to connect the technology with pedagogical principles, curriculum objectives and subject-specific didactics. The two recommendations in this section therefore focus on embedding S.T.E.P.S. resources within core teacher-education curricula and on supporting the design of interdisciplinary learning sequences.

Recommendation 2. Integrating the S.T.E.P.S. Pedagogical Manual into Core STEM Didactics Curricula. Robotics is often presented as an isolated workshop rather than as an integral part of integrated STEM education. Consequently, pre-service teachers struggle to connect robotics activities with curriculum requirements and learning theories.

The recommendation proposes adopting the S.T.E.P.S. Pedagogical Manual as a core resource within STEM didactics courses. Student teachers can use its theoretical foundations to examine constructivist and inquiry-oriented learning and its practical guidance to design, analyse and adapt robotics-based lessons to their own subject specialisation. PR1 provides the evidence base on European practices and recurring implementation challenges, while PR5 and the PR6 learning scenarios show how these principles can be translated into curriculum-aligned activities. Implementation can take place in standard lectures or seminars without requiring robotics hardware, allowing conceptual preparation before practical sessions.

Success is evidenced by lesson plans explicitly based on the Manual and by students' ability to justify robotics activities in relation to curriculum standards and pedagogical principles. Finally, the recommendation can be adapted to different national curricula by aligning the proposed learning outcomes and activities with local educational requirements.

Recommendation 3. Designing Interdisciplinary Learning Sequences: Linking Robotics to Math and Physics Standards. This recommendation extends the previous one by addressing disciplinary isolation. The challenge is not simply a lack of robotics knowledge, but the limited capacity of pre-service teachers, who are typically trained as subject specialists, to connect robotics with curriculum objectives across different STEM disciplines.

The recommendation therefore promotes interdisciplinary co-design through collaborative seminars in which future teachers from different specialisations work in mixed teams to develop robotics-based learning sequences. Using FOSSBot, supported by the Pedagogical Manual and the School Box/MOOC, robotics becomes a shared investigative tool that generates data, behaviours, and problems requiring interpretation from multiple disciplinary perspectives. Implementation requires coordination between faculties to organise joint design sessions and access to S.T.E.P.S. teaching resources that inspire interdisciplinary lesson planning.

Success is evidenced not only by the production of interdisciplinary lesson plans but also by the quality of the cross-disciplinary reasoning reflected in them and in peer feedback on their curriculum relevance. The recommendation is particularly useful in education systems moving towards competency-based curricula that emphasise cross-curricular learning, where robotics can support integration rather than remain a standalone technological activity.

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3.3. Classroom Implementation and Management Skills

Designing strong robotics lessons is not enough unless teachers can also manage the practical realities of classroom implementation. Robotics activities combine equipment, collaborative work, movement, troubleshooting and time constraints, all of which require specific organisational and facilitation skills. The two recommendations in this section therefore focus on preparing teachers to manage collaborative robotics activities and to rehearse their delivery through practical workshops and micro-teaching.

Recommendation 4. Classroom Management Strategies for Collaborative Robotics Activities. Even when pedagogical understanding is strong, classroom implementation introduces a different layer of complexity. Novice teachers often struggle to manage the logistical demands of robotics lessons, including equipment distribution, battery management, group dynamics, and time constraints.

The recommendation introduces laboratory-management simulations into initial teacher education, allowing pre-service teachers to rehearse realistic classroom scenarios. The PR5 Pedagogical Manual and selected PR6 learning scenarios provide reference points for planning group roles, equipment use, differentiation, troubleshooting and time management. Implementation requires practical classroom or laboratory sessions that reproduce authentic teaching conditions as closely as possible.

Indicators of success include instructors' observations of classroom management skills, their capacity to respond to simulated difficulties and increased confidence in managing collaborative active-learning environments. The strategies should be adapted to local class sizes, available equipment, learner profiles and school routines.

Recommendation 5. Practical Robotics Workshops in Initial Secondary Teacher Training. This recommendation addresses the persistent gap between theoretical preparation and classroom practice. Many pre-service secondary teachers complete their training with limited experience in designing, delivering, and assessing robotics-based STEM activities, reducing their confidence and willingness to use robotics in the classroom.

The recommendation proposes integrating a practicum-style robotics module into Master's programmes for Secondary Education, where participants design a lesson using FOSSBot, deliver a micro-teaching session, receive feedback, and refine their lesson through iterative cycles. It builds on the S.T.E.P.S. ecosystem by integrating the FOSSBot, the Manual, and the School Box/MOOC. Implementation requires practical workshops in small groups with access to the robot and teaching materials, while addressing authentic classroom conditions such as time management, collaborative learning, differentiation, and assessment.

Success can be measured through improvements in teaching self-efficacy, the quality and feasibility of the lesson plans produced, and participants' reflective accounts of the revisions made after feedback. The exact format can be adapted to national teacher-education structures and the resources available within each HEI.

3.4. Assessment and Inclusive Teaching Strategies

Effective robotics-based STEM education also depends on how learning is assessed and how participation is made possible for all learners. Open-ended and collaborative activities require assessment approaches that recognise both the learning process and the final outcome, while inclusive design is needed to accommodate diverse abilities, experiences and forms of participation. The two recommendations in this section address these complementary dimensions.

Recommendation 6. Developing Formative and Summative Assessment Approaches for Robotics Projects. Many teachers lack suitable strategies for assessing open-ended robotics activities and may focus primarily on whether the final robot or programme works, while giving insufficient attention to planning, collaboration, testing, debugging, reflection and improvement.

The recommendation proposes workshops in which pre- and in-service teachers develop assessment criteria, rubrics or assessment plans that consider both the learning process and the final outcomes of robotics projects. The activities may draw on the learning outcomes, assessment elements and reflective tasks included in the PR6 learning scenarios, together with the pedagogical guidance provided in the PR5 Pedagogical Manual. These resources offer useful examples and points of reference rather than a single ready-made assessment tool. Implementation can take place through seminar-based workshops using selected scenarios, sample learner work or case studies and does not necessarily require access to the robot.

Possible indicators of success include the production of coherent and adaptable assessment rubrics or assessment plans, appropriate consideration of both process and outcomes, and participants' ability to justify their assessment decisions during peer review. The recommendation supports the broader move towards competency-based, formative and process-oriented assessment.

Recommendation 7. Inclusive Robotics: Adapting S.T.E.P.S. Activities for Diverse Learner Needs addresses a fundamental challenge in robotics education: the problem of unequal access. Robotics is often perceived as suitable only for high-achieving or mathematically oriented students, while many teachers lack strategies to include learners with disabilities, learning difficulties, or those underrepresented in STEM.

The recommendation proposes incorporating a module on differentiation in robotics, in which pre-service teachers analyse and adapt S.T.E.P.S. activities for diverse learner profiles using Universal Design for Learning (UDL) principles. The PR5 Pedagogical

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Manual, the digital environment and the modular nature of the FOSSBot ecosystem provide multiple ways to vary instructions, roles, interfaces, levels of technical complexity and modes of participation. Implementation requires teacher educators to integrate UDL principles into robotics training and provide opportunities for participants to design and justify inclusive adaptations.

Success is evidenced by the quality of the adaptations proposed in lesson plans and by participants' reflections on equity and inclusion in integrated STEM education. The recommendation is particularly relevant across European Higher Education Institutions, as it supports current EU priorities on inclusion, accessibility, and diversity in education.

3.5. Institutional Innovation and School Engagement

Beyond individual teacher competence, sustainable implementation depends on the structures and partnerships surrounding teacher education. Higher Education Institutions can use digital preparation, school-based practice and contextual planning to connect training more closely with the realities of secondary education. The three recommendations in this section focus on these institutional mechanisms and on strengthening collaboration between universities and schools.

Recommendation 8. Flipped Learning: Utilizing the S.T.E.P.S. MOOC for Autonomous Student Preparation. At institutional level, limited face-to-face time can result in teacher-education sessions being devoted mainly to introductory technical explanations rather than lesson design, troubleshooting and pedagogical reflection.

The recommendation proposes adopting a flipped learning model in which student teachers complete the S.T.E.P.S. MOOC before attending practical sessions. Its link to the S.T.E.P.S. project is centred on the School Box/MOOC, which provides the technical foundations needed for autonomous preparation, allowing classroom time to focus on lesson design, troubleshooting, and pedagogical reflection. Implementation requires students to have internet access and instructors to monitor MOOC completion.

Indicators of success include completion of the selected modules, participants' preparedness for the practical session and a greater proportion of contact time devoted to active learning rather than introductory explanation. The model can be integrated into both initial teacher education and continuing professional development. The recommendation is also applicable across European Higher Education Institutions and supports the development of teachers' digital competences in line with the DigCompEdu framework.

Recommendation 9. Service-Learning Modules: Delivering Robotics Workshops in Local Secondary Schools extends teacher education into authentic learning environments. The problem is that university simulations cannot fully reproduce the unpredictability and complexity of working with real secondary students, limiting opportunities for situated professional learning.

The recommendation proposes establishing service-learning partnerships in which pre-service teachers design and deliver S.T.E.P.S. robotics workshops in local secondary schools. FOSSBot, the Pedagogical Manual, the School Box, the MOOC and selected PR6 learning scenarios provide a practical foundation for this authentic classroom experience. Implementation requires close coordination between the HEI and partner schools, suitable supervision and safeguarding arrangements, agreement on learning objectives, and logistical planning for equipment, space and schedules.

Indicators of success include feedback from school teachers and learners, the quality of participants' reflective journals and the revisions they make to their teaching plans. Repeated partnerships can also support longer-term university–school collaboration rather than one-off outreach.

Recommendation 10. Feasibility Analysis: Evaluating School Readiness for S.T.E.P.S. Implementation. Enthusiasm for educational robotics may not lead to sustainable implementation when curricular relevance, teacher preparation, time, infrastructure, storage, maintenance, accessibility or organisational support have not been considered.

The recommendation proposes preparing pre-service teachers and other participants to conduct the contextual review described in Section 2.9 during school placements, practicum experiences or institutional planning activities. Using the recommendations, selected learning scenarios and aggregated implementation feedback presented in Annexes 1 to 3 as reference points, participants examine local conditions and identify a realistic entry point into the S.T.E.P.S. ecosystem. This may involve a physical, blended or digital-first route, or a period of preparation before implementation. The review should lead to a context-sensitive action plan identifying required adaptations, responsibilities and support needs.

Indicators of success include the realism of the proposed implementation route, the quality of the identified adaptations and, where implementation follows, reflection on the usefulness of the selected resources. The exercise is intended as a planning and learning process, not as a formal audit or a judgement of whether a school is suitable or unsuitable for robotics.

3.6. From Programming Confidence to Computational Thinking

The final area addresses a barrier that cuts across both technical and pedagogical preparation: anxiety about programming. Teachers from non-computing backgrounds do not need to become specialist programmers, but they do need sufficient confidence to interpret algorithms, predict robot behaviour and guide learners through debugging. The recommendation in this section proposes a progressive route from block-based programming towards deeper computational thinking and, where appropriate, text-based code.

Recommendation 11. From Block to Code: Scaffolding Programming Skills for Non-CS Teachers. Programming anxiety can discourage teachers from using robotics even when they recognise its pedagogical value. The main challenge is often not syntax alone, but limited confidence in interpreting algorithms, predicting behaviour and understanding how code, sensors and actuators interact.

The recommendation proposes a progressive sequence that begins with visual or block-based programming and moves, where appropriate, towards the logic of text-based coding. The aim is to develop computational thinking and code comprehension rather than specialist programming expertise. By emphasising decomposition, prediction, code interpretation and debugging before independent code creation, the sequence builds conceptual understanding and confidence. FOSSBot's programming environments and the School Box and MOOC resources support this progression. Implementation requires computer-laboratory sessions or access to suitable devices and may begin in the digital environment before transferring tasks to the physical robot.

Indicators of success include improved performance on progressively more complex logic and programming tasks, participants' ability to explain the relationship between code and robot behaviour, and reduced self-reported anxiety. The pace and endpoint should be adapted to participants' starting levels and professional needs. The recommendation is particularly relevant across European Higher Education Institutions, where strengthening digital competence is a priority for addressing the digital skills gap in teacher education.

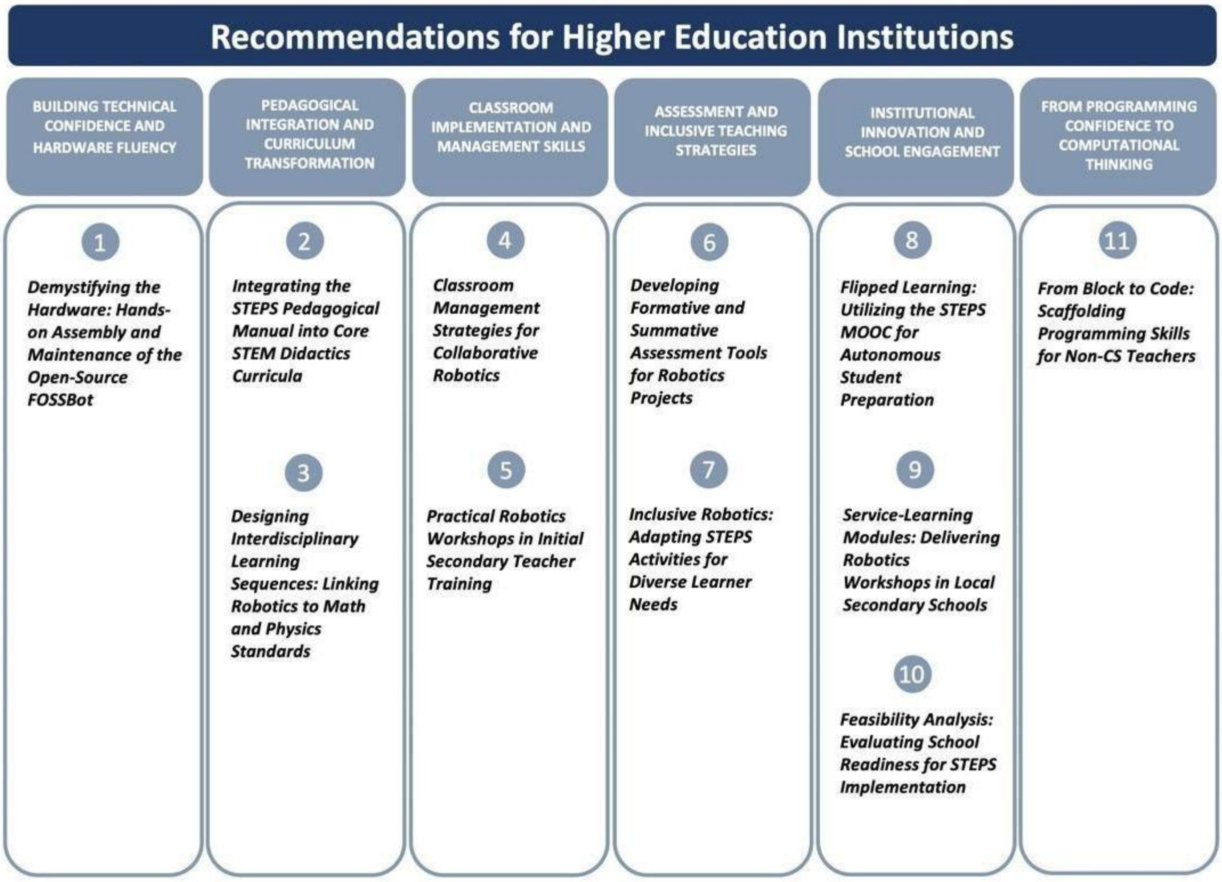
3.7. Conclusion

The recommendations presented in this chapter show that the meaningful integration of educational robotics into initial and continuing teacher education requires more than introducing a technological tool into university classrooms. It depends on a coherent progression connecting technical confidence, pedagogical understanding, curriculum design, classroom management, assessment, inclusion and practical experience. The main challenges are therefore not only technical, but also pedagogical, organisational and institutional, particularly where teacher education remains fragmented between theory and practice.

The S.T.E.P.S. ecosystem provides complementary resources to support this progression. The physical and digital FOSSBot environments enable hands-on experimentation, while the Instruction and Pedagogical Manuals provide technical and didactic guidance. The School Box, MOOC and learning scenarios further support the transition from preparation and technical fluency to interdisciplinary lesson design, classroom implementation and reflection. Higher Education Institutions can combine these elements according to their programmes, participant profiles and available infrastructure, rather than adopting the entire ecosystem at once.

Taken together, the 11 recommendations provide HEIs with an adaptable pathway for strengthening the capacity of pre- and in-service teachers to use educational robotics within integrated, inclusive and inquiry-oriented STEM education. By connecting technical fluency with computational thinking, assessment, inclusive teaching and school engagement, they support a more coherent approach in which robotics moves beyond isolated or complementary activities and becomes a meaningful component of STEM didactics and educational innovation.

Figure 1 provides an overview of the six categories and the recommendations addressed to Higher Education Institutions.



4. Recommendations for Secondary Schools and Teachers

Secondary schools are where the S.T.E.P.S. ecosystem is translated into direct learning experiences. At this level, educational robotics can help learners connect scientific, mathematical, technological and engineering knowledge with authentic questions, practical design and collaborative problem-solving. Its educational value, however, depends less on the presence of a robot than on the way activities are framed, facilitated and connected to the curriculum.

The project evidence and implementation experience point to several recurring challenges: robotics may remain confined to technology-centred tasks, links with science and mathematics may be implicit, participation may be uneven, and successful task completion may receive more attention than inquiry, reflection or explanation. The recommendations in this chapter address these challenges by linking classroom practice to the PR5 Pedagogical Manual, the PR6 School Box and learning scenarios, and the physical and digital FOSSBot environments.

The 11 recommendations are numbered from 12 to 22 and organised into seven categories:

1. Socially Relevant and Contextualised Robotics Learning
2. Data Literacy and Scientific Inquiry through Robotics
3. Interdisciplinary and Humanities-Integrated Robotics
4. Engineering Design, Creativity and Technical Agency
5. Computational Thinking and Algorithmic Reasoning
6. Inclusion, Equity and Accessibility in Robotics Education
7. From Task Completion to Scientific Inquiry and STEM Integration

4.1. Socially Relevant and Contextualised Robotics Learning

Robotics becomes more meaningful when learners can connect technical decisions with environmental, social or community issues. Contextualised activities can broaden participation and help students understand why STEM knowledge matters beyond the completion of a technical task.

Recommendation 12. Promoting Environmental Citizenship through Socially Relevant Robotics. Schools should frame selected robotics activities around authentic environmental or sustainability questions, using FOSSBot as a tool for observation, modelling, automation or decision-making rather than as an end in itself. Learners might investigate energy use, mobility, environmental monitoring or resource management and then explain the scientific and social implications of their design choices.

PR6 provides relevant starting points through scenarios such as Smart Lighting for the Environment and Safety, Solar Oven, Environmental Patrol and Sustainable Road Transport Management. Teachers can adapt these examples to local curriculum objectives and environmental priorities, using the physical robot, the digital environment or a blended route according to the resources available.

Implementation can take place in ordinary classrooms, laboratories or project settings and should combine collaborative technical work with opportunities for data interpretation, discussion and reflection. Possible indicators of success include learners' ability to connect robotics decisions with environmental evidence, the quality of their explanations and the extent to which participation is shared across the group.

Recommendation 13. Contextualised Robotics to Reduce the Gender Gap in STEM. Contextual relevance can also help broaden participation when it is combined with deliberate attention to classroom dynamics. Teachers should use meaningful real-world challenges, inclusive language, diverse STEM role models and rotating group roles so that technical responsibilities are not repeatedly assigned to the same learners. The recommendation draws on the inclusive guidance in PR5 and on PR6 scenarios that offer multiple entry points into programming, design, scientific interpretation and communication. Possible indicators include more balanced participation in technical roles, learners' sense of belonging and self-efficacy, and the quality of group reflection. Contextualisation alone will not remove gender inequalities, but it can form part of a wider gender-responsive teaching approach.

4.2. Data Literacy and Scientific Inquiry through Robotics

Robotics can serve as a scientific instrument when learners use sensors, movement and programming to generate evidence, test predictions and interpret variation. This requires teachers to make data collection and reasoning explicit rather than treating the robot only as a device to be controlled.

Recommendation 14. Empirical Kinematics and Data Literacy with FOSSBot. Teachers should use FOSSBot to connect physical movement with measurement, programming and mathematical interpretation. Learners can predict a result, programme the robot, collect or record data on distance, time or velocity, compare observations with expectations and discuss sources of error.

The PR6 Measuring Velocity scenario provides a direct example of this approach, while other sensor-based activities can be adapted to local science and mathematics curricula. Implementation may begin with digital preparation before moving to the physical robot and should include structured recording and reflection. Possible indicators include the accuracy of learners' data interpretation, their ability to explain the relationship between code and observable behaviour, and the quality of the evidence used to support conclusions.

4.3. Interdisciplinary and Humanities-Integrated Robotics

Interdisciplinary use of robotics need not stop at the boundaries of the four STEM disciplines. When robotics is used as a means of gathering evidence, representing movement or exploring a simulated environment, it can also support historical, geographical, cultural and artistic inquiry.

Recommendation 15. Using Robotics as a Tool for Historical and Cultural Investigation. Teachers should design activities in which learners programme FOSSBot to explore a simulated historical, geographical or cultural environment and then interpret the evidence generated through the activity. The PR6 scenarios Discovering Atapuerca and We Are Archaeologists illustrate how robotics can connect technology, mathematics, arts and social sciences. Implementation benefits from collaboration between subject teachers and should balance the technical task with source analysis, contextual knowledge and communication. Possible indicators include the effectiveness of the exploration strategy, the quality of the evidence-based narrative produced and learners' ability to explain the contribution of each discipline.

4.4. Engineering Design, Creativity, and Technical Agency

Open hardware creates opportunities for learners to move from operating a finished product to understanding, adapting and improving a technological system. This shift supports engineering design, creativity and a stronger sense of technical agency.

Recommendation 16. Fostering Technical Agency through Open-Hardware Customisation. Schools should use the open-source design of FOSSBot to involve learners in iterative design activities. Depending on the available facilities, students may analyse components, propose functional or aesthetic modifications, create digital models, fabricate parts or test alternative configurations. The technical documentation developed through PR2–PR4 provides the basis for understanding and modifying the robot. Implementation may use CAD and 3D printing where available, but lower-resource settings can begin with design sketches, virtual models or non-permanent prototypes. Possible indicators include the quality of the design rationale, evidence of testing and refinement, and learners' ability to explain how a modification affects function, usability or sustainability.

4.5. Computational Thinking and Algorithmic Reasoning

Computational thinking develops when learners can explain how an algorithm transforms inputs into decisions and actions. Transparent links between sensor data, code and robot behaviour help move learning beyond trial-and-error programming.

Recommendation 17. Developing Algorithmic Logic through Transparent Sensor-Motor Feedback. Teachers should ask learners to predict behaviour, represent decision processes through flowcharts or pseudocode, programme multi-step or multi-sensor tasks and use debugging evidence to revise their algorithms. FOSSBot's physical and digital environments, together with the block-based activities in the School Box and MOOC, support this progression. Implementation can begin with guided tasks and gradually reduce scaffolding as learners become more confident. Possible indicators include learners' ability to decompose a problem, explain the relationship between conditions and actions, identify the source of an error and justify a revised solution.

4.6. Inclusion, Equity, and Accessibility in Robotics Education

Inclusive robotics education requires more than providing equal access to the same task. Activities, roles, interfaces and levels of technical complexity should be designed so that learners with different backgrounds, abilities and confidence levels can participate meaningfully and contribute to shared outcomes.

Recommendation 18. Inclusive Engineering and Assistive Technology: FOSSBot for Accessibility. Teachers can frame engineering challenges around accessibility and assistive technology, asking learners to identify a user need, define design criteria and develop or simulate a FOSSBot-based response. The objective is not to present classroom prototypes as finished assistive devices, but to connect technical design with empathy, ethics and user-centred problem-solving. PR5 provides relevant inclusive and UDL principles, while the open architecture of FOSSBot allows activities to be adapted. Possible indicators include the quality of the needs analysis, the accessibility rationale and learners' reflection on the social responsibilities associated with technological design.

Recommendation 19. Gender-Inclusive STEM Classrooms with FOSSBot. Teachers should monitor participation actively and organise mixed teams with rotating roles in programming, building, data interpretation, documentation and presentation. Meaningful challenges, inclusive language and varied role models can further support a sense of belonging without reducing technical expectations. The PR5 Pedagogical Manual and the collaborative structure of PR6 scenarios provide practical reference points. Possible indicators include balanced access to technical roles, the distribution

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of speaking and decision-making opportunities, learner feedback on belonging, and teachers' ability to recognise and address unequal group dynamics.

Recommendation 20. Robotics Education for Every School. Schools should adopt implementation routes that reflect their actual infrastructure rather than treating full access to multiple physical robots as a prerequisite. The digital twin, the MOOC, shared-hardware rotations, collaborative group work and open learning materials allow institutions to begin through digital-first or blended approaches and expand physical use over time. The contextual review in Section 2.9 and the framework in Chapter 6 can support these decisions. Possible indicators include the number and diversity of learners able to participate, the manageability of the selected route, teacher willingness to reuse the activity and the adaptations required for future implementation.

4.7. From Task Completion to Scientific Inquiry and STEM Integration

The final category concerns the purpose of the learning activity itself. Robotics should not end with the successful completion of a programmed task; it should create opportunities for learners to ask questions, interpret evidence and connect technological choices with scientific, mathematical and engineering reasoning.

Recommendation 21. From Task Completion to Scientific Inquiry. Teachers should frame robotics activities around investigative questions and structured inquiry cycles such as predict-test-observe-explain-reflect. Learners should formulate expectations, use sensor data or observed behaviour as evidence, examine unexpected results and revise their explanations. PR5 and several PR6 scenarios, including Measuring Velocity, Solar Oven and Smart Lighting, offer suitable foundations. Possible indicators include the quality of hypotheses, the use of evidence in conclusions, the treatment of error and uncertainty, and learners' capacity to revise their reasoning.

Recommendation 22. Teaching All of STEM—Not Just the T. Lesson planning should make the contribution of science, technology, engineering and mathematics explicit. Teachers can identify the scientific phenomena being investigated, the mathematical relationships being used, the technological system being programmed and the engineering decisions being tested. The PR5 Pedagogical Manual and the interdisciplinary PR6 scenarios provide examples for this planning process. Possible indicators include lesson plans that integrate several STEM domains meaningfully and learners' ability to explain how each domain contributed to the investigation or solution.

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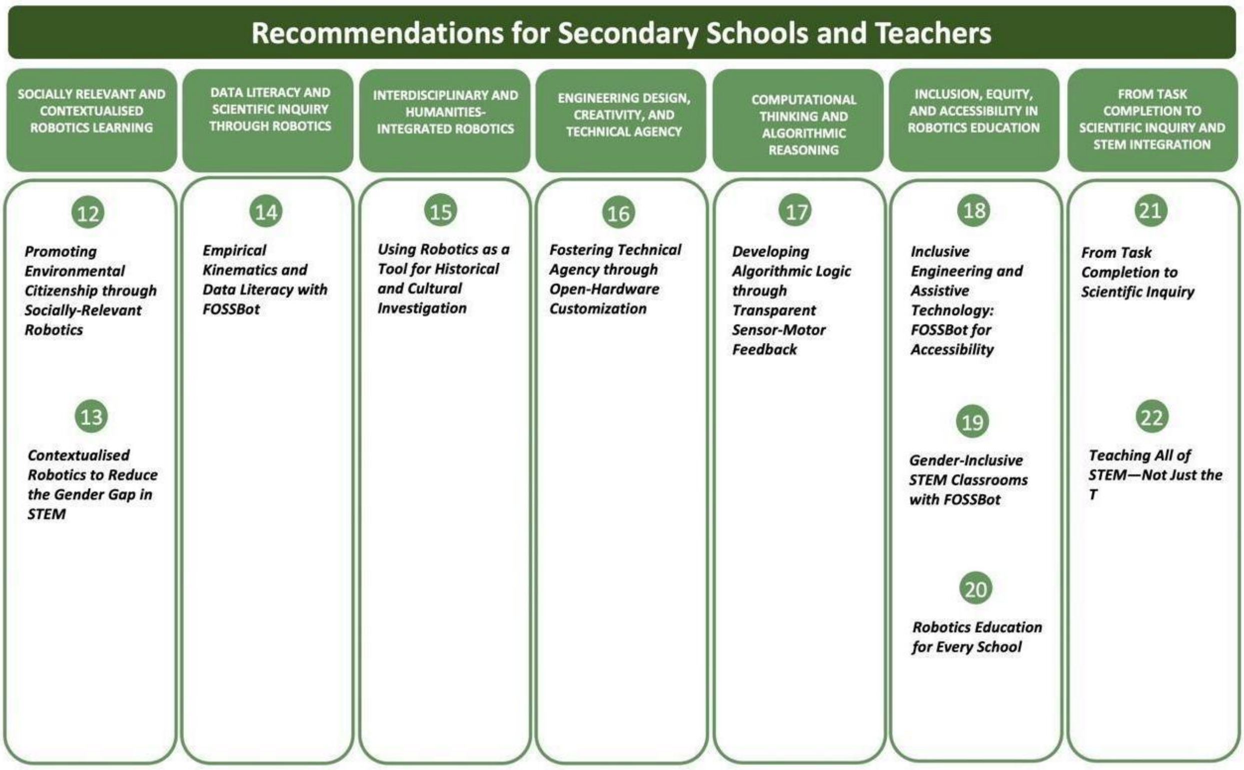
4.8. Conclusion

The recommendations presented in this chapter show that the effective integration of robotics in secondary education depends not only on access to technology, but on how that technology is framed, taught and connected to the curriculum. The main challenges concern contextual relevance, disciplinary fragmentation, unequal participation and a tendency to prioritise task completion over inquiry and reflection.

The S.T.E.P.S. ecosystem provides practical routes for addressing these challenges. Its open physical and digital environments, pedagogical guidance and learning scenarios enable teachers to connect robotics with sustainability, data literacy, humanities, engineering design, computational thinking and inclusive participation. The recommendations can be introduced progressively, beginning with one scenario or one pedagogical priority and expanding as teacher confidence and institutional capacity develop.

Taken together, the 11 recommendations support a shift from fragmented, task-oriented robotics activities towards a more coherent educational model grounded in inquiry, interdisciplinarity, creativity and inclusion. They position robotics not as an isolated technical subject, but as an adaptable learning environment through which secondary-school learners can investigate, design, interpret and communicate.

Figure 2 shows an overview of the categories and recommendations for secondary schools and teachers.



5. Policy Recommendations

The sustainable integration of educational robotics cannot depend solely on individual teachers or isolated school initiatives. Policy and system-level support influence access to infrastructure, curriculum time, teacher preparation, inclusion, maintenance and the capacity of institutions to reuse and adapt resources over time.

This chapter presents six recommendations for national and regional education authorities, curriculum bodies, procurement and digital-infrastructure services, teacher-education institutions and other actors responsible for the conditions surrounding STEM education. The recommendations draw on the comparative evidence from PR1 and on the technical, pedagogical and implementation resources developed through the subsequent project results.

The recommendations are numbered from 23 to 28. They are intended as adaptable policy directions rather than as uniform requirements for every education system.

They are organised into four categories:

1. Open-Source Infrastructure and Digital Sovereignty in Education
2. Curricular Transformation and Transdisciplinary STEM Integration
3. Equity, Inclusion and Gender-Sensitive STEM Policy
4. Teacher Workforce Development and Accreditation

5.1. Open-Source Infrastructure and Digital Sovereignty in Education

Infrastructure policy should consider the full life cycle of educational technology, including acquisition, interoperability, repair, adaptation, maintenance and long-term access to learning resources. Open solutions can strengthen institutional autonomy when they are supported by realistic technical and organisational arrangements.

Recommendation 23. Democratising STEM Infrastructure through Open-Source Hardware Sovereignty. Education authorities and procurement bodies should include openness, repairability, interoperability, documentation and total cost of ownership among the criteria used to evaluate robotics infrastructure. The FOSSBot ecosystem demonstrates how open hardware and software can enable institutions to inspect, adapt and maintain educational technology rather than remain dependent on a closed vendor environment. Implementation options may include shared fabrication or repair capacity, regional support networks, repositories for verified files and documentation, and training for technical or teaching staff. Appropriate indicators include the availability of reusable documentation, the proportion of equipment that can be maintained locally, transparency of life-cycle costs and the continuity of access to resources. Policy decisions should remain sensitive to local support capacity, since open-source procurement is sustainable only when maintenance responsibilities and expertise are also planned.

5.2. Curricular Transformation and Transdisciplinary STEM Integration

Curricular and digital policies should enable robotics to support interdisciplinary learning while allowing institutions to select implementation routes that match their resources. The two recommendations in this domain address curriculum coherence and continuity between physical and digital learning environments.

Recommendation 24. Curricular Integration of Transdisciplinary STEM-Robotics Models. Curriculum authorities should create explicit opportunities for robotics to connect mathematics, science, engineering, technology and, where relevant, other subject areas through inquiry- and project-based learning. This does not require robotics to become a compulsory standalone subject. Instead, curriculum frameworks, guidance and assessment expectations can recognise robotics as one possible methodology for achieving interdisciplinary learning outcomes. PR1 identifies the need for stronger disciplinary integration, while PR5 and the 25 PR6 scenarios provide practical examples. Possible indicators include the presence of cross-curricular robotics pathways in guidance documents, the development of jointly planned activities across subject departments and evidence that teachers can relate robotics tasks to defined curriculum outcomes.

Recommendation 25. Building Resilience through Hybrid Robotics and Digital-Twin Ecosystems. Education systems should support complementary physical and digital pathways so that learning can continue when hardware is limited, learners require rehearsal or remote access is necessary. The S.T.E.P.S. digital environment and physical FOSSBot illustrate how simulation and hands-on experimentation can be combined progressively. Policy support may include reliable connectivity, compatible devices, technical guidance, accessible platforms and clear arrangements for data protection and maintenance. Possible indicators include the number of learners able to participate through different routes, successful progression from digital preparation to physical implementation, reduced loss of learning time caused by equipment constraints and sustained access during temporary disruption. Hybrid provision should expand pedagogical options rather than replace meaningful physical experimentation where it is available.

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5.3. Equity, Inclusion, and Gender-Sensitive STEM Policy

Equity policy should address both access to resources and the quality of participation once learners enter a robotics activity. Inclusive design, gender-responsive facilitation and varied ways of demonstrating competence are needed if wider access is to translate into meaningful engagement.

Recommendation 26. Institutionalising Equity and Gender-Sensitive STEM Pedagogy. Education authorities, teacher-education providers and school leaders should embed accessibility, Universal Design for Learning and gender-responsive practice within guidance, professional development and quality-review processes for robotics-based STEM education. Recommended measures include multimodal instructions, differentiated roles and pathways, monitoring of participation, rotating technical responsibilities and the use of diverse role models and socially meaningful contexts. PR5 and the inclusive pathways across the S.T.E.P.S. ecosystem provide practical foundations. Possible indicators include the systematic inclusion of accessibility criteria in programme planning, more balanced participation in technical roles, teacher confidence in adapting activities and reduced differences in access between schools or learner groups.

Implementation should be proportionate to national and local contexts and should be accompanied by access to suitable infrastructure, staff development and mechanisms for gathering learner feedback. The objective is not to impose one classroom model, but to ensure that equity is considered from the design stage rather than added after activities have been developed.

Recommendation 27. Regional Inter-School Robotics Championships to Boost STEM Motivation. Regional authorities and school networks may use inclusive robotics challenges, championships and public showcases to strengthen motivation, exchange and visibility. To avoid reproducing existing inequalities, events should offer several forms of participation, including design, investigation, programming, sustainability, documentation and presentation, as well as non-competitive showcase routes. The open S.T.E.P.S. resources can provide a common starting point while allowing teams to adapt challenges to local priorities and available equipment. Implementation requires teacher support, accessible participation conditions and transparent criteria that value collaboration, inquiry and improvement rather than speed or technical complexity alone. Possible indicators include the diversity of participating schools and learners, balanced role distribution, the number of teachers sharing or reusing activities and participant feedback on motivation and belonging.

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5.4. Teacher Workforce Development and Accreditation

Teacher-workforce policy is a decisive condition for sustainable implementation. Short-term access to equipment will have limited impact unless educators can build technical confidence, pedagogical judgement and classroom-management competence through recognised and continuing professional learning.

Recommendation 28. Systematic Upskilling and Accreditation of the STEM Teaching Workforce. National and regional systems should integrate educational robotics and digital pedagogy into initial teacher education and continuing professional development, with appropriate recognition through existing qualification, accreditation or micro-credential arrangements where these are available. The S.T.E.P.S. MOOC, manuals and learning scenarios can be used as open components within broader training pathways, but they should not be presented as a substitute for supervised practice, peer learning and contextual adaptation. Implementation may combine self-paced preparation, hands-on workshops, mentoring and school-based experimentation. Possible indicators include completion of recognised learning pathways, growth in teacher confidence and troubleshooting capacity, the incorporation of S.T.E.P.S. resources into teacher-education programmes and evidence of sustained classroom reuse.

Policy support should also consider protected planning time, access to equipment or simulation, technical assistance and opportunities for teachers to exchange practice. Recognition mechanisms should build on existing national frameworks rather than require a single new European certificate.

5.5. Conclusion

This chapter has outlined six complementary policy directions across infrastructure, curriculum, equity and teacher development. Together, they show that the sustainable adoption of educational robotics depends on coordinated action across several parts of the education system rather than on isolated technology purchases or short-term projects.

The main barriers are both technical and structural: unequal access to equipment and support, dependence on closed systems, fragmented curriculum opportunities, uneven participation and insufficient preparation time for teachers. The S.T.E.P.S. results provide practical examples of how open technologies, physical and digital pathways, inclusive pedagogies and reusable training resources can help address these conditions. Taken together, the recommendations support a transition from occasional robotics activities towards accessible, curriculum-connected and sustainable integrated STEM provision. The pace and form of this transition will vary across education systems, but it requires long-term attention to governance, infrastructure, professional learning,

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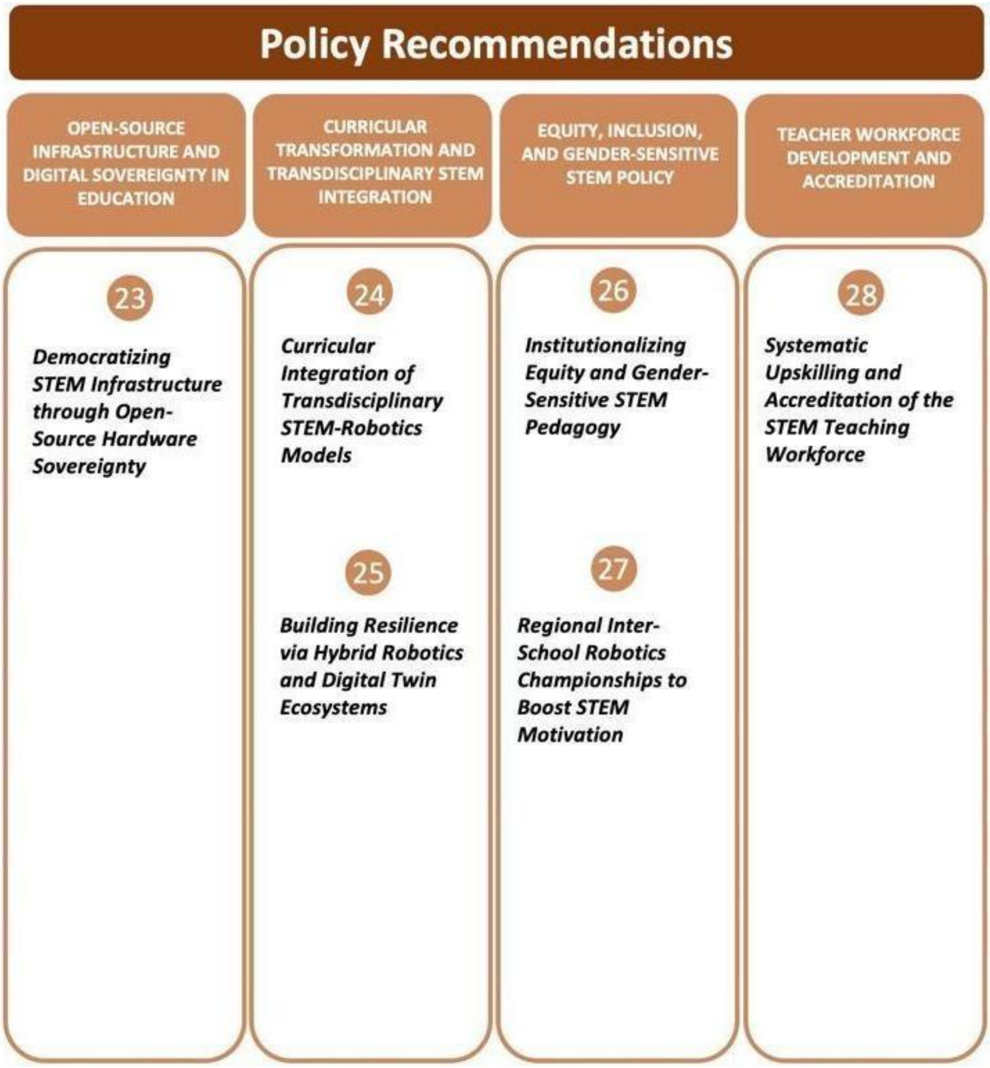
maintenance and evidence of educational value. Figure 3 provides an overview of the four policy domains and Recommendations 23 to 28.



6. S.T.E.P.S. Implementation Feasibility and Usefulness Review Framework

This framework responds directly to the PR7 objective of providing a tool to review the feasibility and usefulness of the S.T.E.P.S. offer for secondary STEM teaching. It consolidates criteria and questions derived from PR1, the PR5 Pedagogical Manual, the PR6 learning scenarios and the implementation feedback into a compact planning and reflection process. It may be completed by a teacher, pre-service teacher, teacher educator, school leader or implementation team.

Important scope note

The framework is a practical self-assessment and planning aid. It is not a formal accreditation instrument, a ranking of schools or an externally validated audit. Its purpose is to make implementation decisions more realistic, inclusive and evidence-informed

6.1. How to Use the Framework

Use the pre-implementation review before selecting a learning scenario or committing resources. Discuss each dimension with the relevant staff and record the main evidence available. Complete the status column using one of three judgements: Ready, Adaptation needed or Further preparation required. Critical issues relating to safety, accessibility, connectivity or staff support should be addressed before full physical implementation. The framework is not designed to produce a single aggregate score.

After the activity, complete the usefulness review using evidence such as learner work, observation, the PR6 feedback forms, teacher reflection and technical records. Use the 1–5 rating as a prompt for discussion, where 1 indicates that the criterion was not met and 5 indicates that it was met very well. The aim is to decide what should be retained, adapted, supported or discontinued before the next implementation.

6.2. Pre-Implementation Feasibility Review

Table 4. Pre-implementation feasibility review

Dimension	Guiding questions	Status	Priority action / evidence
Curricular relevance	Is there a clear connection between the selected scenario, learning outcomes and the local curriculum?	Ready / Adaptation needed / Further preparation required	

Teacher readiness	Does the teacher have the required pedagogical and digital confidence, or access to PR5, the MOOC, mentoring or technical support?	Ready / Adaptation needed / Further preparation required	
Digital infrastructure	Are suitable computers or tablets, browser access, local connectivity and required software available and reliable?	Ready / Adaptation needed / Further preparation required	
Physical resources and maintenance	Are sufficient FOSSBot units, charging, storage, assembly or repair resources, consumables and spare parts available?	Ready / Adaptation needed / Further preparation required	
Alternative access	Can the digital twin, group rotation, shared hardware or an offline preparation activity compensate for limited physical resources?	Ready / Adaptation needed / Further preparation required	
Classroom organisation and safety	Can the activity be delivered within the available time, room, class size and group structure, with appropriate safety procedures?	Ready / Adaptation needed / Further preparation required	

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Inclusion and accessibility	Can learners participate through differentiated roles, UDL, multimodal instructions, adapted interfaces or simulation?	Ready / Adaptation needed / Further preparation required	
Institutional support and sustainability	Are leadership, timetable, budget, technical support and plans for reuse or maintenance sufficiently clear?	Ready / Adaptation needed / Further preparation required	

6.3. Post-Implementation Usefulness Review

Table 5. Post-implementation usefulness review

Review area	Guiding question	Rating (1–5)	Evidence and next step
Pedagogical relevance	Did the activity support the intended subject knowledge, competences and learning outcomes?		
Clarity and manageability	Were the lesson plan, worksheets, instructions and sequence clear and manageable?		
Subject integration	Was FOSSBot used as a meaningful learning tool rather than as an isolated technological add-on?		
Learner engagement and agency	Did learners participate actively, collaborate, persist and explain their decisions?		
Inclusion and accessibility	Could learners with different backgrounds, confidence levels and needs participate meaningfully?		

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Technical manageability	Could the activity be implemented with the available infrastructure, time and support?		
Reusability and scaling	Would the teacher reuse, adapt or expand the activity? What needs to change first?		

6.4. Selecting an Implementation Route

The review should lead to a proportionate entry route rather than an all-or-nothing decision. Institutions may move between routes as capacity develops.

Route	When it is appropriate	Recommended first action
Physical-first	Hardware, staff confidence, space and support are available.	Select one PR6 scenario and conduct a small, documented classroom implementation.
Blended physical–digital	Hardware is limited or learners benefit from rehearsal and differentiation.	Prepare and debug in the digital environment, then rotate groups through the physical robot.
Digital-first	Physical hardware is unavailable, remote learning is required or technical risk needs to be reduced.	Begin with the MOOC, digital twin or block-based environment and plan a later physical transition.
Preparation-first	Critical gaps exist in safety, access, staff support, connectivity or curriculum alignment.	Address the priority gaps, use PR5 for training and revisit the feasibility review before implementation.

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6.5. Short Implementation Action Plan

Planning item	Decision / notes
Selected PR6 scenario or learning goal	
Target learners and curriculum connection	
Chosen implementation route	
Priority adaptations and inclusion measures	
Technical or organisational support required	
Evidence and success indicators to collect	
Responsible person(s) and review date	

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7. Conclusions and Sustainability

7.1. Main Conclusions

The S.T.E.P.S. Erasmus+ project addressed a shared challenge across European education: how to make integrated STEM learning more accessible, practical and pedagogically meaningful through open educational robotics. The project produced an open-source FOSSBot ecosystem, technical and pedagogical manuals, a digital learning environment, a School Box and MOOC, 25 learning scenarios, implementation feedback and the recommendations and review framework presented in PR7.

A central conclusion is that educational robotics creates the greatest value when it is used as a means of inquiry, design, data interpretation and interdisciplinary problem-solving rather than as an isolated technical activity. The project resources provide practical ways to connect programming and hardware with science, mathematics, engineering, sustainability and other curriculum areas. Their effectiveness nevertheless depends on teacher preparation, appropriate facilitation and adaptation to the local context.

The project also shows the value of offering several entry points. The physical robot enables hands-on experimentation, while the digital environment, MOOC and open learning materials can support preparation, rehearsal or participation where hardware is limited. These routes are complementary and allow institutions to build capacity progressively rather than adopt the complete ecosystem at once.

Collaboration across engineering, education, open-source development and school practice was essential to the design of the results. The European partnership enabled the consortium to compare needs and practices, develop multilingual resources and combine technical and pedagogical expertise. This collaborative approach remains relevant for future reuse, adaptation and dissemination.

Finally, teacher education remains a decisive condition for sustainable implementation. Educators need technical confidence, but they also need opportunities to design curriculum-connected activities, manage collaborative learning, assess iterative processes, support inclusion and reflect on implementation. The 28 recommendations translate these needs into actions for HEIs, schools and education-system actors.

7.2. Sustainability of the Project Results

The sustainability of the S.T.E.P.S. results rests on three complementary dimensions: continued access to open resources, institutional reuse and ongoing dissemination.

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These dimensions are addressed through the project Sustainability Plan and the follow-up arrangements agreed by the consortium.

From a pedagogical perspective, the manuals, learning scenarios and digital materials were designed to be reusable and adaptable. Their modular structure allows educators to select individual resources, translate or contextualise activities and integrate them into different curricula, teacher-education programmes and levels of available infrastructure. The Creative Commons licensing of the educational materials supports continued non-commercial reuse and adaptation under the applicable licence terms.

Institutionally, partners indicated their intention to continue using and promoting the project results through university courses, teacher-training activities, robotics workshops, school initiatives, conferences, partner networks and future European projects. Embedding the resources within existing programmes and maintaining links between HEIs and schools will be more sustainable than relying only on occasional dissemination events.

Continued exchange between educators, technical contributors and open-source communities can also support sustainability by enabling users to share adaptations, report technical issues and develop new examples. Such exchange should build on the networks created during the project and on documented post-project dissemination and reuse activities.

From a technological perspective, the open-source architecture of FOSSBot allows future users to inspect, repair and further develop the system. The consortium agreed that the project website and platform should remain accessible for five years after the end of the project. Continued accessibility, however, should be accompanied by clear responsibilities for hosting, essential maintenance, documentation and the preservation of downloadable resources.

A dedicated sustainability folder and follow-up documentation will support the recording of external events, reuse and dissemination after the funded period. Scalability should be understood as context-sensitive reuse rather than uniform replication: institutions may begin with one scenario, a digital-first pathway or a teacher-training module and expand their use as confidence and capacity develop.

7.3. Future Perspectives

The completed project provides a foundation for further development, but future actions will depend on the priorities and resources of the organisations and communities that continue to use the results. The following perspectives should therefore be understood as possible directions rather than commitments under the completed grant.

One priority is to maintain and refine the existing ecosystem. Technical documentation, software compatibility, platform access and learning materials may require periodic review as technologies and educational requirements evolve. Future contributors could also explore carefully selected extensions, including data-rich sensing, artificial intelligence or immersive environments, where these additions serve clear pedagogical purposes and remain consistent with the project’s principles of openness and accessibility.

A second direction is to extend interdisciplinary use. The PR6 scenarios already connect robotics with sustainability, physics, mathematics, engineering and the humanities. Further activities could deepen links with the arts, social sciences, ethics, local environmental issues and community-based challenges while preserving explicit learning outcomes and meaningful disciplinary integration.

Broader European and international reuse may also support the project’s legacy. Additional schools, universities, teacher networks and innovation hubs can adapt the open resources to their own curricula and languages, provided that local implementation conditions and licensing requirements are respected. Documenting these adaptations would strengthen the evidence base for transfer across contexts.

Teacher professional development will remain a key priority. Future training could combine the MOOC and manuals with supervised workshops, peer mentoring, school-based experimentation and reflection. Particular attention should be paid to inclusive facilitation, assessment of open-ended projects, troubleshooting and the progression from block-based programming to computational thinking.

Future reuse should also be accompanied by stronger and more systematic evaluation. Common but proportionate indicators could capture learner outcomes, participation, teacher confidence, implementation conditions, resource reuse and institutional adoption. The framework in Chapter 6 and the PR6 feedback instruments provide a starting point, but longer-term studies would be needed to examine sustained educational impact.

In conclusion, S.T.E.P.S. provides an open and adaptable foundation for integrated STEM education through robotics. Its long-term value will depend on continued access, responsible maintenance, contextual adaptation, professional learning and the collection of credible evidence from future use.

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Annexes

ANNEX I — Reference Information for the PR6 Learning Scenarios Selected as Didactic Examples

This annex provides concise reference information and direct access to the seven PR6 didactic examples highlighted in Table 3. The examples were selected because, together, they illustrate programming, scientific inquiry, mathematics, engineering design, environmental applications, humanities integration and safe robot operation. The complete learning scenarios, worksheets and evaluation materials remain available through the S.T.E.P.S. School Box.

> *The Atapuerca example is presented as a paired sequence comprising Module 17, which introduces the historical and STEAM context, and Module 25, which develops the simulated archaeological investigation. Course titles and module numbers follow the public Moodle platform.*

Table A1. Reference information and direct access to the selected PR6 scenarios

Scenario and access	Age / duration	Main learning areas	Core learning focus	PR7 connection and suggested use
Draw with Code! Module 7 Open course page	13-15 years 45 minutes	Computer Science, Mathematics and Technology	Visual programming, sequences, loops, geometric shapes and angles, debugging, pattern recognition and creative problem-solving.	R3, R11, R17, R22 Use the progression from movement commands to loops to analyse scaffolding, algorithmic efficiency and curriculum adaptation.

Measuring Velocity Module 12 Open course page	14-15 years 45 minutes	Information Technology, Natural Sciences, Mathematics and Robotics	Experimental measurement of distance and time, application of the velocity formula in code, data interpretation and discussion of friction, battery level and measurement error.	R3, R14, R21, R22 Use the scenario to design an inquiry cycle, connect physics and algorithms and develop process-based assessment criteria.
Smart Lighting for the Environment and Safety Module 1 Open course page	13-15 years 90 minutes	Computational Systems, Technology and Environmental Education	Light and ultrasonic sensors, conditional logic, automation, energy saving, environmental awareness and public safety.	R12, R14, R17, R21 Use the module to examine contextualised lesson design and how sensor thresholds shape scientific reasoning and sustainability decisions.
Discovering Atapuerca / We Are Archaeologists Modules 17 and 25 Discovering Atapuerca - Module 17 We Are Archaeologists - Module 25	Approx. 11-13 years 50 minutes per module	Social and Natural Sciences, Technology and Engineering, Mathematics, STEAM and Visual Arts	A paired transdisciplinary sequence: activating prior knowledge about Prehistory and Atapuerca, then programming FOSSBot to navigate a simulated excavation, detect artefacts, record coordinates and document findings.	R15, R16, R21, R22 Use the paired sequence to explore interdisciplinary planning beyond traditional STEM boundaries and robotics as a mediator of historical inquiry.

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Solar Oven Module 9 Open course page	13-14 years 45 minutes	Science (Energy and Heat), Mathematics, Technology and Design	Engineering design cycle, construction with recycled materials, reflection, absorption, insulation, greenhouse effect, temperature measurement, graphing and sustainability.	R12, R14, R16, R21, R22 Use the scenario to plan a project-based sequence, identify safety and classroom-management requirements and compare design iterations.
Edge Detection and Safe Robot Navigation Module 24 Open course page	14-15 years 45 minutes	Information Technology, Natural Sciences, Engineering and Robotics	Floor sensors, if/else structures, logical AND, hazard detection, risk avoidance, safe manoeuvres and parameter optimisation.	R4, R17, R21 Use the scenario to rehearse troubleshooting, anticipate misconceptions and compare alternative safety parameters.
Sustainable Road Transport Management Module 21 Open course page	13-15 years 90 minutes	Computer Science, Technology, Physics, Environmental Sciences and Mathematics	Ultrasonic sensing, speed calculation, motor power, distance and time measurement, data analysis, energy efficiency and sustainable transportation.	R12, R14, R16, R21, R22 Use the scenario to connect experimental data with environmental decision-making and examine the balance between technical and pedagogical complexity.

All eight course pages represented in the seven examples include a downloadable lesson plan and evaluation activity. Several also provide additional implementation materials, such as a programming environment, measurement and recording resources, or interactive activities. These resources should be consulted in their current online version to ensure that users access the latest files.

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ANNEX II — PR6 Implementation Form: Instrument and Aggregated Results

The student-facing Implementation Form collected feedback on the School Box after use in a learning situation. The PDF export contains 62 responses. Results are reported in aggregate and percentages are calculated using the number of valid responses for each item.

> *The subject-effectiveness question used three anchored response options (1 = Not Effective, 3 = Neutral, 5 = Highly Effective). The objective checklist was available in 57 of the exported responses. Multiple objectives could be selected, so percentages do not sum to 100%.*

AII.1. Instrument Overview

Table A2. Structure of the student-facing Implementation Form

Instrument item	Response format	Purpose
Effectiveness of the School Box materials in Physics, Mathematics and Information Technologies	Three-point anchored scale: 1, 3 or 5	Review perceived support across core subject areas
Clarity and flow of the lesson plans	Five-point scale: 1 to 5	Assess the structure and manageability of the learning materials
FOSSBot as a distraction or facilitator	Open-text response	Capture learners' interpretation of the robot's role in understanding complex concepts
Objectives successfully met during the session	Multiple-selection checklist	Review programming logic, application of maths/physics, collaboration and interest in Green STEM

AII.2. Aggregated Quantitative Results

Table A3. Perceived effectiveness of the School Box and lesson-plan clarity (n = 62)

Item	Mean / 5	Rating 1	Rating 2	Rating 3	Rating 4-5 or Rating 5
Physics support	3.90	9 (14.5%)	—	16 (25.8%)	37 rated 5 (59.7%)
Mathematics support	3.81	5 (8.1%)	—	27 (43.5%)	30 rated 5 (48.4%)
Information Technologies support	4.16	4 (6.5%)	—	18 (29.0%)	40 rated 5 (64.5%)

Lesson-plan clarity and flow	3.97	0	5 (8.1%)	11 (17.7%)	46 rated 4 or 5 (74.1%)

For the three subject areas, respondents could select only 1, 3 or 5. The lesson-plan item used the full five-point scale. The mean values are included as descriptive summaries of these anchored ratings.

Table A4. Objectives perceived as successfully met (valid responses n = 57; multiple selections allowed)

Objective	Selections	Percentage of valid responses
Applied mathematics or physics concepts to a physical device	36	63.2%
Understood basic programming logic	32	56.1%
Collaborated effectively in teams	29	50.9%
Showed increased interest in Green STEM solutions	26	45.6%

AII.3. Open-Text Feedback

The open question asked whether FOSSBot acted as a distraction or a facilitator for learning complex concepts. A broad manual coding of the 62 responses produced the distribution below. The categories are descriptive and should not be interpreted as a validated qualitative scale.

Table A5. Broad coding of the student comments on FOSSBot's role

Primary coding	Responses	Share of all responses
Clearly described FOSSBot as a facilitator or learning support	56	90.3%
Mixed or ambiguous comment	3	4.8%
Explicitly described FOSSBot as a distraction	1	1.6%
No substantive comment	2	3.2%

Recurring positive themes included the immediate connection between code and physical movement, the visualisation of mathematics and physics, real-time feedback during debugging, increased attention to sensor data, collaborative problem-solving and the application of robotics to Green STEM challenges. The few mixed comments mainly referred to the novelty of the robot as an initial distraction before it became a learning tool.

ANNEX III — Teacher's Immediate Reflection Form: Instrument and Aggregated Results

The Teacher's Immediate Reflection Form gathered observations immediately after, or in some cases in anticipation of, using S.T.E.P.S. materials. The PDF export contains 20 responses. Several respondents explicitly stated that they had not yet implemented a STEM or FOSSBot lesson; the qualitative findings should therefore be read as a combination of implementation feedback and informed expectations.

> *The integration rating is available for all 20 responses. The infrastructure question is available in four exported responses. All results are presented anonymously and percentages use valid responses for each item.*

AIII.1. Instrument Overview

Table A6. Structure of the Teacher's Immediate Reflection Form

Instrument item	Response format	Purpose
Moment that triggered a 'spark' of interest or understanding	Open-text response	Identify features that generated curiosity or conceptual understanding
Intuitiveness of integrating FOSSBot into the subject	Five-point scale: 1 = Very Difficult/Distracting to 5 = Very Seamless/Natural	Review perceived ease of disciplinary integration
Engagement and hands-on participation compared with a traditional STEM lesson	Open-text response	Capture perceived changes in learner participation
One change before teaching the lesson again	Open-text response	Identify practical refinements and implementation needs
Ease of setup with existing infrastructure	Three response options	Review low-cost/open-access compatibility and technical manageability

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AIII.2. Aggregated Quantitative Results

Table A7. Intuitiveness of integrating FOSSBot into the subject (n = 20)

Rating	Interpretive anchor	Responses	Percentage
1	Very difficult / distracting	2	10.0%
2	Difficult	2	10.0%
3	Intermediate	4	20.0%
4	Relatively seamless / natural	8	40.0%
5	Very seamless / natural	4	20.0%

The mean integration rating was 3.50 out of 5. Twelve of the 20 respondents (60.0%) selected rating 4 or 5.

Table A8. Compatibility with existing school infrastructure (valid responses n = 4)

Response option	Responses	Percentage
Very easy to set up and required no extra budget	2	50.0%
Manageable, but required some technical troubleshooting	2	50.0%
Difficult to implement with current equipment	0	0.0%

AIII.3. Qualitative Synthesis

Teacher comments most frequently associated the strongest learner interest with immediate physical feedback, successful robot movement, sensor-based problem-solving and real-world contexts such as zero-waste schools, smart lighting and energy efficiency. Other comments highlighted the value of moving from passive observation to experimentation, debugging and collaborative decision-making.

Table A9. Broad coding of comments on engagement compared with traditional STEM lessons

Primary coding	Responses	Percentage
Higher or more active engagement and hands-on participation	15	75.0%
No direct implementation or no basis for comparison	4	20.0%
No substantive response	1	5.0%

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Table A10. Primary improvement theme identified in each teacher response

Primary improvement theme	Responses	Examples of the proposed refinement
More time for debugging, reflection, peer exchange or open exploration	7	Dedicated troubleshooting time, peer review, group debriefing, failure logs or longer project time
Clearer technical scaffolding	2	Step-by-step visual guidance, short videos or clearer Blockly instructions
More hands-on or personalised materials	2	More structured practical activities or physical customisation
Stronger interdisciplinary collaboration or content	2	Closer work with IT teachers or greater integration of Social Sciences
Other pedagogical refinement	1	A broader technopedagogical enhancement
No change, no direct implementation or no substantive proposal	6	Nothing to change, no implementation basis or general thanks

Overall, the forms support the use of the PR6 scenarios as practical examples while also confirming the need for context-sensitive implementation. The feedback points to the importance of sufficient time, technical preparation, troubleshooting opportunities, interdisciplinary collaboration and adaptable entry routes. These findings directly inform the contextual review proposed in Section 2.9 and the feasibility and usefulness framework presented in Chapter 6.

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