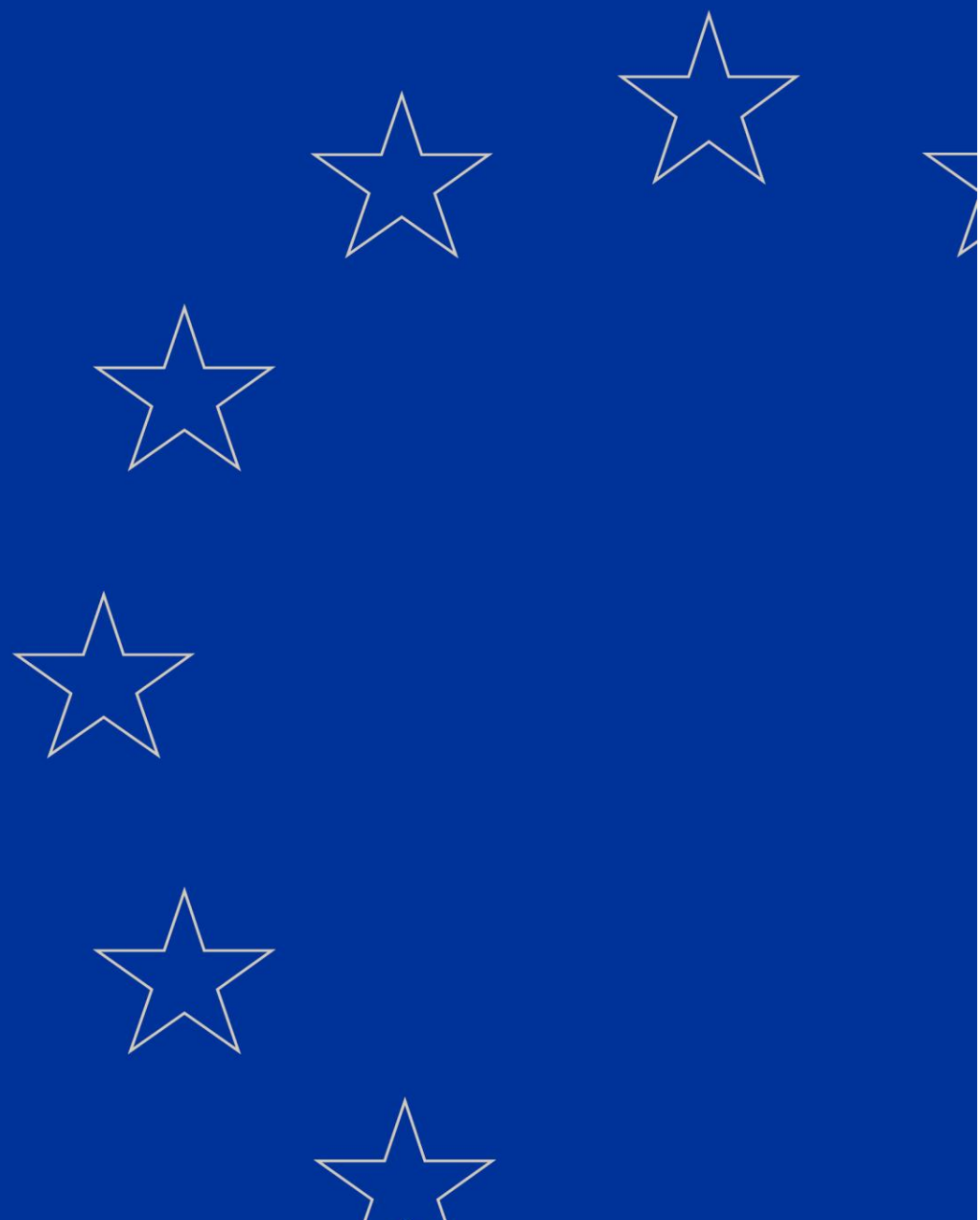
European Commission

# Promoting STEM Education in Schools

Final report



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# Promoting STEM Education in Schools

Final report

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*In grateful memory of Beatrice Boots, 1967–2025, chair of the EU STEM Coalition, who shaped and inspired educational innovation, bringing her heartfelt enthusiasm and endless energy to connect people and ideas. She will be missed in the STEM education community in Europe and beyond.*

Directorate-General for Education, Youth, Sport and Culture

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# Foreword

## Europe’s future will be shaped in our classrooms

If we want a continent that leads in artificial intelligence, clean technologies and advanced manufacturing, we must ensure that every young person develops strong basic competences in science, technology, engineering and mathematics. STEM education is not only about competences for the labour market. It is about curiosity, critical thinking and the confidence to understand and shape a fast-changing world.

This study on Promoting STEM Education in Schools comes at a crucial moment. Across Europe, there is strong political momentum to strengthen STEM. Yet, as this comprehensive analysis shows, important structural challenges remain.

The report highlights six systemic obstacles that continue to limit progress. Governance is often fragmented, with responsibilities spread across ministries and levels of administration, weakening strategic coherence. Teacher shortages persist in almost all Member States, particularly in disadvantaged and rural areas. Curricula can be rigid and overloaded, leaving too little space for interdisciplinary and project-based learning. Infrastructure gaps create unequal access to high-quality learning environments. Non-formal and informal learning opportunities are underused. And in many systems, evaluation frameworks are not yet strong enough to guide reform and scale what works.

At the same time, the study shows that change is possible. It points to promising national strategies, innovative teacher training models, investments in infrastructure supported by EU funds, and inspiring Erasmus+ projects that show impact and scalability. It also shows that the integration of digital tools including AI is a strategic lever for modernising STEM education and helps to convert classrooms into innovative learning environments. This supports the shift to learner-centred, inquiry-based, and interdisciplinary learning and teaching practices: students build robots, simulate AI systems and solve real-world problems through iterative design and collaboration. Such experiential, hands-on learning is a central success factor identified across the most effective schemes.

These findings strongly support the direction we have set at European level. The Union of Skills and the STEM Education Strategic Plan provide a vision of how to boost excellence, inclusion and attractiveness in STEM across Europe. The study underlines why this integrated approach is essential.

We must move beyond short-term, project-based initiatives and embed STEM across entire education systems – from early childhood to vocational education and training. We must strengthen the STEM teaching profession, improve career pathways and invest in high-quality professional development. We must ensure

that every school, regardless of location or socioeconomic context, has access to modern infrastructure and strong partnerships with universities, research centres and industry.

STEM education should also be more inclusive. Too many young people – especially girls and those from disadvantaged backgrounds – are still underrepresented in STEM pathways. Through initiatives under the STEM Action Plan, including targeted actions to attract one million girls into STEM by 2028, we are committed to widening participation and unlocking Europe's full talent potential.

The report also reminds us of the importance of evidence. Better data, stronger evaluation and closer links between research and policy will help us design smarter interventions and scale successful models across borders.

STEM education is a shared responsibility. Lasting transformation requires commitment at national, regional and local levels, and the engagement of teachers, school leaders, families, researchers and employers.

This study provides a valuable roadmap for action. It offers both an honest diagnosis and practical guidance for reform. I am confident that it will inform policy discussions across Europe and support our collective ambition: to build education systems that empower every learner, strengthen our competitiveness, and uphold our shared values.

By investing in STEM education today, we are investing in Europe's capacity to innovate, to compete and to lead tomorrow.

Roxana Mînzatu

Executive Vice-President for

Social Rights and Skills, Quality Jobs and Preparedness

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# List of abbreviations

| | |
|---|---|
| CPD | continuing professional development |
| ECEC | early childhood education and care |
| ERDF | European Regional Development Fund |
| ESF+ | European Social Fund Plus |
| ESIFs | European Structural and Investment Funds |
| ITE | initial teacher education |
| PhBL | Phenomenon-Based Learning |
| RRF | Recovery and Resilience Facility |
| SRSP | Structural Reform Support Programme |
| STEAM | Science, technology, engineering, arts and mathematics |
| STEM | science, technology, engineering and mathematics |
| TSI | Technical Support Instrument |
| VET | vocational education and training |

# Abstract

This report examines how science, technology, engineering and mathematics (STEM) education is promoted across European school systems and identifies key challenges, policy responses, good practice examples and opportunities for systemic improvement. Drawing on extensive desk research, 265 stakeholder interviews, thematic focus groups, analysis of Erasmus+ and other EU actions, and comparative analysis across all EU Member States alongside selected non-EU countries, the study provides a comprehensive overview of national- and EU-level STEM education policies and practices.

The findings reveal persistent structural challenges, including fragmented governance, teacher shortages, rigid curricula, unequal access to infrastructure, limited use of non-formal learning, and weak monitoring and evaluation frameworks. At the same time, the report identifies promising approaches emerging across Europe, such as integrated national STEM strategies, interdisciplinary and inquiry-based pedagogies, strengthened teacher professional development, targeted infrastructure investment and expanded partnerships with industry, research institutions and civil society.

The report highlights the growing role of EU programmes and initiatives – particularly Erasmus+, Horizon Europe and the Recovery and Resilience Facility – in supporting national STEM reforms, while underlining the need for greater coherence, sustainability and evidence-informed policy design. It concludes with targeted recommendations for policymakers, educators and stakeholders to advance inclusive, high-quality and future-oriented STEM education across Europe.

# 1. Executive summary

## 1.1. Introduction to the study

Science, technology, engineering and mathematics (STEM) education is a vital lever for Europe's transition to a digitally competent, environmentally sustainable and economically competitive future. This report offers a comprehensive and comparative analysis of STEM education policies and practices across European school systems, with an emphasis on systemic challenges, national policy responses and promising pathways for reform. It draws on recent literature, country reports, EU policy instruments and good practice examples to assess how well current approaches prepare young people to thrive in a complex and fast-changing world.

While there is increasing momentum for change, the findings reveal that STEM education across Europe remains constrained by fragmented governance, rigid curricular structures, persistent teacher shortages and unequal access to high-quality learning environments. At the same time, there are promising practices emerging in several EU Member States that demonstrate how coherent policy design, strategic investment and cross-sectoral collaboration can drive meaningful transformation. The report calls for a shift from short-term, project-based interventions to long-term, integrated reforms that embed STEM education across all dimensions of the school system.

## 1.2. Overview of the key findings

The analysis identifies six overarching systemic challenges.

### 1.2.1. Fragmented governance and weak policy alignment

Many national education systems lack a coherent and integrated vision for STEM education. Fragmentation is evident both vertically, across different levels of government and different educational stages, and horizontally, between ministries responsible for education, labour, research, innovation and digital policy. This lack of alignment hampers coordination and limits the impact of reforms. In contrast, countries such as Ireland, Finland and Sweden have developed national STEM strategies that align goals across sectors and levels, facilitating a more strategic approach to implementation.

### 1.2.2. Persistent teacher shortages and limited professional development

Across nearly all the countries analysed, there are shortages of qualified STEM teachers, especially in rural, remote and disadvantaged areas. Initial teacher education (ITE) often lacks sufficient STEM-specific content and pedagogy, while professional development opportunities tend to be fragmented, optional or unevenly distributed. Many systems do not offer clear career progression pathways or incentives for STEM teaching roles. Promising responses include Austria's mentoring initiatives, the Netherlands' alternative entry routes and Finland's partnerships between schools and universities to build long-term professional capacity.

### 1.2.3. Curriculum rigidity and lack of interdisciplinary learning

Most STEM curricula remain subject specific and compartmentalised, limiting opportunities for interdisciplinary learning and real-world application. High-stakes assessments and content overload further constrain teacher and school-level flexibility. Some systems, such as those in Czechia, Estonia and Lithuania, are beginning to adopt more integrated and project-based approaches. However, broader reform is needed to embed competence-based learning and transversal skills such as adaptability, creativity and problem-solving into curriculum frameworks in ways that are accessible and adaptable across school types.

### 1.2.4. Infrastructure gaps and unequal learning environments

Significant disparities exist in access to modern laboratories, digital tools and high-quality STEM learning spaces. In many countries, schools in rural or disadvantaged areas lack the infrastructure needed to deliver practical, inquiry-based STEM education. National investment strategies in Estonia, Ireland, Spain and Italy have begun to address these gaps, often supported by EU recovery and resilience funds. Still, there is a pressing need for systematic, equity-oriented investment in physical and digital infrastructure across all Member States.

### 1.2.5. Underuse of non-formal and informal learning opportunities

Non-formal and informal learning opportunities, including through science centres, industry partnerships, makerspaces and STEM clubs, remain underutilised in most systems. Where they exist, they are often dependent on short-term funding or confined to urban areas. Countries such as Portugal,

Slovakia and Finland offer models for how to embed such activities into school curricula and regional networks, enhancing student engagement and motivation, and real-world skills development.

### 1.2.6. Limited evaluation and weak use of evidence

Many countries lack robust monitoring and evaluation frameworks for STEM education. Where data are collected, they are often limited to participation rates or test scores, with little focus on teaching practices, equity or longer-term impact. Few systems systematically evaluate the outcomes of STEM-related initiatives or use the evidence to inform policy design and scale up innovation. Ireland's national dashboards and France's research–policy collaborations offer examples of emerging good practice in this area.

## 1.3. Summary of major trends in STEM education policies and practices in Member States

### 1.3.1. Strategic integration of STEM into national agendas

A growing number of countries are positioning STEM education as a cross-sectoral priority linked to broader national objectives, ranging from innovation and labour market competitiveness to climate adaptation and digitalisation. Ireland, Finland and Sweden exemplify this trend, with national STEM strategies integrated into broader education and skills frameworks. These strategies often align with economic recovery plans, national digital agendas or green transition roadmaps, thereby embedding STEM beyond the education sector.

This integrative approach is helping some countries to:

- coordinate policies across ministries (e.g. those of education, science, labour and digital affairs);
- leverage funding more strategically (e.g. through the Recovery and Resilience Facility (RRF) or the European Social Fund Plus (ESF+));
- create long-term visibility and stability for STEM education planning.

However, in many countries, STEM remains a fragmented policy domain, implemented through isolated projects or pilot schemes without systemic reach or sustainability.

### 1.3.2. Strengthening the teaching profession through reform and investment

Teacher recruitment, training and retention are increasingly recognised as foundational to STEM education reform. National responses coalesce around three main areas.

- **Diversifying entry routes into teaching.** Countries such as the Netherlands and Austria are offering alternative or accelerated pathways into STEM teaching to address shortages and attract professionals with STEM backgrounds.
- **Reforming initial teacher education (ITE).** Estonia and Finland embed digital pedagogy, interdisciplinary content and research-based practice in ITE programmes.
- **Scaling up continuing professional development (CPD).** More systems are creating structured, nationally coordinated CPD offers, moving beyond ad hoc provision. Ireland, France and Austria are investing in regional hubs or online platforms that enable access to sustained and accredited STEM-related training.

Despite these efforts, significant gaps remain in supporting teacher collaboration, enabling school-based learning communities and linking CPD to career progression and systemic reform.

### 1.3.3. Curriculum reform and interdisciplinary learning

There is a growing policy emphasis on making STEM education more engaging, relevant and interdisciplinary. This shift is evident in the following areas.

- **Curriculum integration.** Countries such as Croatia, Lithuania and Sweden are redesigning curricula to allow thematic and cross-disciplinary learning, often linked to real-world challenges or the UN sustainable development goals.
- **STEAM orientations**. Some systems are embedding the arts, psychology, the social sciences and the humanities into STEM subjects to broaden participation and connect with students' interests and identities.
- **Sustainability and digital themes.** New curricula often include climate change, artificial intelligence (AI) and ethical innovation as core components of STEM learning.

However, national reforms are frequently constrained by rigid assessment systems and content-heavy curricula that leave little space for experimentation or local adaptation. Successful implementation of curriculum reform depends on

alignment with teacher training, school autonomy and formative assessment practices.

### 1.3.4. Targeted investment in infrastructure and digital transformation

Addressing resource disparities and enabling modern STEM teaching requires sustained and targeted investment. Several countries have launched national programmes to:

- upgrade laboratories, science facilities and makerspaces;
- provide equitable access to digital tools, software and broadband;
- support experimentation with hybrid and virtual STEM environments.

Estonia's 'digital-first' approach, Ireland's targeted equity investments and Italy's school 4.0 initiative, supported by the RRF, demonstrate how national and EU funding can be aligned for infrastructure modernisation. However, uneven implementation persists, especially in rural and underserved communities. A more equity-sensitive allocation of infrastructure funding is needed across Member States.

### 1.3.5. Expanding partnerships with industry, research institutions and civil society

Cross-sectoral partnerships are becoming a core pillar of national STEM strategies. Countries are increasingly institutionalising mechanisms to bring education systems together with:

- higher education and research institutions (e.g. Finland's LUMA centres, Germany's MINT network);
- industry and employers (e.g. work-based learning, role model programmes, innovation hubs);
- civil society and science outreach actors (e.g. science centres and museums, foundations, youth organisations).

These partnerships aim to:

- enrich learning experiences with real-world relevance;
- build student awareness of STEM careers;
- support teacher development and curriculum co-design.

While promising, such collaborations often depend on short-term projects or motivated individuals. More sustainable models require national coordination

platforms, regional brokerage mechanisms and clearer frameworks for ethical and educational quality assurance.

### 1.3.6. Inclusive and equity-oriented approaches

A positive trend is the growing inclusion of equity and diversity goals in national STEM policies. Governments are expanding efforts to:

- address gender gaps through mentoring, gender-sensitive pedagogy and inclusive curriculum design (e.g. Austria's MINT girls challenge, Ireland's national STEM gender strategy);
- engage disadvantaged learners and rural communities through targeted funding, outreach and mobile STEM laboratories;
- support early years STEM learning to build foundational skills and reduce later-stage disparities.

However, equity measures are often underfunded or siloed, and few countries have systematic data collection mechanisms to monitor participation and outcomes for under-represented groups.

### 1.3.7. Growing use of EU funding and coordination mechanisms

EU funding programmes are playing a central role in supporting national STEM reforms. Erasmus+, Horizon Europe, the Digital Europe Programme and the RRF are being used to:

- support teacher mobility, curriculum innovation and whole-school transformation;
- fund infrastructure, digital tools and blended-learning models;
- enable research–policy partnerships and system experimentation.

Countries such as Estonia, Ireland and Portugal have effectively leveraged EU funds for targeted national programmes. However, challenges remain in ensuring:

- greater coherence and interoperability between funding mechanisms;
- accessibility of funding for smaller schools or rural actors;
- long-term sustainability beyond project cycles.

### 1.3.8. Shared challenges in monitoring and evaluation

Most national STEM strategies and interventions lack robust monitoring, evaluation and feedback mechanisms that can support the needs of multiple funding mechanisms. Emerging practices, such as Latvia's self-evaluation tools and France's research–policy partnerships, illustrate how countries can build evaluation capacity and use data for continuous improvement. However, few systems currently:

- collect disaggregated data on STEM access and achievement;
- evaluate the impact of reforms on teaching and learning practices;
- link school-level outcomes with system-wide indicators.

More effort is needed to develop common frameworks, comparable indicators and shared approaches across Member States and the EU.

## 1.4. The role of the EU in promoting STEM education in schools

Over the past decade, the EU has implemented a range of initiatives aiming to foster the development of STEM education in schools. These efforts reflect the increasing recognition of the importance of STEM skills in a rapidly changing world and the need for strategic policy intervention to ensure that Europe remains competitive in the global knowledge economy. However, the EU's role in education is supportive and complementary, with Member States retaining primary responsibility for their education systems as outlined in the Treaty on the Functioning of the European Union.

At the strategic level, the EU has initiated key policies, such as those relating to the European Education Area and the European Skills Agenda, which prioritise improving STEM education across Europe. The 2017 Commission communication on school development and excellent teaching underscored the need for cooperation between the higher education, business and research sectors and schools, while aligning STEM education with real-world challenges, such as economic, environmental and social issues. The 2023 Council recommendation on improving the provision of digital skills and competences emphasised the importance of integrating the development of digital skills in STEM education, thereby supporting interdisciplinary approaches such as STEAM, particularly through digital pedagogy.

Most recently, two major EU-level developments have signalled a stronger and more coordinated approach to skills and STEM policy. The Union of Skills strategy, launched in 2025, seeks to integrate education, training, labour market and innovation policies under a common framework, reinforcing the EU's

ambition to create a genuine skills ecosystem. By embedding STEM education within this broader agenda, the Union of Skills aims to address fragmentation, ensure consistency across national reforms and better align STEM priorities with Europe's twin digital and green transitions.

Complementing this, the STEM Education Strategic Plan (2025) provides, for the first time, a comprehensive EU roadmap for advancing STEM in schools. It outlines priorities for curriculum innovation, teacher professionalisation, inclusion and equity, and evidence-informed policy design. The plan also establishes mechanisms such as the STEM Executive Panel to support coordination across Member States and ensure that EU programmes and funding instruments are used more strategically. Together, the Union of Skills and the STEM Education Strategic Plan mark a new phase in EU action, providing a more coherent policy framework to support systemic and sustainable STEM education reforms.

At the programme level, the EU has leveraged various funding mechanisms, including Erasmus+, Horizon Europe, the European Structural and Investment Funds (ESIFs) and the Recovery and Resilience Facility (RRF), to implement these strategic goals. These programmes fund projects that address a wide range of policy aspects, such as STEM curricula, pedagogy, teacher professional development, non-formal learning and the creation of STEM-friendly school infrastructures. Despite these efforts, challenges remain in ensuring the systematic coordination of these initiatives and the effective transfer of good practices across different EU programmes and Member States.

### 1.4.1. EU funding instruments

**Erasmus+** and **Horizon Europe** are central to the EU's efforts in supporting STEM education. Horizon Europe, for example, has funded over 50 projects related to STEM education, focusing on topics such as science communication, innovative learning methods and gender equality in STEM fields. **European Structural and Investment Funds** (ESIF) and **Recovery and Resilience Facility** (RRF) provide significant investments for infrastructure upgrades in schools and support for regional development, including the creation of STEM centres and laboratories. However, the lack of coherent monitoring and reporting systems across these programmes hampers the ability to assess the overall impact of EU investments in STEM education.

### 1.4.2. Challenges in coordination and data availability

Despite the numerous initiatives, there is a lack of systematic coordination across the various EU funding instruments. This fragmentation complicates efforts to monitor the effectiveness of STEM education interventions and share best practices across Member States. The absence of a unified monitoring framework

makes it difficult to track the impact of EU projects on student outcomes, such as STEM achievement or long-term career choices.

### 1.4.3. Gaps in policy and practice

One significant gap identified is the limited EU-level research on effective strategies for promoting STEM education across Europe. While the EU supports practical interventions, there is a lack of targeted research on the long-term effectiveness of these interventions. There is a clear absence of initiatives focused on recruiting and retaining STEM teachers or on addressing issues such as career progression and working conditions. Programmes such as Erasmus+ and Horizon Europe support teacher development but do not tackle the broader structural issues faced by STEM educators. A consistent approach to supporting transitions between educational levels (e.g. from primary to secondary school or from secondary to tertiary education) is lacking. Although some projects address this issue on a case-by-case basis, there is no systematic strategy in place to ensure smooth transitions for students pursuing STEM careers.

### 1.4.4. Opportunities for improvement

There is potential for greater coordination across EU programmes, particularly through the Union of Skills initiative and the STEM Education Strategic Plan launched in 2025. New bodies, such as the European Skills High-Level Board and the STEM Executive Panel, could play a crucial role in addressing coordination challenges and ensuring that STEM education strategies align with national and regional priorities. Improved communication about the benefits of various funding programmes for STEM education could help Member States and schools better leverage EU resources, especially under the RRF, InvestEU and Technical Support Instrument (TSI) programmes, which remain underutilised in supporting STEM education interventions.

### 1.4.5. The role of Europe-wide initiatives

A growing ecosystem of Europe-wide initiatives, supported by EU funding, complements official EU programmes. Networks such as European Schoolnet, the EU STEM Coalition and Science on Stage Europe contribute to the STEM education landscape by fostering collaboration, sharing best practices and providing resources for STEM teachers and students. These initiatives play a key role in advancing STEM education, particularly through professional development for educators and the creation of hands-on learning experiences for students, such as those provided by the European Space Education Resource Office.

## 1.5. Key recommendations for policymakers, educators and stakeholders

To realise the transformative potential of STEM education across Europe, coordinated action is required at the national, EU and local levels. This report's findings and analysis underline the need to move beyond fragmented, short-term initiatives towards systemic, whole-school and whole-system reforms that embed STEM education in all aspects of schooling. The following recommendations are structured by actor group and provide a roadmap for achieving coherent, inclusive and future-oriented STEM education across Europe.

### 1.5.1. Recommendations for national policymakers

- Develop integrated national STEM strategies that foster coherence across ministries and levels of government, supporting a whole-governance STEM approach that spans leadership, curricula, pedagogy, infrastructure and community engagement.
- Empower school leadership and teams to champion interdisciplinary STEM innovation and inclusion, supported by targeted professional development and collaborative networks.
- Address persistent teacher shortages by diversifying recruitment pathways, investing in ITE and CPD focused on interdisciplinary and digital STEM pedagogy, and establishing clear career progression incentives.
- Reform curriculum frameworks to enable flexible STEM learning aligned with real-world challenges, supported by exemplar resources and adaptive assessment systems.
- Invest equitably in physical and digital infrastructure, ensuring that all schools have access to modern laboratories, broadband and the digital tools necessary for inquiry-based STEM learning.
- Embed equity and inclusion as core elements of STEM culture through whole-school strategies, early intervention, mentoring and family engagement, especially targeting under-represented groups.
- Build robust national evaluation systems that capture school-level STEM implementation, learning processes and outcomes, facilitating continuous improvement and knowledge sharing.
- Institutionalise sustainable partnerships with industry, higher education and civil society to enrich STEM learning environments and career pathways.

### 1.5.2. Recommendations for the EU

- Strengthen coordination and integration of funding streams (Erasmus+, Horizon Europe, the Digital Europe programme and the Recovery and Resilience Facility (RRF) in alignment with the Union of Skills and the STEM Education Strategic Plan (2025) to support national STEM strategies with a focus on systemic and sustainable reforms.
- Promote and disseminate the whole-school STEM approach through practical guidance, case studies and peer-learning initiatives, leveraging EU education platforms (e.g. eTwinning, European School Education Platform and Scientix).
- Facilitate structured exchanges between countries on priority issues such as curriculum innovation, formative assessment, early years STEM education and teacher professional development.
- Support teacher education and professional learning by promoting a European STEM competence framework, facilitating mobility and funding collaborative curriculum and CPD programmes.
- Prioritise inclusive and gender-focused actions across all STEM initiatives, building on existing EU programmes to expand outreach and representation.
- Deepen investment in monitoring, research and evidence use by supporting comparative studies, applied research and evaluation frameworks.
- Foster an EU-wide STEM learning ecosystem by connecting schools, universities, research institutions and industry through regional hubs and coordinated innovation networks.

### 1.5.3. Recommendations for schools, educators and industry

- Schools should adopt a whole-school STEM approach that integrates STEM priorities into the school's vision, leadership, pedagogy and partnerships, fostering inclusive and engaging learning environments.
- Educators are encouraged to implement interdisciplinary, inquiry-based STEM teaching practices, engage in professional learning communities and adapt teaching instruction to meet the needs of diverse learners.
- Industry partners should invest in long-term, curriculum-linked collaborations with schools, support STEM career awareness and actively participate in local and regional STEM ecosystems.

### 1.5.4. Cross-border cooperation and funding synergies

Enhancing cross-border cooperation and the strategic alignment of EU and national funding mechanisms is critical for scaling up effective STEM education reforms. Joint planning, thematic clusters, shared resources and multi-actor consortia can reduce fragmentation, increase sustainability and expand access, especially in underserved regions.

# 2. Introduction

## 2.1. Purpose and objectives of the study

This is the Final report of the study entitled 'Promoting STEM education in schools', which was undertaken by Technopolis Group and its consortium partners for the Directorate-General for Education, Youth, Sport and Culture.

The main objective of the study was to map key obstacles to and determinants of successful STEM education. The study also aimed to inform future policy actions at various governance levels to enhance STEM education throughout Europe, including possible multilevel policy mixes with synergies between the EU and national/regional/local efforts. The specific objectives of the study were as follows.

- Conduct a comprehensive mapping of national and local/regional STEM education reforms, strategies, policies and best practices. This includes assessing their goals, their actions and the impact of these initiatives.
- Identify the main policy challenges in STEM education within the Member States.
- Highlight and detail the successful STEM education strategies employed by Member States, including the factors contributing to their success.
- Examine policy initiatives and programmes outside the EU that have successfully advanced STEM education and present possible learning opportunities for Member States and the EU.
- Analyse EU-level policies and programmes, particularly focusing on Erasmus+, to evaluate their effectiveness in promoting STEM education, drawing on existing evidence and case studies.
- Offer recommendations for enhancing STEM education policies at various levels of governance.

## 2.2. Scope of the study

This study focuses on STEM education within the school education sector, encompassing pre-primary, primary and lower- and upper-secondary levels, including secondary vocational education and training (VET). Particular attention is given to the transitions between these levels and the development of key STEM competences throughout a learner's educational journey. In line with the EU key competence framework, the analysis covers not only formal education systems but also non-formal and informal learning opportunities that contribute to competence development in STEM fields. The study spans all 27 Member States,

complemented by six non-EU countries identified for their promising or successful STEM education practices, offering additional international insights. The study primarily considers policy initiatives and programmes implemented within the past 10 years.

Throughout this report, careful attention has been given to the conceptual distinction between STEM competences and digital competence. While these two areas are closely related and often intersect – particularly through the 'technology' component of STEM and the increasing integration of digital tools in science and mathematics learning – they represent distinct domains of knowledge, skills and attitudes. STEM education focuses on disciplinary and interdisciplinary learning in science, technology, engineering and mathematics, serving as a foundation for digital literacy. Competence in science refers to the ability to explain the natural world, whereas competences in technology and engineering are applications of that knowledge, and mathematics contributes the analytical and design tools needed for problem-solving. When combined, these disciplines create a dynamic educational framework equipping students with competences to engage with a complex world. Digital competence, as framed in EU policy (e.g. the Council recommendation on key competences for lifelong learning and the Digital Education Action Plan), refers more specifically to the confident and critical use of digital technologies across all sectors and fields. Where relevant, this report highlights the synergies between STEM and digital competences, while paying attention to conceptual boundaries. Examples or initiatives focused primarily on digital skills are referenced to illustrate intersections or contextual relevance.

## 2.3. Structure of the report

This report presents an overview and cross-analysis of data collected through multiple activities carried out by the study team, addressing the main objectives of the study. The key findings provided in the report were validated with key stakeholders during a dedicated validation seminar, which took place during the study's final phase. The report is structured as follows.

- **Section 1** is the executive summary, outlining the main findings and conclusions of the Final report.
- **Section 2** introduces the study, summarising its key objectives and scope.
- **Section 3** describes the methodological approach, including the intervention logic, data collection strategy, and an overview of methodological limitations and challenges encountered.
- **Section 4** provides background and context to the study, emphasising the importance of STEM education in schools, reviewing the existing

literature and research landscape, and outlining the relevant EU policy framework.

- **Section 5** summarises the key findings of the study:
    - **Section5.1** presents results from country-level research. Section 5.1.1 reviews national and regional policy frameworks; Section 5.1.2 analyses structural challenges and enabling factors across Member States; Section 5.1.3 examines national instruments promoting STEM education and highlights selected good practices; and Section 5.1.4 offers additional insights from six selected non-EU countries.
    - **Section 5.2** analyses the role of the EU in supporting STEM education in schools, including contributions from various programmes and stakeholders, with a particular focus on Erasmus+, identifying gaps and proposing ways forward.
- **Section 6** presents the study's conclusions.
- **Section 7** provides a set of tailored recommendations for different stakeholder groups.

# 3. Methodology

## 3.1. Intervention logic

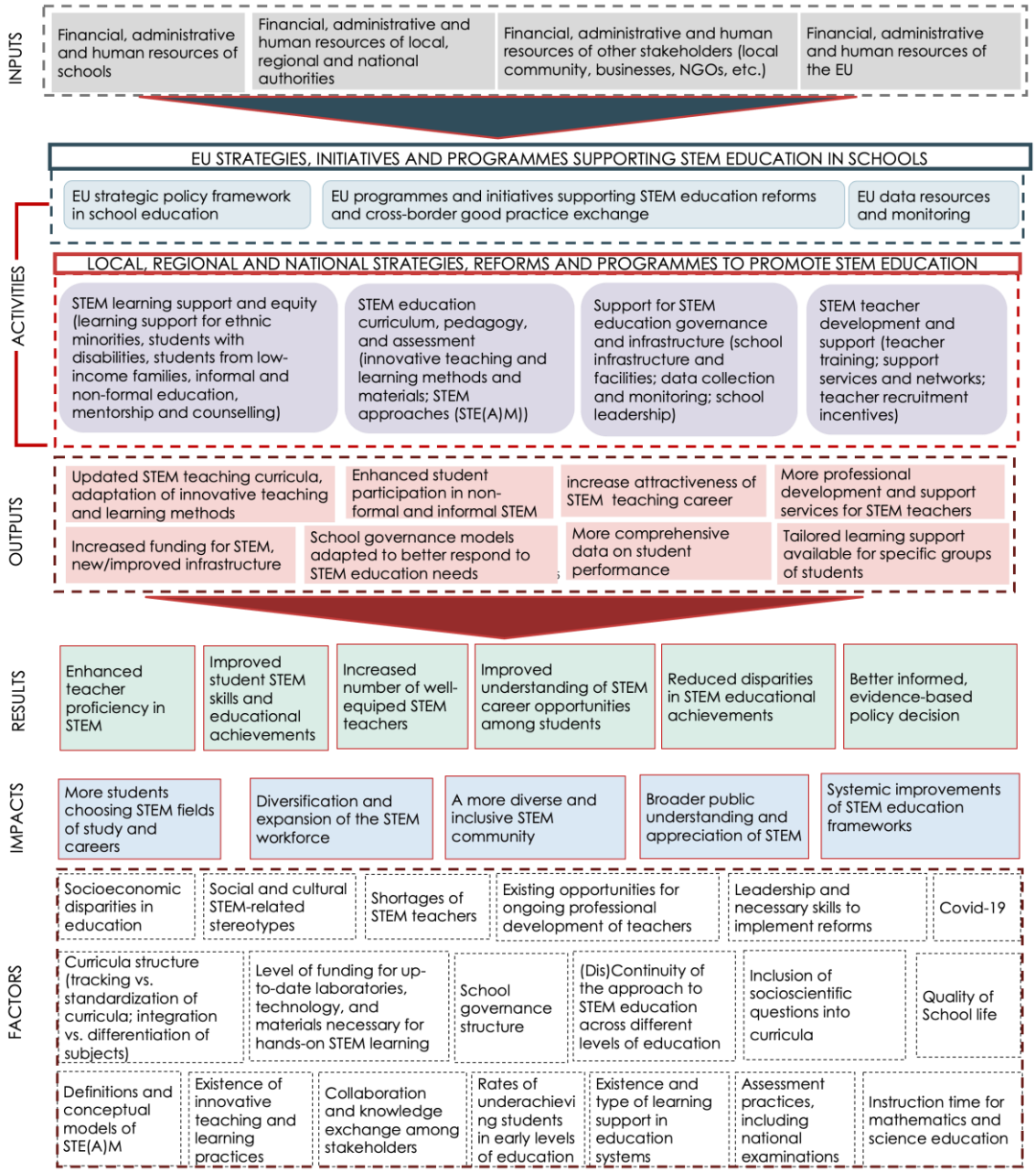
The study was guided by a comprehensive intervention logic that maps the key elements influencing STEM education outcomes across European school systems. This framework provides a structured lens through which to analyse how various factors – such as policy design, curriculum structure, teaching practices and support mechanisms – translate into improved student engagement, achievement and progression in STEM fields.

The intervention logic supports a systemic view of STEM education by considering both enabling and inhibiting factors across multiple dimensions, including pedagogy, equity, governance and school-level implementation. It also accounts for the broader socioeducational context, recognising the interconnected nature of influences on student outcomes.

This framework was developed through detailed desk research and extensive analysis of recent literature, international assessment data and national policy documentation. It was further refined during the inception phase of the study through scoping interviews with key stakeholders and input from the expert advisory board. This iterative process ensured that the intervention logic accurately captured the complexity of STEM education systems and reflected both research evidence and practitioner insights.

The logic model served as the foundation for selecting case studies, designing interview protocols, mapping national policies and programmes and identifying success factors and barriers across the studied education systems. It ensured that the analysis remained aligned with the study's objectives and that findings could be meaningfully compared across countries and education levels.

**Box 1. Intervention logic**




NB: NGO, non-governmental organisation.
*Source:* Study team.

## 3.2. Data collection approach

The study employed a multiphase, mixed-methods data collection strategy designed to capture a comprehensive and comparable picture of STEM education reforms, strategies and practices across the EU-27 and the six non-EU countries. The approach was rooted in the intervention logic developed at the outset of the study and aimed to ensure both breadth and depth of evidence through systematic triangulation of sources.

The data collection phase followed a structured methodology, aligned with five overarching study tasks. These included inception and planning, extensive desk research, stakeholder interviews, thematic focus groups and the development of detailed country and EU-level reports. Throughout the process, the research team maintained strong coordination between national experts, central analysts and the project's expert advisory board to ensure coherence and quality across outputs.

- As part of the data collection, the study team developed an **inventory of 127 Erasmus+ projects** identified as good practices in STEM education, based on their impact, innovation and scalability. This was derived from an initial dataset of over 20 000 projects through keyword filtering and manual screening. From this inventory, 15 projects were selected for in-depth analysis, resulting in **15 Erasmus+ good practice case study reports**.
- In parallel, EU-level desk research and interviews provided the basis for the standalone **EU report**. Seven interviews were conducted with representatives of European institutions, networks and international organisations working on STEM-related themes.
- In total, **264 interviews were completed during the study**. These include scoping interviews, 186 expert interviews conducted to support the development of the country reports, 7 EU-level interviews and 71 interviews carried out for the Erasmus+ case studies, which complemented desk research and document analysis to produce 15 in-depth case studies and a good practice inventory.
- **Two thematic focus group** discussions involving 27 external stakeholders were also organised. These events enabled comparison of emerging trends among countries, identification of structural barriers and exploration of potential synergies across national contexts. Participants included a mix of policymakers, practitioners, researchers and representatives from EU networks and agencies. Their contributions were instrumental in shaping the cross-cutting analysis in this final report.

All data collection activities were guided by tools and templates developed during the inception phase, including interview protocols, country report guidelines and the EU report template. AI-supported source identification methods were also deployed by the central study team to improve efficiency in literature scanning and policy mapping.

## 3.3. Limitations and mitigation strategies

Throughout the study implementation, several operational and methodological challenges were encountered across different phases of data collection and analysis.

- It is important to acknowledge that the results of country research reflect, to a certain extent, the individual judgements of national experts. This is particularly evident in the mapping of instruments and initiatives promoting STEM education in schools. In larger and more decentralised countries, comprehensive coverage of all relevant programmes and reforms was not feasible within the scope of this study. Given this, the mapping sometimes prioritises those initiatives that national experts deemed most relevant or representative of national trends and practices.
- A key challenge during the in-country research phase – one of the most resource-intensive components of the study – was ensuring consistency and analytical depth across all country reports. While detailed guidance and templates were provided, the level of detail and interpretation varied, reflecting the diverse contexts and approaches of participating experts. In some cases, additional support and coordination from the central study team were required to align the reports with the overall analytical framework. Furthermore, balancing a harmonised reporting structure with the need to reflect national specificities involved iterative editorial adjustments to ensure clarity, coherence and comparability across countries.
- Challenges were also observed in identifying, monitoring and analysing STEM-relevant interventions within EU programmes. Although the Erasmus+ Project Results Platform supports filtering for STEM-flagged projects, project data from other EU programmes remained fragmented and difficult to consolidate. This hindered the ability of the researchers to monitor and evaluate systemic outcomes. The selection of Erasmus+ good practices was particularly labour intensive due to the manual screening of projects from an initial pool of over 4 000. Furthermore, some innovative ongoing actions, such as Teacher academies, were not flagged as good practices and had to be manually identified and included in the inventory.
- There were additional challenges related to the retrospective nature of case study research. Project websites were sometimes unavailable and, in several cases, key personnel had left their organisations, complicating interview arrangements and follow-up. Two of the case studies originally selected had to be replaced due to non-responsiveness of project stakeholders.
- For the thematic focus group discussions, in the preparatory phase the study team identified the risk of under-representation of specific stakeholder groups. To mitigate this, the invitation pool was expanded to include additional experts from non-formal education, such as STEM centres, and country-level institutions. This proactive adjustment ensured balanced representation and enriched the discussions.

Across all study components, the study team employed a flexible and collaborative approach to mitigate emerging challenges and uphold methodological integrity and analytical quality.

# 4. Context and background

## 4.1. The importance of STEM education in schools

STEM education is widely recognised as a critical enabler of Europe's future economic competitiveness, social resilience and environmental sustainability ([1]). At both the policy and practice levels, there is growing consensus that high-quality STEM education, across general schooling and VET, is essential for equipping young people with the knowledge and skills needed to thrive in a rapidly changing world.

### 4.1.1. Meeting labour market demands

STEM occupations are projected to be among the **fastest-growing and most in-demand sectors in the European labour market**, especially in fields related to digitalisation, green technologies and advanced manufacturing ([2]). However, many Member States face persistent skills shortages in these areas, highlighting the need to strengthen STEM education pipelines at all levels.

The European Commission's STEM Education Strategic Plan (2025) stresses that **aligning STEM curricula with labour market needs** is crucial not only for economic growth but also for social inclusion, as emerging STEM roles can offer pathways to high-quality employment for diverse learners. The plan advocates comprehensive strategies that combine academic learning with practical, work-based experiences, including those offered through VET systems ([3]).

### 4.1.2. The role of schools

At the school level, **integrating STEM education early and effectively is seen as fundamental to nurturing scientific curiosity, critical thinking and**

([1]) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A STEM Education Strategic Plan: Skills for competitiveness and innovation, COM(2025) 89 final of 5 March 2025, https://education.ec.europa.eu/sites/default/files/2025-03/STEM_Education_Strategic_Plan_COM_2025_89_1_EN_0.pdf.

([2]) Cedefop, 'Cedefop skills forecast 2035: The twin transition and the demographic challenge drive demand for high-level skills', Cedefop website, 14 March 2025, https://www.cedefop.europa.eu/en/news/cedefop-skills-forecast-2035-twin-transition-and-demographic-challenge-drive-demand-high-level.

([3]) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A STEM Education Strategic Plan: Skills for competitiveness and innovation, COM(2025) 89 final of 5 March 2025, https://education.ec.europa.eu/sites/default/files/2025-03/STEM_Education_Strategic_Plan_COM_2025_89_1_EN_0.pdf.

**problem-solving skills**. Embedding interdisciplinary and inquiry-based approaches helps students understand real-world challenges, such as climate change and public health, and fosters their capacity to engage as informed citizens ([4]). Moreover, targeted efforts to enhance teacher competence, improve classroom resources and revise outdated curricula are central to national reforms across Europe.

While these pedagogical ideals are widely recognised, many schools face structural constraints such as rigid curricula and limited resources that challenge the full implementation of inquiry-based and interdisciplinary STEM learning.

### 4.1.3. Vocational education and applied STEM learning (in schools)

Vocational education and training (VET) plays a particularly vital role in preparing young people for technical careers in sectors such as renewable energy, information and communications technology (ICT), construction and manufacturing. The Osnabrück Declaration (2020) called for VET to be modernised across Europe, with an emphasis on green and digital skills, noting that high-quality **STEM content should be embedded in both initial and continuing VET programmes** ([5]).

It is important to clarify that initial VET programmes embedded within school education form a focus of this study, while work-based learning occurring outside formal school settings, such as apprenticeships, is also relevant but beyond the main scope.

### 4.1.4. Equity, inclusion and lifelong learning

A strong STEM foundation in school and VET also supports wider goals around equity and lifelong learning. **Increasing participation in STEM, especially among girls, migrants and disadvantaged learners**, has been identified as a key policy priority by the Organisation for Economic Co-operation and Development (OECD) and European institutions ([6]). Integrating inclusive pedagogies, role models and career guidance into school and VET systems is critical for broadening participation and ensuring that STEM opportunities are accessible to all. These efforts are supported and informed by a growing body of literature, which explores both persistent challenges and emerging innovations in

([4]) European Commission: Joint Research Centre, *Learning by Leaving: Equipping students for mobility*, Publications Office of the European Union, Luxembourg, 2024, JRC141438.

([5]) Council of the European Union, *Osnabrück Declaration on vocational education and training as an enabler of recovery and just transitions to digital and green economies*, Brussels, 2020.

([6]) OECD, *OECD Skills Outlook 2023 – Skills for a resilient green and digital transition*, OECD Publishing, Paris, 2023.

STEM education across Europe. The next section synthesises key insights from this literature.

## 4.2. Overview of existing literature and research trends

Advancing STEM education remains a strategic priority for Europe. Recent literature reveals a complex and evolving picture of how STEM education is defined, delivered and assessed, pointing to both significant progress and ongoing challenges ([7]).

Despite extensive policy and research attention, STEM education remains diverse and context specific, characterised by varying definitions, pedagogical approaches and implementation frameworks across Member States. Recent studies, including comprehensive analyses from the European Commission's Joint Research Centre (JRC) ([8]), highlight critical issues such as the integration of STEM disciplines, digitalisation, equity and inclusion, innovative pedagogies (including STEAM approaches), and effective assessment methods. Understanding these evolving trends is essential for informing robust educational policies and initiatives that equip learners with the skills and competences required in a rapidly changing technological landscape. This section synthesises key insights from the latest literature, providing evidence-based foundations for future policy development at both the national and European levels.

### 4.2.1. Conceptualisation and definitions

STEM education literature reveals **significant variation in how STEM is conceptualised**, reflecting diverse educational and policy contexts. The recent report from the European Commission's JRC ([9]) underscores that a **universally accepted definition of STEM competences remains elusive**, which complicates curriculum design, teaching practices and assessment frameworks. Research consistently advocates clarity in defining what STEM competences entail, highlighting the interplay of subject knowledge, cognitive skills and

([7]) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A STEM Education Strategic Plan: Skills for competitiveness and innovation, COM(2025) 89 final of 5 March 2025, https://education.ec.europa.eu/sites/default/files/2025-03/STEM_Education_Strategic_Plan_COM_2025_89_1_EN_0.pdf.

([8]) JRC, *Improving STEM Education: Policy and practice recommendations*, Publications Office of the European Union, Luxembourg, 2024; see also Pokropek, A., *STEM Competences, Challenges, and Measurements: A literature review*, Publications Office of the European Union, Luxembourg, 2024, JRC138618.

([9]) JRC, *Improving STEM Education: Policy and practice recommendations*, Publications Office of the European Union, Luxembourg, 2024; see also Pokropek, A., *STEM Competences, Challenges, and Measurements: A literature review*, Publications Office of the European Union, Luxembourg, 2024, JRC138618.

transversal competences such as critical thinking, problem-solving and creativity ([10]).

### 4.2.2. Integration versus discipline-specific approaches

A substantial body of research highlights the **distinction between disciplinary and interdisciplinary approaches to STEM education**. Integrated STEM curricula, which intentionally link the four disciplines (science, technology, engineering and mathematics) in cohesive learning experiences, are increasingly promoted for their effectiveness in fostering students' understanding of complex, real-world problems ([11]). However, the JRC report ([12]) acknowledges that the integration of STEM disciplines poses significant challenges, including teachers' preparedness and curricular rigidities. Evidence from empirical studies indicates that **effective interdisciplinary STEM education demands substantial teacher training**, curriculum flexibility and alignment with assessment practices ([13]).

### 4.2.3. Equity, diversity and inclusion in STEM

Persistent disparities in STEM participation, particularly regarding gender and socioeconomic background, remain a critical research area. Recent literature, including reports by the United Nations Educational, Scientific and Cultural Organization (2025) ([14]), emphasises that, despite targeted policies, **women and minority groups remain significantly under-represented in STEM education pathways and careers**. The JRC report ([15]) highlights that tackling these disparities requires systemic changes beyond the classroom, involving

([10]) Li, Y., Schoenfeld, A. H., diSessa, A. A., Graesser, A. C., Benson, L. C., English, L. D. and Duschl, R. A., 'On thinking and STEM education', *Journal for STEM Education Research*, Vol. 3, No 1, 2020, pp. 1–13.

([11]) Li, Y., Schoenfeld, A. H., diSessa, A. A., Graesser, A. C., Benson, L. C., English, L. D. and Duschl, R. A., 'On thinking and STEM education', *Journal for STEM Education Research*, Vol. 3, No 1, 2020, pp. 1–13; see also Honey, M., Pearson, G. and Schweingruber, H. (eds), *STEM Integration in K–12 Education – Status, prospects, and an agenda for research*, National Academies Press, Washington DC, 2014; and Maspul, K. and Kurniawan, A., 'Exploring STEM education for real-world climate change concerns to empower students as change agents', *Journal of Physics Education and Science*, Vol. 1, No 2, 2024, pp. 1–12, https://doi.org/10.47134/physics.v1i2.249.

([12]) Pokropek, A., *STEM Competences, Challenges, and Measurements: A literature review*, Publications Office of the European Union, Luxembourg, 2024, JRC138618.

([13]) Margot, K. C. and Kettler, T., 'Teachers' perception of STEM integration and education: A systematic literature review', *International Journal of STEM Education*, Vol. 6, No 2, 2019.

([14]) United Nations Educational, Scientific and Cultural Organization (UNESCO), *Global Education Monitoring Report 2025: Inclusion and education*, UNESCO Publishing, Paris, 2025.

([15]) Pokropek, A., *STEM Competences, Challenges, and Measurements: A literature review*, Publications Office of the European Union, Luxembourg, 2024, JRC138618.

addressing societal attitudes and teacher biases, promoting mentorship and creating inclusive curricula that reflect diverse experiences and role models. This aligns with broader research indicating the importance of inclusive practices in promoting sustained engagement in STEM fields ([16]).

The German National Educational Panel Study – a long-term cohort study of educational trajectories – found that **student achievement and interest in STEM are strongly shaped by social background and gendered influences**. Recent longitudinal analysis (following students from university entry to their first job) found that parental and peer influences are critical to persistence in STEM studies: having a parent employed in a STEM occupation significantly increases the likelihood of the child (especially a son) pursuing and sticking with STEM in higher education and into a career ([17]). Daughters of STEM-professional mothers were more likely to choose a STEM field in higher education, although mothers' influence did not strongly affect whether they completed STEM degrees or entered STEM jobs. In contrast, fathers in STEM had a sustained encouraging effect on sons' long-term STEM trajectories. The study also highlighted that peer and family support during university was a key success factor for young men's continuation in STEM fields.

### 4.2.4. Digitalisation and technological innovations

Digitalisation is identified as a strategic imperative across national STEM education policies. Emerging research trends indicate **widespread adoption of digital technologies, including virtual reality, augmented reality, AI and online collaborative tools** ([18]). According to the JRC report ([19]), such technologies have significant potential to enhance teaching quality, personalise learning experiences and facilitate formative assessments. However, the literature also provides a word of caution about disparities in access and digital skills proficiency, stressing the need for equitable implementation of technology-enhanced STEM education ([20]).

([16]) Wang, M. T. and Degol, J. L., 'Gender gap in science, technology, engineering, and mathematics (STEM): Current knowledge, implications for practice, policy, and future directions', *Educational Psychology Review*, Vol. 29, 2017, pp. 119–140.

([17]) Stefani, A., 'Parental and peer influence on STEM career persistence: From higher education to first job', *Advances in Life Course Research*, Vol. 62, No 100642, 2024, https://doi.org/10.1016/j.alcr.2024.100642.

([18]) OECD, *Digital Education Outlook 2023: Paving the way for digital literacy*, OECD Publishing, Paris, 2023.

([19]) Pokropek, A., *STEM Competences, Challenges, and Measurements: A literature review*, Publications Office of the European Union, Luxembourg, 2024, JRC138618.

([20]) OECD, *Digital Education Outlook 2023: Paving the way for digital literacy*, OECD Publishing, Paris, 2023.

### 4.2.5. Pedagogical innovations and STEAM

Contemporary pedagogical approaches in STEM increasingly embrace active learning methods, such as project-based learning, inquiry-based learning and design-based thinking ([21]). Additionally, there is growing advocacy for STEAM, often understood as the combination of STEM subjects with the arts, or more broadly with 'any other discipline' – that is, the social sciences and humanities. Integrating artistic and creative disciplines into STEM curricula enhance creativity, innovation and learner engagement ([22]). Research identifies positive outcomes of STEAM approaches, notably increased student interest, improved problem-solving skills and broader appeal across diverse student populations ([23]). Nevertheless, a recent JRC publication ([24]) highlights ongoing debates about STEAM, noting challenges around teacher competences and the structural integration of the arts, social sciences and humanities within traditional STEM curricula.

### 4.2.6. Assessment and measurement challenges

The literature consistently identifies **assessment as a critical challenge for STEM education**. Given STEM's interdisciplinary nature, traditional assessment methods focused on disciplinary knowledge often fail to measure essential skills such as collaboration, innovation and practical problem-solving ([25]). The JRC report echoes this concern, calling for the development of more nuanced, performance-based assessments capable of capturing the breadth of STEM competences. Research increasingly supports formative and authentic ([26])

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([21]) Li, Y., Schoenfeld, A. H., diSessa, A. A., Graesser, A. C., Benson, L. C., English, L. D. and Duschl, R. A., 'On thinking and STEM education', *Journal for STEM Education Research*, Vol. 3, No 1, 2020, pp. 1–13; see also Honey, M., Pearson, G. and Schweingruber, H. (eds), *STEM Integration in K–12 Education: Status, prospects, and an agenda for research*, National Academies Press, Washington DC, 2014.

([22]) Amanova, A. K., Butabayeva, L. A., Abayeva, G. A., Umirbekova, A. N., Abildina, S. K. and Makhmetova, A. A., 'A systematic review of the implementation of STEAM education in schools', *Eurasia Journal of Mathematics, Science and Technology Education*, Vol. 21, No 1, 2025, article em2568.

([23]) Conradty, C. and Bogner, F. X., 'STEAM teaching professional development: From training to implementation', *Frontiers in Education*, 2020.

([24]) Mazzeo Ortolani, G., *STEM and STEAM Education, and Disciplinary Integration: A guide to informed policy action*, European Commission, Brussels, 2025, JRC141438.

([25]) Honey, M., Pearson, G. and Schweingruber, H. (eds), *STEM Integration in K–12 Education: Status, prospects, and an agenda for research*, National Academies Press, Washington DC, 2014; see also Maric, D., Fore, G. A., Nyarko, S. C. and Varma-Nelson, P., 'Measurement in STEM education research: A systematic literature review of trends in the psychometric evidence of scales', *International Journal of STEM Education*, Vol. 10, No 1, 2023, article 39.

([26]) Authentic assessment involves evaluating students' learning through tasks that mirror real-world situations and challenges.

assessment methods, such as portfolios, collaborative projects and real-world problem-solving tasks, that align better with STEM's educational goals ([27]).

### 4.2.7. Alignments with labour market needs and economic competitiveness

STEM education is widely linked to national innovation and competitiveness agendas. The literature indicates that the **alignment of STEM curricula with labour market demands and industry needs remains a core policy priority** across Europe and internationally ([28]). The JRC advocates curricula that balance immediate workforce needs with competences for lifelong learning, such as adaptability and critical thinking. Reports frequently highlight that effective STEM education must not only prepare students for existing jobs but also equip them to navigate rapidly evolving labour markets ([29]).

## 4.3. EU policy context

Building on the challenges and opportunities identified in the literature, this section outlines the evolving policy landscape of STEM education in Europe, with a focus on EU-level strategic initiatives (the analysis of specific support instruments is provided in Section 5.2).

Over the last decade, several EU initiatives have sought to foster STEM education development, recognising the need for STEM skills policy intervention. Since the field of education is a **Member State competence** as defined by Article 165 of the Treaty on the Functioning of the European Union, EU-level actions in education are supportive in character. Hence, the EU coordinates or complements Member State activities ([30]). In the field of education, the EU employs the open method of coordination, which uses jointly defined objectives, monitoring and benchmarking ([31]). The Council resolution on a strategic framework for European cooperation in education and training towards the European Education Area and beyond (2021–2030) provides a platform for EU

([27]) Shavelson, R. J., Zlatkin-Troitschanskaia, O. and Marino, J. P., 'International performance assessment of learning in higher education', *Assessment & Evaluation in Higher Education*, Vol. 44, No 7, 2019, pp. 993–997.

([28]) OECD, *OECD Employment Outlook 2023*: Artificial intelligence and the labour market, OECD Publishing, Paris, 2023.

([29]) The Lisbon Council, 'Future-proof skills for Europe: STEM, competitiveness, and social fairness', The Lisbon Council website, May 2025, https://lisboncouncil.net/summits/future-proof-skills-for-europe-stem-competitiveness-and-social-fairness/.

([30]) Treaty on the Functioning of the European Union (OJ C 202, 7.6.2016, p. 52, http://data.europa.eu/eli/treaty/tfeu_2016/art_6/oj) (Article 6).

([31]) European Union, 'Open method of coordination', EUR-Lex, accessed 29 July 2025, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM:open_method_coordination.

cooperation in the field of education. Notably, the European Education Area thematic working groups, peer-learning activities and joint progress monitoring offer the underlying structure through which EU-level coordination is ensured ([32]).

Enhancing STEM education is a long-standing priority within the EU, closely aligned with broader strategic objectives concerning education, innovation, competitiveness, digital transformation and social inclusion. European Commission policies consistently emphasise the role of STEM competences in addressing contemporary and future economic, societal and technological challenges, reflecting their critical importance for European prosperity, sustainability and global competitiveness ([33]).

The vision of the **European Education Area** is to create more connected, more inclusive and high-performing education systems across the EU by 2025. The European Education Area explicitly identifies STEM and digital competences as essential to achieving the broader objectives of quality, equity and innovation in education. It supports national reforms, mutual recognition of qualifications and stronger transnational cooperation, including in the development of joint programmes, teacher mobility and mutual learning in curriculum and assessment design and in other aspects of education and training ([34]).

STEM education has been on the EU's agenda for some time, with notable initiatives being launched under the **2017 Commission communication on school development and excellent teaching for a great start in life** ([35]), which highlighted the importance of connecting school-level STEM education with the higher education, business and research sectors. It also advocated linking STEM learning to economic, environmental and social challenges, and to the arts and

([32]) European Commission, 'Strategic framework', European Commission website, 25 October 2023, accessed 29 July 2025, https://education.ec.europa.eu/about-eea/strategic-framework; see also Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on achieving the European Education Area by 2025, COM(2020) 625 final of 30 September 2020, https://education.ec.europa.eu/sites/default/files/document-library-docs/eea-communication-sept2020_en.pdf.

([33]) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – European skills agenda for sustainable competitiveness, social fairness and resilience, COM(2020) 274 final of 1 July 2020; see also European Commission, 'Digital education action plan 2021–2027: Resetting education and training for the digital age', European Commission website, https://education.ec.europa.eu/focus-topics/digital-education/actions.

([34]) Commission staff working document accompanying the document communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on progress towards the achievement of the European Education Area, SWD(2022) 750 final of 18 November 2022.

([35]) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – School development and excellent teaching for a great start in life, COM(2017) 248 final of 30 May 2017.

design, to demonstrate its relevance to everyday life ([36]). The **Council recommendation of 22 May 2018 on key competences for lifelong learning** included a definition of STEM competences and stressed that 'the support of competence development in STEM becomes increasingly relevant' ([37]). There is also a connection of STEM-related concepts to digital skills. The **Digital Education Action Plan** dedicates a specific action to reducing the gender gap in STEM studies and careers (action 13, 'Women's participation in STEM studies and careers') ([38]). In addition, the **2023 Council recommendation on the key enabling factors for successful digital education and training** highlights the need for equal access to learning opportunities in STEAM fields, including through digital pedagogy and interdisciplinary approaches ([39]). In parallel, the **2023 Council recommendation on improving the provision of digital skills and competences in education and training** recommends that Member States develop cross-curricular approaches linking digital skills with different subjects and improving both their assessment and related teacher training. The recommendation specifically focuses on integrating digital skills and competences with STEAM ([40]).

A key strategic framework supporting STEM skills development at the EU level is the **European Skills Agenda** ([41]). Within this agenda, action 7 ('Increasing STEM graduates and fostering entrepreneurial and transversal skills') specifically targets the enhancement of STEM-related human capital. The action seeks to boost the number of STEM graduates by promoting the attractiveness of STEM studies and careers, addressing teacher shortages, supporting science education through research and innovation actions, and facilitating transitions between secondary and tertiary education through research-informed approaches ([42]).

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([36]) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – School development and excellent teaching for a great start in life, COM(2017) 248 final of 30 May 2017.

([37]) Council recommendation of 22 May 2018 on key competences for lifelong learning (OJ C 189, 4.6.2018, p. 1, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=oj:JOC_2018_189_R_0001) (recital 16).

([38]) European Commission, 'Women's participation in STEM studies and careers', European Commission website, 20 June 2025, accessed 29 July 2025, https://education.ec.europa.eu/focus-topics/digital-education/action-plan/action-13.

([39]) Council recommendation of 23 November 2023 on the key enabling factors for successful digital education and training (OJ C, C/2014/1115, 23.11.2023, https://data.consilium.europa.eu/doc/document/ST-15741-2023-INIT/en/pdf).

([40]) Council recommendation of 23 November 2023 on improving the provision of digital skills and competences in education and training (OJ C, C/2024/1030, 23.11.2023, ELI: http://data.europa.eu/eli/C/2024/1030/oj).

([41]) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – European skills agenda for sustainable competitiveness, social fairness and resilience, COM(2020) 274 final of 1 July 2020.

([42]) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – European skills agenda

In parallel, action 3 ('EU support for strategic national upskilling action') encourages Member States to develop comprehensive, whole-of-government skills strategies, with a particular emphasis on competences needed for the green and digital transitions ([43]). This is further reinforced by action 6 ('Skills to support the twin transitions'), which explicitly highlights the central role of STEM education in equipping individuals with the skills required to drive innovation in critical areas such as AI and cybersecurity. The communication accompanying the European Skills Agenda underscores the importance of fostering high levels of STEM competences and places a strong emphasis on reducing the gender gap, especially in tertiary STEM education, as a key enabler of inclusive and sustainable growth.

Most recently, in March 2025, the European Commission unveiled the **STEM Education Strategic Plan** ([44]), a cornerstone of the broader 'Union of Skills initiative to improve the quality of education, training and lifelong learning ([45]). The STEM Education Strategic Plan aims to tackle critical challenges in STEM education and unlock opportunities across the EU, ensuring its competitiveness, preparedness and technological leadership. The plan sets out three key objectives.

- **Lead.** Anchor STEM as a strategic pillar in the EU's education and skills policy. This includes proposing 2030 EU-level STEM targets, establishing a European STEM Executive Panel to advise on strategic issues and improving STEM skills intelligence by measuring graduate outcomes and anticipating sector-specific needs.
- **Level up.** Build a stronger and more inclusive EU STEM talent pipeline. Actions under this objective involve developing a STEM competence framework; working towards a European degree for engineers; launching the 'STEM tech talent induction' to attract more young people to STEM careers; piloting STEM education centres for schools to foster local and regional learning ecosystems; and piloting the development of 'STEM skills foundries' in strategic sectors, for mentoring young student entrepreneurs.

for sustainable competitiveness, social fairness and resilience, COM(2020) 274 final of 1 July 2020.

([43]) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – European skills agenda for sustainable competitiveness, social fairness and resilience, COM(2020) 274 final of 1 July 2020.

([44]) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A STEM Education Strategic Plan: Skills for competitiveness and innovation, COM(2025) 89 final of 5 March 2025, https://education.ec.europa.eu/sites/default/files/2025-03/STEM_Education_Strategic_Plan_COM_2025_89_1_EN_0.pdf.

([45]) Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions – The union of skills, COM(2025) 90 final of 5 March 2025.

- **Lift barriers.** Advance women in STEM and inspire future innovators. Initiatives include Girls Go STEM, which aims to train 1 million young women by 2028; STEM futures, which aims to identify and disseminate successful STEM education practices; showcasing and exchanging good practices to attract and support girls and women in STEM apprenticeships; and piloting a STEM specialists' fellowship to attract top international STEM experts.

In parallel, the **Action Plan on Basic Skills**, also introduced in 2025, as part of the Union of Skills package ([46]), reinforces foundational learning to improve proficiency in reading, mathematics, science, digital and citizenship skills. It complements the STEM strategy by advocating evidence-informed pedagogical approaches, improved teacher support and systemic interventions to ensure that all learners acquire essential skills for life and work.

The Commission's emphasis on equity and gender inclusion in STEM has also gained traction. A recent Commission report synthesised evidence and best practices for addressing gender disparities at all educational levels ([47]). The Commission has launched education initiatives such as Girls Go Circular ([48]), and calls through Erasmus+ and Horizon Europe encourage the boosting of female participation in STEM and ICT fields.

EU support for STEM education is further operationalised through targeted funding and stakeholder engagement. Programmes such as Erasmus+, the Recovery and Resilience Facility (RRF) and the Digital Europe programme provide financial backing for teacher training, infrastructure modernisation and digital curriculum development (for more details, see Section 5.2). Complementary stakeholder-led initiatives such as Scientix ([49]) and the EU STEM Coalition ([50]) facilitate cross-border collaboration, knowledge exchange and joint action among policymakers, educators and industry.

Overall, EU policy frameworks consistently underline the strategic importance of STEM education as an integral part of Europe's long-term economic, digital, social and environmental goals. Through coherent policy initiatives, targeted funding and international cooperation, the European Commission actively seeks

([46]) Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions – Action plan on basic skills, COM(2025) 88 final of 5 March 2025.

([47]) Evagorou, M., Puig, B., Bayram, D. and Janeckova, H., *Addressing the gender gap in STEM education across educational levels – Analytical report*, Publications Office of the European Union, Luxembourg, 2024, accessed 29 July 2025, https://op.europa.eu/en/publication-detail/-/publication/5c74b478-3ffe-11ef-865a-01aa75ed71a1.

([48]) https://eit-girlsgocircular.eu/.

([49]) https://www.scientix.eu/.

([50]) https://www.stemcoalition.eu/.

to foster innovative, inclusive and future-oriented STEM education across all Member States.

# 5. Findings

## 5.1. The STEM education landscape in the analysed countries

This section draws on rich and diverse evidence from the 27 Member State reports and the 6 non-EU country reports, and the complementary desk research evidence. While every effort has been made to identify and reflect key trends, the report does not claim to be exhaustive. Country-level information is used illustratively to highlight emerging patterns and policy directions, rather than to categorically map or benchmark individual Member States against each thematic area. This is due both to the diversity of national contexts and to the fact that data could not be collected in a fully harmonised or systematic way across all dimensions. Thus, examples are selected to illuminate broader insights rather than to offer definitive comparisons.

### 5.1.1. Overview of the existing national and regional policy frameworks for STEM education in schools

This section provides an **analysis of how STEM education is defined, conceptualised and operationalised across national and regional education systems in Europe**. It begins by tracing the evolution of STEM definitions, from traditional, discipline-based understandings to more interdisciplinary and competence-focused models that reflect broader educational, economic and societal goals. Countries are grouped into five conceptual clusters based on how STEM is framed in terms of curriculum structure, policy integration, innovation, labour market alignment and inclusion of other disciplines (particularly the arts, social sciences and humanities, within STEAM). This typology offers a lens through which to examine the coherence between conceptualisation and implementation. The second part of the section explores how these conceptual approaches are embedded in national policy frameworks, strategies and reform agendas, including digital transformation, interdisciplinary learning, teacher training, equity and cross-sectoral collaboration. Together, these analyses reveal the varying degrees of alignment between how STEM is understood and how it is promoted through concrete policies and institutional mechanisms.

#### 5.1.1.1. Definition and conceptualisation of STEM

Historically, STEM was conceptualised as a set of distinct academic disciplines, with mathematics and science dominating the formal curricula ([51]). Over time, both European policy and international literature have promoted a more integrated and interdisciplinary approach ([52]). This **evolving understanding** highlights not only disciplinary knowledge but also transversal competences such as critical thinking, creativity, problem-solving and collaboration. Additionally, it encompasses efforts to address gender and participation gaps, embed STEM across subject areas and connect learning to real-world challenges, notably the green and digital transitions. This view is echoed in recent literature, which notes the increasing emphasis on systems thinking, collaboration and the ability to apply STEM knowledge in authentic and cross-disciplinary contexts (see Section 4.2).

**Box 2. STEM definitions: background**

Before 2000, STEM was generally defined as separate school subjects (particularly science and mathematics), with technology and engineering being more consistently under-represented ([53]). Starting **from the early 2000s**, there was a move towards looking at STEM in schools as being intrinsically linked to national innovation and workforce skills, which increased the link to policy ([54]). Over the last 20 years, the wider literature has called for interdisciplinary teaching, problem-solving and real-world applications, and for STEM to be framed as a tool for addressing societal challenges, with broader inclusion of 21st-century and transversal skills ([55]).

More recently, through the **STEM Education Strategic Plan**, the European Commission has underscored the importance of STEM for innovation, digital transformation ([56]), gender equity and the sustainability challenges. Member States are encouraged to adopt inclusive and applied approaches to STEM education. This trajectory also reflects broader calls for education systems to shift towards competence-based models that prepare learners for complexity and uncertainty ([57]).

([51]) Breiner, J. M., Harkness, S. S., Johnson, C. C. and Koehler, C. M., 'What is STEM? A discussion about conceptions of STEM in education and partnerships', *School Science and Mathematics*, Vol. 112, No 1, 2012, pp. 3–11.

([52]) European Commission: Directorate-General for Research and Innovation, *Science Education for Responsible Citizenship*, Publications Office of the European Union, Luxembourg, 2015; European Commission: Directorate-General for Education, Youth, Sport and Culture, *Key Competences for Lifelong Learning*, Publications Office of the European Union, Luxembourg, 2018; and European Schoolnet, *Science, technology, engineering and mathematics education policies in Europe*, European Schoolnet, Brussels, 2018.

([53]) OECD, *National Curriculum Frameworks*, OECD Publishing, Paris, 1999.

([54]) Marginson, S., Tytler, R., Freeman, B. and Roberts, K., *STEM: Country comparisons*, Australian Council of Learned Academies, Melbourne, 2013.

([55]) Kelley, T. R. and Knowles, J. G., 'A conceptual framework for integrated STEM education', *International Journal of STEM Education*, Vol. 3, No 11, 2016.

([56]) European Commission, *Digital Education Action Plan 2021–2027: Resetting education and training for the digital age*, Brussels, 2020.

([57]) Pokropek, A., *STEM Competences, Challenges, and Measurements: A literature review*, Publications Office of the European Union, Luxembourg, 2024, JRC138618.

Despite the increasing alignment around interdisciplinary and competence-based visions of STEM education, the concept remains fluid and context dependent, with varying interpretations among countries, institutions and stakeholders ([58]).

## National definitions and conceptualisations of STEM: a comparative overview

The reviewed country reports reveal **substantial variation** in how STEM education is defined and conceptualised across Member States. **Most countries do not have a formal or legally binding definition of STEM.** National approaches are inferred from policy strategies, curriculum frameworks or programme initiatives. While many continue to define STEM through its core disciplines – science, technology, engineering and mathematics – others adopt broader interpretations that reflect goals related to digitalisation, labour market needs, educational reform and social inclusion.

Terminology also varies: some countries refer to STEAM (incorporating the arts, humanities and social sciences) while others use national equivalents such as CTIM (*ciencia, tecnología, ingeniería y matemáticas*) (Spain), SNiT (Sweden) and MINT (Germany and Austria). In many systems, STEM is not explicitly named but understood implicitly through the way the curriculum is structured (e.g. Czechia, France and Slovenia).

To better capture these divergences, **four main conceptual clusters and one emerging cluster** have been identified. These reflect different emphases (on curriculum content, policy integration, technological innovation and skills development) and help assess the degree to which national approaches align with integrated, inclusive and future-ready STEM education ([59]). The four main clusters are:

- cluster 1 – interdisciplinary and policy-integrated approaches;
- cluster 2 – curriculum-centred and discipline-based definitions;
- cluster 3 – innovation- and technology-driven framing;
- cluster 4 – industry-aligned and skills-oriented definitions.

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([58]) Evagorou, M. and Konstantinidou, E., *European collaboration and mobility in professional development of pre- and in-service STEM teachers*, Policy Brief 1, ICSE Academy, Freiburg im Breisgau, 2023, https://drive.google.com/file/d/1xQzT1w3LDhogAqBU6-3cqfLT7hZXBcdT/view?usp=share_link; European Schoolnet, *Science, technology, engineering and mathematics education policies in Europe*, European Schoolnet, Brussels, 2018, http://www.eun.org/resources/detail?publicationID=1481; Evagorou, M., Puig, B., Bayram, D. and Janeckova, H., *Addressing the gender gap in STEM education across educational levels – Analytical report*, Publications Office of the European Union, Luxembourg, 2024, accessed 29 July 2025, https://op.europa.eu/en/publication-detail/-/publication/5c74b478-3ffe-11ef-865a-01aa75ed71a1.

([59]) European Commission, 'STEM education and training', European Commission website, 6 March 2026, accessed 29 July 2025, https://education.ec.europa.eu/focus-topics/stem.

The **emerging fifth cluster** prioritises the integration of the arts and/or other subjects (STEAM), as highlighted above. This is closely associated with cluster 1 (interdisciplinary and policy-integrated approaches). It warrants separate consideration due to its distinct emphasis on creativity and transdisciplinary learning, which encompasses the arts, psychology, the humanities and the social sciences. Additionally, many countries exhibit characteristics of multiple clusters or are transitioning between them, so country examples may appear in more than one cluster ([60]). The clusters are described below.

### Cluster 1. Interdisciplinary and policy-integrated approaches

Countries in this first cluster frame STEM as a cross-cutting educational priority, embedding it within wider policy agendas such as curriculum reform, social inclusion and sustainability. Definitions tend to emphasise interdisciplinarity, equity and real-world relevance, often supported by national strategies or multi-sectoral initiatives ([61]).

**Box 3. Examples of STEM conceptualisations (cluster 1)**

Member States in this cluster**:** Belgium (Flemish Region), Ireland, Italy, Latvia, Malta, the Netherlands, Poland and Sweden.

In these countries, national strategies often highlight the role of STEM in fostering transversal competences, digital literacy and civic engagement. **Italy** references STEM in connection with national priorities around the green transition and gender equity. **Latvia** embeds STEM within its education development guidelines for 2021–2027 ([62]), emphasising digital skills and alignment with economic needs. **Ireland** has a formal STEM education policy, focusing on equity, excellence and engagement ([63]), while **Sweden's** competence-based curriculum integrates STEM within broader sustainability and innovation goals. This type of STEM framing is sensitive to the key educational competences set out at the European level and is reinforced by recent literature highlighting STEM's role in fostering systems thinking and civic engagement ([64]).

*Source:* Country reports.

([60]) A further distinction emerging across the country reports relates to momentum in reform. Some countries are moving towards future-facing definitions of STEM, as embedded in national innovation and equity strategies. Others remain in the early phases of subject-based reform.

([61]) This approach aligns closely with the European Commission's STEM Education Strategic Plan objectives on interdisciplinary learning, gender inclusion and societal relevance.

([62]) Ministry of Education and Science (Latvia), *Education Development Guidelines 2021–202 – 'Future skills for a future society'*, Ministry of Education and Science, Riga, 2021, https://eprasmes.lv/wp-content/uploads/2022/02/Latvijas-Izglitibas-attsitibas-pamatnostadnes-2021-2027.pdf.

([63]) Department of Education and Department of Children, Equality, Disability, Integration and Youth (Ireland), *STEM Education Implementation Plan to 2026*, Department of Education and Department of Children, Equality, Disability, Integration and Youth, 2023, https://assets.gov.ie/249002/3a904fe0-8fcf-4e69-ab31-987babd41ccc.pdf.

([64]) Pokropek, A., *STEM Competences, Challenges, and Measurements: A literature review*, Publications Office of the European Union, Luxembourg, 2024, JRC138618.

## Cluster 2. Curriculum-centred and discipline-based definitions

Countries in this cluster define STEM education through subject-specific lenses, with a focus on enhancing outcomes in traditional core areas such as mathematics and science. The emphasis is on standardised testing, attainment targets and curriculum reform within established disciplinary boundaries. This traditional framing aligns with what Pokropek ([65]) describes as the 'subject-centric' model, in which STEM is primarily seen as a vehicle for boosting performance metrics rather than addressing broader societal challenges or competence development.

**Box 4. Examples of STEM conceptualisations (cluster 2)**

**Country examples:** Bulgaria, Czechia, Denmark, Greece, Spain, France, Croatia, Cyprus, Luxembourg, Hungary, Austria, Poland ([66]), Portugal, Romania, Slovenia and Slovakia.

This group represents the largest cluster, comprising countries with curricula that are typically built around traditional subjects such as mathematics, chemistry, biology and physics, with engineering and technology either under-represented or confined to vocational education.
This approach reflects an earlier phase in the evolution of STEM education, focused primarily on improving achievement and uptake in core subjects. While some countries, such as **Denmark and Portugal**, are undertaking curricular reforms, their foundational STEM structures remain discipline-centric. In **France**, STEM is not commonly used as a formal term in education policy. Science and mathematics are treated as distinct disciplines within the national curriculum. Integration is limited and occurs mainly through cross-curricular or extracurricular initiatives.

*Source:* Country reports.

## Cluster 3. Innovation- and technology-driven framing

This cluster includes countries that link STEM education directly with innovation ecosystems, economic competitiveness and emerging technological fields. STEM is defined as a strategic lever for digital transformation, often embedded in national AI or digital skills strategies. Definitions in these contexts tend to prioritise adaptability, data literacy and entrepreneurial thinking. Pokropek ([67]) notes that such definitions are increasingly shaped by technological imperatives and national industrial policy goals, reflecting a utilitarian approach to STEM education.

**Box 5. Examples of STEM conceptualisations (cluster 3)**

**Countries:** Estonia, Lithuania and Finland

([65]) Pokropek, A., *STEM Competences, Challenges, and Measurements: A literature review*, Publications Office of the European Union, Luxembourg, 2024, JRC138618.

([66]) Although Poland currently sits in this cluster and it is reported that the term STEM is rarely used outside policy circles, Poland is preparing for major curriculum reform and a shift towards holistic science education.

([67]) Pokropek, A., *STEM Competences, Challenges, and Measurements: A literature review*, Publications Office of the European Union, Luxembourg, 2024, JRC138618.

**Estonia** and **Finland** integrate programming, AI education and computational thinking from early years education onwards, supported by a strong digital infrastructure and national strategies. **Lithuania** has invested in modernising education through **School 2030** and the general curriculum framework, embedding digital literacy and cross-disciplinary competences. Cluster 3 aligns closely with the Digital Education Action Plan ([68]) and Horizon Europe goals ([69]).

*Source:* Country reports.

## Cluster 4. Industry-aligned and skills-oriented definitions

Countries in this fourth cluster align their STEM definition more closely with labour market demands, vocational training and employer expectations. The focus is on developing job-ready skills, particularly in engineering, manufacturing and applied sciences. STEM is framed as a pipeline for economic productivity and sector-specific workforce needs. Pokropek ([70]) highlights that, while this model supports strong industry–education linkages, it can risk narrowing the educational scope of STEM and underemphasising critical thinking or ethical considerations.

**Box 6. Examples of STEM conceptualisations (cluster 4)**

**Country examples:** Germany and Austria

**Germany** and **Austria** promote strong links between STEM education and the world of work. **Germany**, through its dual education system, integrates VET school learning with industry-based apprenticeships, particularly in engineering and applied sciences. **Austria's** vocational pathways also demonstrate this alignment, focusing on technical education and employer collaboration. While these models support economic competitiveness, they may underemphasise interdisciplinary or civic dimensions of STEM.

*Source:* Country reports.

## Cluster 5. From STEM to STEAM: emerging trends across Europe

An emerging cluster focuses on expanding STEM to STEAM by incorporating the arts, humanities and social sciences. This reflects an increasing recognition of the role of creativity, design and cultural literacy in tackling complex societal challenges. Countries in this fifth cluster indicate that they include the arts and creativity in STEM education and their definitions; however, implementation varies significantly. For example, Ireland and Portugal have established national frameworks that support STEAM learning, while countries such as Greece and

([68]) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Digital education action plan 2021–2027: Resetting education and training for the digital age, COM(2020) 624 final of 30 September 2020.

([69]) European Commission, 'Horizon Europe', European Commission website, accessed 29 July 2025, https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en.

([70]) Pokropek, A., *STEM Competences, Challenges, and Measurements: A literature review*, Publications Office of the European Union, Luxembourg, 2024, JRC138618.

Slovakia are still exploring integration through pilot programmes and project-based learning, with STEAM not indicated in their definitions.

As mentioned, many countries have characteristics from multiple clusters. For example, Ireland combines policy integration (cluster 1), innovation (cluster 3) and skills development (cluster 4), while Finland bridges interdisciplinary learning (cluster 1) and STEAM (cluster 5). The cluster framework allows for nuanced comparison and supports a systems-level understanding of how **STEM education is evolving across different national contexts**. The following summary table sets out each country and under which clusters their definition falls.

### Box 7. Country mapping by STEM definition conceptual cluster

| Country | Interdisciplinary and policy integrated | Curriculum centred and discipline based | Innovation and technology driven | Industry aligned and skills oriented | Incorporating STEAM |
|---|---|---|---|---|---|
| Belgium | ■ | ■ | ■ | ■ | |
| Bulgaria | | ■ | ■ | ■ | |
| Czechia | | ■ | | | |
| Denmark | ■ | | ■ | ■ | ■ |
| Germany | | ■ | ■ | ■ | |
| Estonia | | ■ | ■ | | |
| Ireland | ■ | | ■ | ■ | ■ |
| Greece | ■ | ■ | ■ | ■ | |
| Spain | | ■ | | | ■ |
| France | | ■ | | | |
| Croatia | ■ | ■ | ■ | ■ | |
| Italy | | ■ | ■ | ■ | |
| Cyprus | ■ | ■ | ■ | ■ | |
| Latvia | ■ | ■ | | | |
| Lithuania | ■ | ■ | | | |
| Luxembourg | ■ | ■ | ■ | ■ | |
| Hungary | ■ | ■ | ■ | ■ | |
| Malta | ■ | | ■ | ■ | |
| Netherlands | ■ | | | ■ | ■ |
| Austria | | ■ | ■ | ■ | |
| Poland | ■ | | ■ | ■ | |
| Portugal | ■ | | | | ■ |
| Romania | ■ | ■ | ■ | ■ | |
| Slovenia | | ■ | | | |
| Slovakia | | ■ | | | |
| Finland | ■ | | ■ | ■ | ■ |
| Sweden | ■ | | ■ | ■ | |

*Source:* Analysis based on country reports.

While countries vary significantly in how they define and conceptualise STEM, these orientations also influence, and are influenced by, national policy frameworks and strategic priorities. The next section provides an overview of STEM strategies and priorities in the Member States. This policy overview also revisits STEM definitions to assess where alignment exists and where gaps remain.

#### 5.1.1.2. STEM strategies and priorities

Across the EU, STEM education has emerged as a strategic priority, although national approaches vary significantly. Many Member States have embedded STEM objectives into long-term educational reforms, often as part of broader efforts to modernise curricula, enhance teacher competences and invest in digital infrastructure. While some countries, such as **Germany**, **Ireland**, **Austria** and **Finland**, have developed dedicated STEM strategies, others, including **Greece**, **Poland**, **Portugal** and **Romania**, integrate STEM within general education frameworks.

In countries operating within broader frameworks, STEM subjects, particularly at the secondary level, tend to be taught in disciplinary silos, with limited integration of interdisciplinary or STEAM approaches. Even where national STEM strategies exist, implementation is frequently uneven across regions, school types and educational levels. Individual schools often serve as pioneers of innovation, experimenting with interdisciplinary methods, experiential learning and STEAM integration. However, these practices are rarely scaled up or systematised at the national level.

Despite these challenges, policy momentum is growing across Europe. This section explores the six most prominent strategic trends shaping STEM education reform:

- digitalisation and integration of digital tools,
- interdisciplinary and experiential learning,
- STEAM approaches and creative integration,
- innovative pedagogy and teacher training,
- equity in access and attainment,
- systemic multistakeholder collaboration.

A final section highlights notable gaps in national strategies, including under-representation of early years education and inconsistencies between how STEM is defined and how it is operationalised.

## Digital education and integration of digital tools

Nearly all Member States recognise **digital education and integration of digital tools as a strategic imperative for modernising STEM education**.

National frameworks are increasingly linking digital transformation with supporting education strategies and broader economic strategies. However, digital integration is often more advanced in policy than in practice. Even though most countries invest in modernising school resources and digitalisation, implementation depth varies, with some countries demonstrating well-funded, comprehensive plans and others still in early or stages or having fragmented implementation.

The incentives for advancing STEM have emerged not exclusively from educational reforms but rather from overarching policy objectives aiming to foster innovation, strengthening national and European competitiveness. Thus, national digitalisation strategies often overlap with STEM goals. For example, **Estonia** has pursued a long-standing digital-first approach, embedding ICT competences in curricula and integrating digital tools across education levels ([71]). In **Bulgaria**, the **Digital Transformation for 2020–2030** ([72]) outlines a comprehensive plan to integrate digital technologies across various sectors, including education. The strategy places a strong emphasis on equipping students with the necessary competences to thrive in a technology-driven world. **Cyprus** adopted the National Digital Decade Strategic Roadmap in 2023 ([73]). This strategy outlines a series of interconnected measures to be implemented by 2030, including a specific focus on education. The roadmap addresses the digital transformation of schools, aiming to enhance both digital and STEM-related skills among students.

With an investment of EUR 2.1 billion, the School 4.0 ([74]) initiative in **Italy** focuses on digital transformation, creating student-centred learning environments and enhancing teacher training. The programme aims to convert traditional classrooms into innovative learning environments. Additionally, coding, AI, robotics and/or virtual laboratories are being introduced from primary level in several countries. In **Luxembourg**, since 2020, coding has been introduced to all primary school children in cycle 4 (children aged 10 or 11); in 2021–2022, it

([71]) Education Estonia, 'Digital competence: Empowering teachers and students', Education Estonia website, accessed 29 July 2025, https://www.educationestonia.org/innovation/digital-competence/.

([72]) Council of Ministers of the Republic of Bulgaria, Digital transformation of Bulgaria for the period 2020–2030, Decision No 493/21 of July 2020, adopted 21 July 2020, Sofia, 2020.

([73]) Deputy Ministry of Research, Innovation and Digital Policy (Cyprus), *National Digital Decade Strategic Roadmap*, Deputy Ministry of Research, Innovation and Digital Policy, Nicosia, 2023, https://www.gov.cy/media/sites/13/2024/04/DD-2030-Cyprus-Report_final.docx.pdf.

([74]) Ministry of Education and Merit (Italy), Piano scuola 4.0, adopted by Decree No 161 of 14 June 2022, Rome, 2022, https://pnrr.istruzione.it/news/pubblicato-il-piano-scuola-4-0/.

was also introduced in cycles 1–3 in a transversal manner across different teaching disciplines such as languages ([75]).

In several countries, the digitalisation of education and the modernisation of school facilities have often been supported by the RRF ([76]). For instance, the Digital Spain 2026 strategy includes a EUR 1.3 billion investment in education, covering infrastructure, digital resources and the promotion of advanced digital skills including AI and computational thinking ([77]). Similarly, the Greece 2.0 National Recovery and Resilience Plan allocated a budget of EUR 24 million for the procurement of educational robotics kits for use in kindergartens and primary and lower-secondary schools ([78]).

**Box 8. Validation through international benchmarking**

Countries such as **Denmark**, **Estonia** and **Finland** consider their high performance in international assessments (e.g. the Programme for International Student Assessment and the Trends in International Mathematics and Science Study) to be a validation of current policies and a motivator for continued innovation. These countries often feature strong teacher education systems, early integration of inquiry-based STEM learning and alignment between research, policy and practice. **Germany** and **Austria** also reference international comparison data but often use such data to highlight areas for improvement, particularly around gender participation and vocational STEM pathways.

*Source:* Country reports.

## Interdisciplinary and experiential learning

There is **growing momentum across Member States to make STEM education more relevant through real-world applications, project-based learning and interdisciplinary approaches**. While many countries have committed to these, progress is often limited by funding, teacher shortages or reliance on the initiative of individual teachers. Despite these challenges, policy support for experiential and applied STEM learning continues to strengthen across Member States, as demonstrated in this section.

In **Estonia**, the National Education Strategy for 2021–2035 advocates interdisciplinary and project-based learning to improve student engagement and

([75]) Ministry of Education, Children and Youth (Luxembourg) '"Einfach digital": les compétences du futur pour des enfants forts', Ministry of Education, Children and Youth website, 2022.

([76]) European Commission, 'Recovery and Resilience Facility', European Commission website, accessed 29 July 2025, https://commission.europa.eu/business-economy-euro/economic-recovery/recovery-and-resilience-facility_en.

([77]) Ministry for Digital Transformation and the Civil Service (Spain), *España Digital 2026: Implementation agenda*, Ministry for Digital Transformation and the Civil Service of Spain, Madrid, 2025, https://espanadigital.gob.es/en/implementation-agenda.

([78]) Greece 2.0, 'Greece 2.0 – National Recovery and Resilience Plan', Greece 2.0 website, accessed 29 July 2025, https://greece20.gov.gr/en/.

enhance the practical application of STEM knowledge in real-world contexts ([79]). The strategy aims to integrate coding, data science and interdisciplinary problem-solving into primary and lower-secondary education, ensuring that students acquire a strong STEM foundation from an early age. For example, one key objective is to enable students to apply their theoretical knowledge to real-world challenges by designing sustainable solutions or developing technological prototypes. Similarly, in **Czechia**, the Strategy for Education Policy up to 2030+ promotes critical thinking, adaptability and problem-solving over rote learning, paying significant attention to interdisciplinary and project-based learning, especially within STEM subjects ([80]). In **Italy**, national STEM education guidelines also advocate a mix of theoretical learning and practical application. The country report notes efforts to increase the use of real-world problems and interdisciplinary tasks, particularly in upper-secondary education. Additionally, curricular flexibility introduced through the *Buona Scuola* reform allows schools to tailor project-based learning to local economic and societal contexts.

**Box 9. Sustainability education in Cyprus**

**Cyprus** is a regional leader in Education for sustainable development (ESD) and the only Member State where sustainability is a compulsory primary school subject, taught as 'life education' (grades 1–4) and 'education for sustainable development' (grades 5 and 6). Guided by its National Strategy for ESD since 2008, Cyprus applies a whole-institution approach, integrating sustainability across formal and non-formal education through educator training, infrastructure development and youth engagement in green entrepreneurship. STEM is recognised as essential to ESD goals, with the Cyprus Centre for Environmental Research and Education supporting cross-curricular, real-world STEM projects focused on environmental challenges.

*Sources:* Country report; European Commission, 'Cyprus' [national education system overview], European Commission website, 7 January 2026, https://eurydice.eacea.ec.europa.eu/eurypedia/cyprus/overview.

## STEAM approaches and creative integration

In several countries, **the notion of STEAM is also gaining prominence in strategic plans** (STEM plus the arts, psychology, the social sciences and the humanities). The Strategy and Action Plan for Greening Public Educational and Research Infrastructure in **Slovenia** by 2030 identifies education, including science and the arts, as a key driver of sustainable societal development, particularly in the context of the green and digital transitions ([81]). In this context,

([79]) Ministry of Education and Research (Estonia), *Education Development Plan 2021–2035*, Ministry of Education and Research, Riga, 2021, https://www.hm.ee/sites/default/files/documents/2022-10/haridusvaldkonna_arengukava_2035_kinnittaud_vv_eng_0.pdf.

([80]) Ministry of Education, Youth and Sports (Czechia), *Strategy for the education policy of the Czech Republic up to 2030+*, Ministry of Education, Youth and Sports, Prague, https://msmt.gov.cz/uploads/brozura_S2030_en_fin_online.pdf.

([81]) Ministry of Higher Education, Science and Innovation, and Ministry of Environment, Climate and Energy (Slovenia), 'eGuide to the greening of higher education', Republic of Slovenia website,

the plan underscores the importance of STEAM education, integrating STEM subjects with the arts to foster innovation and interdisciplinary competences. In 2023, **Lithuania** adopted the Plan to Strengthen STEM Education through Creativity (2023–2030), which promotes an integrated, creative approach to STEM by connecting it with real-world contexts and interdisciplinary learning, including the arts ([82]). Key actions include integrating engineering technologies into the general curriculum, establishing a nationwide network of open-access STEAM centres to link schools with universities and industry, and expanding non-formal STEAM education to boost student engagement. **Italy**, as mentioned above, also supports STEAM approaches through curricular flexibility and the *Buona Scuola* reform.

While still emerging in many countries, STEAM policies reflect a growing recognition that creativity and interdisciplinarity are essential for equipping students with the skills needed to navigate complex, real-world challenges.

## Innovative pedagogy and teacher training

Teacher training and pedagogical innovation are central to most national strategies. Recognising that teacher capacity is a critical bottleneck, many countries are investing in initial education and training, and continuous professional development (CPD), with a focus on digital tools and inquiry-based methods. **National teacher competence frameworks increasingly include innovation, interdisciplinarity and digital pedagogy.**

### Strategic frameworks for teacher development

Several countries have launched strategic initiatives to enhance teacher preparation and foster pedagogical innovation. In **Finland**, the Teacher Education Development Programme for 2022–2026 provides a comprehensive, career-long framework to enhance teacher preparation and professional learning ([83]). It emphasises broad competences such as subject expertise, digital pedagogy, classroom diversity management and continuous career development, encouraging inquiry-based teaching and curriculum innovation. In **France**, the *Plan Mathématiques Villani–Torossian* (2018) ([84]) specifically targets

20 December 2023, https://www.gov.si/en/registries/projects/e-vodnik-za-ozelenitev-visokega-solstva/.

([82]) Ministry of Education, Science and Sport (Lithuania), STEAM strengthening plan for general and vocational education 2023–2030, Order No V-1185, adopted 11 September 2023, Vilnius, 2023.

([83]) Ministry of Education and Culture (Finland), *Teacher Education Development Programme 2022–2026*, Ministry of Education and Culture, Helsinki, 2022, https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/164179/TeacherEducationDevelopmentProgramme.pdf?sequence=1.

([84]) Villani, C. and Torossian, C., *21 mesures pour l'enseignement des mathématiques*, French Ministry of National Education, Paris, 2018, https://www.education.gouv.fr.

primary mathematics education, a foundational STEM area, by reforming initial teacher training and ongoing professional development. Key measures include appointing pedagogical advisors and offering structured, hands-on training inspired by the Singapore model. By 2023, 200 000 teachers had received training, with early evidence showing increased teacher confidence and adoption of innovative methods.

In countries such as **Croatia**, where significant teacher shortages have been recorded, especially for STEM subjects ([85]), policies place a particular focus on attracting teachers, improving working conditions and ensuring continuous professional development. Similarly, in **Sweden**, a persistent barrier to addressing foundational skill gaps is the shortage of qualified teachers in STEM subjects. Initiatives such as *Lärarlyftet* (the teacher boost initiative) and *Mattelyftet* (the mathematics boost initiative), in addition to *kompletterande pedagogisk utbildning* (complementary pedagogical education), aim to enhance teacher qualifications.

### Curriculum flexibility and school-level innovation

Policy reforms in several Member States aim to empower schools and teachers to adapt curricula and experiment with new pedagogical approaches.

In **Spain**, a law reform in 2020 introduced greater curricular flexibility into the Spanish education system, supporting competence-based learning and interdisciplinary approaches ([86]). In **Italy**, the *Buona Scuola* reform authorises the development of three-year educational plans by schools; these plans include curricular and extracurricular activities aiming to enrich students' competences in key disciplines, especially STEM ([87]). This allows schools to tailor their educational offerings to local needs and labour market trends, fostering closer links between education and innovation and promoting project-based activities.

In **Estonia**, crucial elements of the National Education Strategy 2021–2035 are teacher support, professional autonomy and capacity building for innovation, which are pivotal for STEM education reform ([88]).

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([85]) Erceg, N., Jelovica, L., Mešić, V., Nešić, L., Poljančić Beljan, I. and Nikolaus, P., 'Causes of the shortage of physics teachers in Croatia', *Education Sciences*, Vol. 13, No 8, 2023, article 788, https://doi.org/10.3390/educsci13080788; Domović, V. and Drvodelić, M., 'Teacher shortage in Croatia – A challenge for educational policy, initial teacher education and educational institutions', *European Journal of Teacher Education*, Vol. 48, No 1, 2024, pp. 64–80, https://doi.org/10.1080/02619768.2024.2430251.

([86]) In 2020, Spain enacted Organic Law 3/2020, commonly known as Lomloe, which introduced significant reforms to the Spanish education system.

([87]) The *Buona Scuola* reform is enacted through Law 107/2015 of Italy.

([88]) Ministry of Education and Research (Estonia), *Education Development Plan 2021–2035*, Ministry of Education and Research, Tallinn, 2021,

### Peer networks and professional learning communities

Countries are also investing in teacher collaboration and peer learning to spread effective practices.

**Germany** and **Austria** promote teacher-led networks, professional communities and interschool exchanges to embed innovative methods into teaching and learning. **Slovakia's** curriculum reform was co-designed through participatory processes involving teachers, researchers and ministry officials, helping to strengthen grassroots ownership and professional engagement.

## Equity in access and attainment

National STEM strategies increasingly acknowledge persistent inequalities in access, participation and attainment, particularly along gender and socioeconomic lines. While gender equity receives the most consistent attention, there is growing awareness across Member States of the need to support disadvantaged learners more broadly, including those in rural areas and lower-income communities.

### Gender equity and representation

Several countries have launched targeted initiatives to promote gender balance in STEM. **Austria's** *MI(N)Tmachen* Action Plan emphasises fostering inclusivity by increasing female participation and addressing regional and socioeconomic disparities in access to STEM education ([89]). The plan introduced the MINT Girls Challenge, which encourages girls from 4 to 19 years old to develop STEM solutions to real-life challenges. **Finland's** LUMA Strategy 2030 places a strong emphasis on reducing gender gaps and ensuring equal access in STEM education across all levels, from early childhood education to adult learning ([90]). In **Slovenia**, the National Programme for Equal Opportunities for Women and Men until 2030 includes goals and actions aiming to reduce gender segregation in education. It emphasises incorporating gender equality content into curricula and promoting non-stereotypical educational choices at all levels, thereby encouraging greater female participation in STEM fields. **Slovakia** has also adopted policies to address equity and inclusivity in STEM education. **France**

https://www.hm.ee/sites/default/files/documents/2022-10/haridusvaldkonna_arengukava_2035_kinnittaud_vv_eng_0.pdf.

([89]) Federal Ministry of Education, Science and Research (Austria), *Aktionsplan MI(N)Tmachen: More young people in STEM – Education to employment*, Federal Ministry of Education, Science and Research, Vienna, 2023, https://www.bmfwf.gv.at/wissenschaft/leitthemen/mi%28n%29t_machen.html.

([90]) Ministry of Education and Culture (Finland), *Finnish National STEM Strategy and Action Plan*, Ministry of Education and Culture, Helsinki, 2021, https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/164953/OKM_2023_22.pdf.

embeds gender equality into STEM education by supporting diverse role models, providing resources to combat stereotypes and promoting inclusive pedagogical practices ([91]). **Ireland's** STEM Education Policy Statement for 2017–2026 includes specific targets for increasing the participation of girls and under-represented groups across all education levels ([92]).

### Broader inclusion and support for disadvantaged learners

Some countries are also working at the policy level to reduce regional and socioeconomic disparities in STEM education. **Slovakia** implements equity-focused policies that aim to support rural and disadvantaged learners, including mentorship programmes and awareness campaigns to challenge stereotypes. Launched in 2024, **Spain's** *Mathematics and Reading Comprehension Reinforcement Plan* ([93]) aims to improve student outcomes in response to declining performance highlighted by the Programme for International Student Assessment (PISA). The plan uses a multifaceted approach, including additional teaching staff, co-teaching and split-class models, and extracurricular support. A key area of focus is promoting equity, with targeted support for schools serving disadvantaged communities to ensure that all students have access to high-quality education. **Latvia's** *Skola2030* programme embeds differentiated support for diverse learners within a universal STEM framework, with the aim of closing performance gaps. **Romania's** country report notes efforts to promote access to STEM education in rural areas, although capacity challenges remain.

These reforms signal a broader Europe-wide trend towards more integrated and forward-looking approaches.

## Systemic multistakeholder collaboration

A clear trend across European STEM education policy is the **strategic embedding of partnership and collaboration mechanisms directly into national and regional frameworks**. As countries seek to modernise STEM education, broaden participation and strengthen its relevance to the labour

([91]) In 2024, Eve Gilles, who had won the Miss France beauty pageant and was a mathematics and computer science student, was appointed as an ambassador to encourage more girls to pursue mathematics. This move aimed to address the significant gender imbalance in mathematics education.

([92]) Department of Education and Skills (Ireland), *STEM Education Policy Statement 2017–2026*, Department of Education and Skills, Dublin, 2017; Government of Ireland, *STEM Education Implementation Plan to 2026*, Government of Ireland, Dublin, 2023, https://gov.ie/en/department-of-education/policy-information/stem-education-policy/.

([93]) European Commission, 'National reforms in general school education – Spain', European Commission website, 12 September 2026, accessed 29 July 2025, https://eurydice.eacea.ec.europa.eu/eurypedia/spain/national-reforms-general-school-education.

market and societal needs, collaboration has emerged as both a structural principle and an operational strategy.

This shift reflects a reorientation of STEM governance, from siloed initiatives towards **systemic, multistakeholder engagement**. Governments increasingly recognise that achieving impact in STEM education requires deliberate coordination among **ministries, education providers, research institutions, industry and civil society**. This is not limited to implementation; it is now a fundamental part of **policy design and reform processes**. Countries such as **Luxembourg** and **Finland**, for example, are moving towards integrated governance approaches that link education ministries with labour, innovation and social inclusion portfolios. In **Ireland**, the STEM Education Policy Statement for 2017–2026 ([94]) considers STEM partnerships between schools and industries a key success factor. In **Germany**, the STEM Action Plan 2.0 (*MINT-Aktionsplan 2.0*) unites actors and networks such as the MINT Community Platform, *MINT-Campus* and *MINTvernetzt*, fostering partnerships with industry and other local and regional stakeholders. Furthermore, the Federation of German Industries and the Association of German Chambers of Commerce and Industry collaborate with educational institutions to ensure that STEM curricula align with labour market needs. Major companies such as Siemens, Bosch and SAP provide digital learning resources and work-based learning opportunities to students.

The country reports offer a range of evidence of how this collaborative approach is being institutionalised. The following table sets out some of the approaches.

**Table 1. Types of collaborative approaches to STEM policy and agenda setting**

| Type of collaboration | Countries and examples |
|---|---|
| Collaboration among public institutions, education authorities and non-state actors | • In **Ireland**, the STEM Education Policy Statement institutionalises national and regional coordination among departments, curriculum bodies and higher education institutions.<br>• **France** establishes national STEM governance involving public education, national research bodies and civil society.<br>• **Germany** uses the Standing Conference of the Ministers of Education and Cultural Affairs to coordinate across federal states and education–research sectors.<br>• In **Portugal**, the *Ciência Viva* programme supports the coordination of schools, research institutions and government which is formalised in a national strategy. |

([94]) Department of Education and Skills (Ireland), *STEM Education Implementation Plan to 2026*, Department of Education and Skills, Dublin, 2023, https://assets.gov.ie/249002/3a904fe0-8fcf-4e69-ab31-987babd41ccc.pdf.

| Type of collaboration | Countries and examples |
|---|---|
| Engagement with regional networks and local clusters to tailor STEM to specific contexts and labour market needs | • In **Hungary**, EU-funded regional STEM clusters align educational reforms with local industry needs.<br>• In **Italy**, consortia under Italy's National Recovery and Resilience Plan include schools, universities and regional authorities.<br>• In **Lithuania**, STEM competence centres and training systems have been developed through regional collaboration.<br>• In the **Netherlands**, regional STEM platforms connect schools, higher education institutions and businesses in decentralised innovation.<br>• In **Ireland**, regional STEM learning networks form a core policy implementation mechanism.<br>• In **Belgium**, partnerships among governments, education networks and industry aim to align STEM education with labour market priorities.<br>• In **Sweden**, industry collaboration is a central policy pillar, that guide funding and curriculum development. |
| Strengthening the integration of academic research, higher education institutions and schools | • **Austria** aligns curriculum innovation with university–school partnerships and research agendas.<br>• In **Finland**, LUMA centres connect universities, municipalities and teacher education institutions.<br>• In **Estonia**, universities and teacher training institutions play key roles in digital STEM education.<br>• **Slovakia** develops its curriculum reforms through participatory design processes involving ministry officials, teacher educators and researchers; these processes are particularly used in EU-funded initiatives. |
| Partnerships to drive equity and inclusion | • In **France**, inclusive and gender-sensitive STEM education is shaped through collaboration with civil society.<br>• In **Romania**, collaborative policy supports STEM education access in rural areas.<br>• In **Portugal**, *Ciência Viva* fosters public engagement and equity in science learning opportunities. |

*Source:* Country reports.

Collectively, these examples illustrate a **strategic redirection of STEM policy towards collaborative governance models**. This not only enhances policy coherence and implementation fidelity but also helps systems respond dynamically to emerging challenges, such as technological change, skills shortages and inequalities in access to high-quality STEM learning.

While many countries have established institutional collaborations at the national and regional levels, these structures often fall short of fostering sustained engagement with grassroots stakeholders. As later sections show, the lack of participatory mechanisms involving teachers, school leaders, parents and students can undermine the effectiveness and uptake of even well-designed policies. Bridging this gap between high-level strategic collaboration and local co-creation remains a critical challenge. This report offers concrete examples of

instruments based on the whole-school approach that are beginning to address this challenge (see Section 5.1.3.3).

### Lack of focus on early years and primary education in STEM policies and strategies

What is less visible in policies and strategies across Member States is a focus on early years and primary education. Despite growing consensus on the importance of engaging children in STEM from an early age, **early years and primary STEM education remains under-represented in many national STEM strategies and approaches** across Europe and beyond.

Most policy frameworks continue to prioritise **secondary and upper-secondary education**, often driven by concerns over workforce readiness, labour market needs or international benchmarks such as PISA. As a result, early development is frequently overlooked in formal strategy documents. However, some countries are beginning to recognise this gap and introduce policy measures aiming to **strengthen STEM in early years and primary education**. For instance, **Finland** promotes inquiry-based science and early coding activities in its national curriculum for primary schools, supported by university-led LUMA centres that offer hands-on training for early childhood educators. **Croatia** has also made advances by aligning early STEM activities with broader curriculum reform and investing in digital infrastructure for disadvantaged primary schools. In **France**, science education has been made mandatory from the age of six, with updated teaching resources and pedagogical guidance to support implementation. Meanwhile, **Portugal's National Digital Competence Plan** includes early years programming and robotics as a component of lifelong digital readiness.

## 5.1.2. Key structural challenges (and factors) related to STEM education in schools

Despite growing policy attention and strategic investment in STEM education across Europe, school systems (including initial VET) continue to face a range of structural challenges that hinder effective and equitable implementation.

This section provides an analysis of the key systemic and policy-related barriers that shape how STEM education is delivered in schools, drawing on evidence from EU-27 country reports. It focuses on challenges that are deeply embedded in education systems, such as curriculum fragmentation, pedagogical limitations, misaligned assessment frameworks, equity gaps, infrastructure deficits and teacher workforce issues. These challenges not only weaken the quality of STEM teaching and learning but also limit countries' ability to foster inclusive participation, innovation-oriented skills and long-term learner engagement across education levels.

The analysis is organised thematically, with sections examining:

- curriculum, pedagogy and assessment challenges;
- discontinuities across education levels (from early childhood to secondary education);
- school governance and infrastructure constraints;
- STEM teacher supply, training, and professional support
- equity and learning support structures;
- the integration of non-formal and informal STEM learning and whole-school approaches;
- the availability of data and research for monitoring progress;
- the structural effects of the COVID-19 pandemic;
- additional cross-cutting systemic issues (e.g. institutional inertia, lack of cross-sectoral coordination and limited focus on transversal skills).

In addition to outlining the structural and systemic challenges hindering effective STEM education across Europe, this section also provides a foundation for Section 5.1.3, which presents promising policy responses and innovative practices. These include practical, scalable models addressing the very challenges identified here.

#### 5.1.2.1. STEM curriculum, pedagogy and assessment

A review of the country reports from the Member States reveals a common set of interlinked policy and structural challenges in STEM education across school systems in the areas of **curriculum design**, **pedagogical practices** and **assessment models**. While each national context varies, shared themes emerge that point to systemic tensions between innovation, coherence and implementation. Overall, four challenge areas were identified, namely:

- fragmented and rigid curriculum structures;
- gaps in pedagogical practice and teacher capacity;
- misalignment in assessment practices;
- structural inequities in access and participation.

##### Fragmented and rigid curriculum structures

One of the most widely reported structural issues is the fragmentation of STEM curricula, where **subjects such as mathematics, biology, chemistry and physics are often taught in silos**. This compartmentalisation undermines

interdisciplinary learning and fails to reflect the integrated nature of real-world STEM challenges, both of which are essential for equipping students with the skills required for the 21st century.

Curriculum reform remains a high priority in most countries; however, the delivery of STEM education continues to present a fundamental obstacle. Even when national frameworks incorporate innovative and integrated approaches, these are frequently diluted in practice due to system rigidity, resource limitations and uneven decentralised governance. The Pokropek literature review ([95]) reinforces that **STEM curriculum fragmentation is** both **conceptual, rooted in traditional subject boundaries**, and structural (in the organisation, governance or institutional arrangements), resulting in entrenched disciplines, hindering interdisciplinary teaching. Additionally, technology and engineering subjects are often neglected or addressed primarily in vocational education tracks, despite their crucial role in real-world problem-solving.

This fragmentation and rigidity manifest differently at different education levels (see further information in Section 5.1.2.2). While early childhood education and care (ECEC) is gradually becoming universal in many countries ([96]), integrated STEM curricula at this stage are rare or not explicitly referenced. The transition from ECEC to primary education is generally managed through preparatory pre-primary stages, but curricula often maintain traditional stage separations with limited focus on interdisciplinary integration. For example, **Belgium's** regional authorities clearly distinguish between ECEC, primary and secondary stages, with no systematic integration of STEM subjects across these stages. At the primary level, disciplines are more commonly integrated, while at the secondary levels curricula remain largely discipline specific and content heavy, limiting opportunities for thematic, interdisciplinary or project-based learning (see further information in Section 5.1.2.2). **Austria** exemplifies this with its highly discipline-focused curriculum and limited scope for interdisciplinary approaches, despite growing recognition of their importance in modern STEM fields. Similarly, in **Germany**, curricula across many *Länder* evolve slowly and often do not incorporate emerging and relevant topics such as climate science, robotics and AI. On the positive side, nationally agreed educational standards (*Bildungsstandards*) have provided a competence-based curriculum framework since 1997 (for more details, see Section 5.1.3.1).

Several countries face additional challenges that further illustrate the complexities of curriculum reform in practice. In **Belgium**, for instance, while regional education authorities have acknowledged the necessity of curriculum reform, they also recognise the difficulties in aligning these reforms with schools'

([95]) Pokropek, A., *STEM Competences, Challenges, and Measurements: A literature review*, Publications Office of the European Union, Luxembourg, 2024, JRC138618.

([96]) European Commission, 'Compulsory education in Europe 2022/2023', European Commission website, 7 October 2022, accessed 29 July 2025, https://eurydice.eacea.ec.europa.eu/publications/compulsory-education-europe-20222023.

capacities to implement innovative teaching methods. Teachers frequently report that curricula remain dense and overly content driven, leaving little room for hands-on or inquiry-based learning. **Estonia**, despite being a leader in digital education and having integrated science modules within its national curriculum, experiences practical barriers: teachers struggle with time constraints and a lack of collaborative planning across departments, which can limit interdisciplinary teaching.

Similarly, in **Poland**, recent curriculum reforms have expanded the volume of STEM content but have largely retained the traditional emphasis on factual knowledge and exam preparation. This focus has left little scope for experimentation, project-based learning or collaborative inquiry. However, Poland is now preparing for a more major curriculum reform, scheduled for implementation in 2026. **Slovakia** has taken steps towards adopting a more competence-based curriculum framework; however, these reforms are still in their early stages. Educators, particularly in rural areas, report insufficient guidance and limited opportunities for professional development to support this transition. A further challenge in Slovakia relates to the late introduction of engineering principles, which are typically confined to secondary vocational education. As a result, primary and lower-secondary students rarely encounter practical, problem-solving approaches grounded in technical concepts, potentially limiting their early interest and familiarity with engineering and other STEM fields.

### Gaps in pedagogical practice and teacher capacity

Curricular aspirations for inquiry-based or project-oriented STEM education are frequently undercut by the **persistence of conventional teaching methods**. This is less a question of teacher resistance than of **systemic underinvestment in professional development and classroom support**.

The **Lithuanian** country report, for example, indicates that many teachers still rely on rote learning methods and often fall back on didactic instruction, especially in mathematics and science. Although the national education strategy encourages experiential learning, many teachers lack concrete guidance or in-service training opportunities to implement these methods effectively. This indicates a policy-to-practice gap rooted in capacity-building shortfalls. In **Germany**, while federal initiatives support pedagogical innovation, implementation is uneven across *Länder*, with many schools lacking access to teacher training in inquiry-led approaches. Despite substantial investment in STEM excellence programmes and networks (e.g. *MINTvernetzt* and *MINT-Regionen*), implementation remains fragmented. Teachers cite insufficient time for preparation and pressure to deliver standardised content (a factor resulting from rigid curricula) as barriers to adopting more exploratory teaching.

**Belgium** and **Estonia** both identify a lack of in-service teacher training tailored specifically to STEM teaching as a bottleneck for improving classroom practices. Teachers in multiple countries report that, even when they are motivated to adopt new methods, they often face constraints such as outdated textbooks, rigid timetables and limited access to laboratories or digital resources that would support more interactive learning. In **Belgium**, new curricula often assume pedagogical shifts without providing the necessary training infrastructure. The reports note that, while curriculum reform introduces active learning methodologies, teacher preparation remains largely traditional, creating tensions between the goals and classroom realities. This is confirmed by the abovementioned JRC literature review ([97]), which highlights the specific resource demands and training gaps that hinder the implementation of integrated or inquiry-based pedagogy.

Across these systems, there is a **structural mismatch between pedagogical ambition and institutional support**. Reforming teaching practice in STEM education requires sustained, system-wide investment, not only in training but also in workload management, resource development and school-level autonomy to experiment with pedagogy.

### Misalignment in assessment practices

Assessment systems across Europe have not kept pace with evolving STEM education goals, particularly in areas such as interdisciplinary learning, inquiry-based pedagogy and transversal competence development. **Traditional forms of assessment, centred on factual recall and high-stakes exams, remain dominant in many countries, limiting innovation in curricula and teaching.**

In **Lithuania** and **Poland**, national assessments are heavily weighted towards closed-ended, content-heavy questions, leaving limited scope for schools to implement project-based learning or experimental approaches in STEM. Teachers in **Poland** often report that exam pressure constrains their ability to promote creativity, collaboration or real-world problem-solving. In **Lithuania**, while formative assessment and student portfolios are gaining attention in primary education, these methods are not yet mainstream or supported through national evaluation standards. As a result, innovative teaching strategies have in the past struggled to gain legitimacy or traction within the formal accountability system. In **Slovakia**, competence-based curriculum reforms have been introduced, but teachers lack clear tools or exemplars for assessing the new competences. This gap generates confusion and inconsistency in classroom practice. The assessment system has yet to evolve in line with the broader educational transformation that is under way. In **Belgium**, regional curriculum reforms increasingly reference transversal competences and applied learning. However,

([97]) Pokropek, A., *STEM Competences, Challenges, and Measurements: A literature review*, Publications Office of the European Union, Luxembourg, 2024, JRC138618.

national assessment frameworks remain misaligned, and educators report uncertainty about how to measure integrated STEM skills, such as systems thinking or interdisciplinary reasoning. **France** has implemented **digital portfolios** and modular evaluations in some upper-secondary tracks, although national assessments still retain a heavy focus on summative exams. Tensions between innovation and tradition persist.

Even in countries with progressive curricula, assessment often lags behind. In **Germany**, although some *Länder* are experimenting with alternative assessments, the high-stakes nature of final exams continues to shape classroom priorities. Teachers are less inclined to adopt exploratory approaches without supportive assessment mechanisms. This widespread misalignment acts as a brake on pedagogical and curricular innovation. Without modernised assessment tools, students are evaluated primarily on their ability to memorise rather than apply, integrate or reflect on STEM knowledge. As a result, even well-designed STEM reforms struggle to fully impact classroom practice. In contrast, **Finland** is piloting **multimodal assessment approaches** that combine formative, peer and project-based evaluation. While challenges remain in scaling these up across schools, the approach is aligned with broader curriculum reforms.

Stakeholders in the focus group on assessment also highlighted a significant misalignment between innovative STEM pedagogies, such as inquiry-based, interdisciplinary and project-based learning, and dominant exam-centric assessment systems. This disconnect discourages educators from adopting assessment practices that capture transversal competences such as creativity, collaboration and problem-solving. There is a strong call for more inclusive, multimodal assessment formats and participatory evaluation approaches that reflect diverse learner identities and experiences ([98]).

Moving forward, Member States should **invest in the development of formative and performance-based assessment frameworks that align with 21st-century STEM competences**. Pilot projects should be evaluated and scaled up through national policy, with corresponding professional development to support teachers in implementing new assessment strategies. Embedding assessment reform within broader STEM strategies will be critical to ensuring coherence and sustainability.

### Structural inequities in access and participation

Curriculum design plays a pivotal role in shaping access to and engagement with STEM education. The structure, content and flexibility of national curricula can either mitigate or exacerbate inequalities in learning opportunities. In particular, rigid, centrally defined curricula often fail to accommodate diverse learning needs

([98]) Focus group on assessment, April 2025.

or adapt to local contexts, limiting the potential for inclusive and engaging STEM education.

Despite widespread policy commitments to equity in education, structural barriers continue to limit equitable access to STEM learning opportunities across the Member States. These inequities are shaped by factors such as geographical location, socioeconomic and/or migration backgrounds, gender, school resources and institutional tracking practices, which collectively reinforce disparities in participation and achievement.

Early tracking into academic and vocational streams can restrict access to STEM pathways for disadvantaged students. The country reports highlight how these decisions are often made before students have had a chance to fully explore their interests or demonstrate potential in STEM subjects. Teacher shortages in key STEM areas also disproportionately affect schools in less affluent regions. **Poland** and **Portugal** highlight stark urban–rural divides in STEM education access. In many rural areas, students face limited availability of qualified STEM teachers, laboratories and digital learning tools. This not only impacts academic outcomes but also reduces students' exposure to STEM role models and career pathways. In **Estonia**, access to STEM learning is reported to be unequal, particularly for non-Estonian-speaking students, those in smaller municipalities and those in more remote regions. Therefore, despite the country's digital strengths, systemic interventions to promote inclusive participation remain underdeveloped. The situation is similar in **Slovakia**, where rural schools are less likely to offer robust STEM programmes, particularly in engineering and applied sciences. In addition, early selection mechanisms and underinvestment in inclusive teacher training exacerbate access issues for students with learning differences or those from minority communities. In **Hungary**, significant urban–rural inequalities are also documented, especially in terms of teacher distribution and infrastructure. Schools in disadvantaged areas report **lower levels of access to digital tools and qualified STEM educators**. The **Greek** country report discusses **regional disparities**, including weaker STEM opportunities on islands and in remote mainland areas. Access to laboratory facilities and up-to-date STEM content is uneven. Persistent **socioeconomic disparities** are noted in **Romania**, particularly in rural areas, where dropout rates are high and schools lack STEM infrastructure. Limited funding also constrains participation in non-formal STEM learning.

**These barriers are reinforced not only by curriculum rigidity but also by assessment practices.** High-stakes exams and standardised benchmarks tend to privilege narrow academic outcomes, leaving little space for differentiated instruction, inquiry-based learning or formative feedback. Even where national frameworks allow for curricular innovation, rigid testing regimes and limited classroom resources make it difficult for teachers to adapt lessons to student needs. As a result, learners who fall behind or face additional challenges often receive less tailored attention, widening gaps over time.

In summary, Member States face a complex array of interconnected policy and structural challenges in STEM education at the school level. While curriculum reform is under way in many contexts, fragmentation and rigidity remain persistent barriers. Pedagogical innovation is constrained by gaps in teacher training and classroom resources, and assessment systems continue to privilege narrow academic outcomes over broader competences. Tackling these issues requires greater coherence across curricula, pedagogy and assessment, and sustained investment in teacher capacity, inclusive design and system-wide alignment.

#### 5.1.2.2. (Dis)continuity in the approach to STEM education across different levels of education

A coherent and continuous approach to STEM education, from early childhood and through primary and secondary education, is increasingly recognised as essential for fostering sustained interest, confidence and competence in STEM subjects ([99]). However, many European countries report structural and policy-related discontinuities that disrupt students' progression. These discontinuities may take the form of conceptual misalignment, pedagogical inconsistencies or institutional gaps between educational levels. Such fragmentation undermines students' cumulative learning experience and reduces the effectiveness of STEM policies that aim to build long-term engagement with STEM. Three major trends are identified, namely:

- curriculum and pedagogical discontinuity between early childhood education and care and primary education;
- curriculum and pedagogical discontinuity between primary and secondary education;
- structural and institutional fragmentation.

**Curriculum and pedagogical discontinuity between early childhood education and care and primary education**

One discontinuity cited in the country reports is between early childhood education and care (ECEC) and the formal start of STEM learning in primary school. As already highlighted in this report, early development is frequently overlooked in strategy documents, which therefore do not reinforce the need for STEM education in early childhood education. Other issues are also highlighted. The **Austrian** country report stresses a disconnect between the open-ended,

([99]) McClure, E. R., Guernsey, L., Clements, D. H., Bales, S. N., Nichols, J., Kendall-Taylor, N. and Levine, M. H., *STEM Starts Early: Grounding science, technology, engineering and math education in early childhood*, The Joan Ganz Cooney Center at Sesame Workshop, New York, 2017, https://joanganzcooneycenter.org/wp-content/uploads/2017/01/jgcc_stemstartsearly_final.pdf.

inquiry-based learning valued in pre-primary education and the more conventional teacher-led instruction that begins in primary school. This transition often results in a loss of curiosity and engagement, particularly among girls and students from disadvantaged backgrounds. In **Portugal**, from early childhood through to upper-secondary and vocational education, students often experience abrupt shifts in curriculum structure, teaching methods and subject integration. In **Hungary**, STEM exposure in pre-primary education is limited and predominantly occurs through play-based activities and general exploratory learning. Early digital skills and scientific inquiry are minimally addressed, leading to inconsistent preparation levels among children entering primary school. In the **Netherlands**, although pre-schools are integrated within child centres, which enables close collaboration with primary schools and offers the opportunity for continuity, STEM is not yet being explicitly addressed in pre-primary education. **Croatia** indicated that participation in ECEC is one of the key structural factors influencing students' performance in STEM in later years. Croatian students who attended ECEC for a longer period achieve better results in mathematical literacy than those who did not attend ECEC at all or attended for only a few months ([100]). In **France**, although the *école maternelle* is part of the formal education system and often lauded for its role in early learning, STEM is not explicitly integrated into ECEC frameworks. The country report notes that transitions into primary education lack STEM-specific continuity, and inquiry-based approaches are rarely maintained.

These examples reveal a common issue: without cross-phase coordination, transitions disrupt learning. Ensuring pedagogical coherence and curriculum continuity between ECEC and primary education is critical to sustaining STEM interest.

### Curriculum and pedagogical discontinuity between primary and secondary education

The transition from primary to lower-secondary education emerges as a critical juncture that significantly shapes students' engagement with, achievement in and long-term orientation towards STEM subjects. Evidence from country reports highlights a range of **structural and pedagogical discontinuities, in curricula, teaching practices and learning expectations**, that disrupt students' progression, hinder the consistent development of STEM competences across educational levels and contribute to emerging inequalities and declining interest in STEM during this formative phase.

One of the key structural issues lies in the **fundamental differences between the training and roles of primary and secondary school teachers**. For example, as evidenced in **Romania** and **Finland**, teacher education pathways

([100]) National Centre for External Evaluation of Education (Croatia), *Međunarodno istraživanje znanja i vještina učenika PISA 2022: Rezultati, odrednice i implikacije*, Zagreb, 2023, https://pisa.ncvvo.hr/wp-content/uploads/2023/12/PISA-2022_Nacionalni-izvjestaj.pdf.

diverge early on: primary school teachers typically receive broad pedagogical training with a strong emphasis on child development and generalist instruction, while secondary school teachers are trained as subject specialists, with a deeper focus on disciplinary knowledge. This bifurcation produces distinct teaching cultures and competences, particularly in science and mathematics. For instance, primary teachers may lack the subject-specific expertise necessary to deliver comprehensive instruction in physics or chemistry, whereas secondary teachers may lack the pedagogical skills to connect abstract concepts to students' prior knowledge or real-world applications.

This divergence is further intensified by the **shift in curricular structure between education levels**. At the primary stage, science is typically taught as an integrated subject, such as – in the case of Finland – 'environmental studies', in which disciplines such as biology, physics, chemistry, geography and health education are combined into a single, holistic curriculum. This approach, grounded in everyday phenomena and cross-disciplinary inquiry, helps students perceive the relevance of science to their immediate environment and daily lives. However, at the lower-secondary level, science education is usually divided into separate subjects, each with its own methodology, content structure and progression logic. While this subject specialisation may deepen conceptual knowledge, it often disrupts the coherence of students' learning experiences and weakens the connections between scientific theory and real-world applications.

Interviewees in **Romania** and **Finland** noted that this sudden **transition from integrated, experience-based science education to fragmented, abstract teaching contributes to confusion and disengagement**. Students may struggle to transfer their prior understanding to new disciplinary contexts, especially when exposed to unfamiliar terminology and conceptual frameworks without sufficient scaffolding. Moreover, when primary-level teaching emphasises a single science area, such as biology, which is perceived as more accessible than other areas, students may enter secondary education without a balanced foundation across the full range of scientific disciplines. This can result in a steep learning curve in subjects such as chemistry and physics, which demand more abstract thinking and are often introduced for the first time in lower-secondary school.

In **Romania**, this challenge is particularly pronounced in mathematics and informatics, where students face a mismatch between prior learning and content introduced in lower-secondary curricula. The lack of structured collaboration between primary and secondary teachers compounds this problem, as each level tends to operate in pedagogical isolation. Similar issues are seen in **Finland**, where, despite curricula aiming to ensure continuity, many teachers, especially from older cohorts, struggle to implement cross-curricular approaches that would ease the transition.

Furthermore, **assessment systems often fail to bridge these educational stages**. In **Romania**, high-stakes exams at the end of lower-secondary education

reinforce rote learning and limit the scope for inquiry-based or contextual learning. This dynamic not only hinders deeper understanding but also exacerbates educational inequalities, particularly for students without access to supplementary tutoring or supportive learning environments.

Similarly, in **Belgium**, students transition from generalist teaching approaches in primary school, where interdisciplinary STEM projects are more common, to subject-specific instruction in secondary school, which is often characterised by an exam-focused and compartmentalised pedagogy. This shift disrupts continuity in both content and learning methods, creating adjustment challenges for students. **Germany** and **Austria** present similar cases: integrated or thematic approaches in primary schools give way to strictly discipline-based curricula in secondary education. The variation across *Länder* in Germany further complicates continuity. While a centralised approach exists for the *Abitur* (baccalaureate) through common task pools for exams, most aspects of education are determined at the *Land* level. This results in a highly heterogeneous landscape, with notable differences in curricula, teaching hours and lesson implementation across the 16 federal states. The **Lithuanian** country report indicates that, while active STEM teaching methods ([101]) are introduced in primary grades, the shift to traditional didactic teaching in secondary grades interrupts pedagogical coherence. **Slovakia** faces challenges in relation to the need to modernise teaching approaches. The conceptual understanding of STEM in Slovakia still lacks consistency across education levels, particularly in the transitions between primary, lower-secondary and upper-secondary education. **Italy** reports that reform efforts have largely targeted secondary education, neglecting earlier stages where foundational competences are formed. This misalignment contributes to a fragmented understanding of scientific and mathematical disciplines and affects students' progression in STEM fields. The **Swedish** country report notes that students often experience a drop in engagement and performance in mathematics and science following the transition from primary to secondary school, in part due to abrupt shifts in teaching style and increased subject compartmentalisation. **Estonia's** national curriculum supports continuity in principle but, in practice, transitions between levels still suffer from a lack of integration in STEM pedagogy, particularly in engineering and technological subjects. In **Latvia**, teachers report challenges in implementing the new curriculum consistently across primary and secondary education, especially in rural schools and for minority-language learners, which contributes to inequities in STEM progression. In **Greece**, STEM transitions are marked by a disconnect between hands-on, inquiry-led activities in primary school and heavily theoretical STEM instruction in secondary school, with few bridging programmes in place.

([101]) Active learning is based on constructivism and introduces guided tasks, assignments and interactions that cultivate deep learning.

To address these issues, countries should develop and implement **vertically aligned STEM curricula and pedagogy that support coherent progression across levels**.

### Structural and institutional fragmentation

Beyond pedagogy and curricula, **discontinuities are reinforced at the structural and institutional levels**. **Separate governance of different educational stages, weak policy alignment and insufficient teacher collaboration across stages** all contribute to gaps in STEM progression (see the next section). Without coherence in policy, governance and teacher training, even well-designed initiatives often fail to ensure sustained STEM engagement across a student's educational journey. For example, in **Bulgaria**, the absence of a cohesive national STEM strategy has led to inconsistencies in teaching, resource allocation and student engagement. **Germany** has invested in STEM hubs and networks, yet these remain fragmented efforts that do not guarantee structural coherence.

The country reports consistently highlight that early interest in STEM is often undermined by later institutional disconnection and misaligned reforms. Addressing these challenges requires systemic responses: coordinated curriculum frameworks, governance structures that explicitly support vertical coherence and stronger collaboration between teacher education institutions. National STEM strategies should therefore go beyond broad visions to include **common learning progressions, cross-level teacher collaboration and assessment systems aligned with cumulative learning goals**. Without these efforts, the promise of long-term engagement in STEM will remain fragmented and inequitable.

#### 5.1.2.3. School governance and infrastructure

STEM education requires more than curriculum reform and pedagogical innovation; it depends on the foundational capacity of the education system to govern and resource schools effectively. Many European countries face persistent structural challenges related to school governance and policy coordination, school-level leadership, and physical and digital infrastructure. These issues shape not only the quality and equity of STEM learning environments but also the feasibility of implementing broader reforms. Three major trends are identified, namely:

- fragmented school governance and policy coordination;
- weak school leadership and capacity;
- infrastructure and resource gaps.

## Fragmented school governance and policy coordination

In addition to systemic fragmentation across the national and regional levels, several country reports point to **governance fragmentation within schools and their immediate ecosystems**. These challenges stem from a **lack of coordination between schools and key actors such as universities, teacher education institutions, industry partners and curriculum agencies**. The result is a patchwork of initiatives and limited capacity for schools to implement coherent, whole-school STEM strategies.

**Portugal** illustrates this type of fragmentation. National policies promote alignment across education, innovation and labour market sectors but the mechanisms to support coordination at the school level are weaker. Some curricular autonomy is granted to schools and municipalities, allowing them to define up to 25 % of the curriculum and providing useful flexibility. However, this autonomy raises concerns about consistency and equity, and the variations in how autonomy is implemented are reported to lead to significant disparities in the quality and content of STEM instruction.

The **Netherlands** and **Austria** highlight similar challenges. In Austria, although school autonomy allows for tailored STEM programmes, there is little evidence of consistent governance structures that incorporate external partnerships or cross-departmental planning. In the Netherlands, while collaboration with universities and industry is encouraged, these efforts are not systematically integrated into school governance, limiting their reach and sustainability.

In **Germany**, strong school–industry links are established through vocational education and university outreach, but these partnerships are often led by individual institutions rather than being embedded in school governance frameworks. This creates uneven access and limits the scalability of innovation.

**Latvia** similarly benefits from extracurricular collaborations with universities and employers, but such initiatives remain peripheral to core school structures. In **Czechia**, while innovative STEM projects such as polytechnic modules have emerged, they are not yet coordinated across governance levels, and their integration into school planning varies considerably. **Spain** reports similar inconsistencies, noting that partnerships between schools and research centres often depend on short-term funding or individual initiatives rather than being embedded in education governance structures.

Moreover, traditional subject-based structures within schools, as noted in **Hungary**, can further isolate STEM efforts within departments, impeding interdisciplinary collaboration and school-wide strategy development. In **Slovenia**, the presence of dedicated leadership institutions and national advisory bodies reflects an effort to support school-level STEM governance but also signals the continued need for external coordination mechanisms. **Lithuania** reports growing municipal responsibilities in education governance, yet uneven

implementation capacity across regions contributes to disparities in STEM provision.

These examples highlight the **need for improved governance models that support schools as active, networked institutions capable of driving and sustaining STEM reform**. Strengthening horizontal coordination, clarifying roles and embedding partnership mechanisms into school governance structures are critical steps towards system-wide impact.

### Weak school leadership and capacity

School leadership plays a vital role in shaping the vision, priorities and culture of STEM education at the school level. However, many countries report a **lack of capacity among school leaders to lead and sustain STEM innovation**.

In **Austria**, school leaders are granted some autonomy over budgeting and staffing but receive limited support for strategic planning in STEM education. In many other countries, including **Belgium**, **Hungary**, **Poland** and **Finland**, the near absence of references to school leadership in national STEM reports underscores a broader gap: while teacher training and curriculum development are often addressed, leadership capacity is not systematically integrated into STEM policy frameworks. Where leadership is mentioned, it tends to focus on administrative responsibilities rather than instructional or strategic leadership.

In **Estonia**, school leaders are expected to support innovation but receive little targeted training in STEM-specific leadership, resulting in uneven prioritisation of STEM development across schools. In **Romania**, although headteachers are involved in school development planning, national guidance on STEM leadership is limited and implementation relies heavily on individual initiative or externally funded projects.

### Infrastructure and resource gaps

The physical and digital infrastructure needed for effective STEM learning remains underdeveloped or unevenly distributed in many European education systems. The country reports frequently cite **shortages of science laboratories, modern equipment and digital tools, and insufficient classroom connectivity, particularly in rural or economically disadvantaged areas**. These deficits represent core capacity challenges that directly constrain the practical implementation of STEM reforms, including hands-on, inquiry-based and interdisciplinary learning.

In **Poland**, large-scale initiatives such as the Future Labs programme have aimed to modernise school infrastructure by supplying 3D printers, robotics kits and programming tools to nearly all primary schools. However, this reflects a response to pre-existing gaps, and further funding is still needed to fully address

schools' infrastructure needs. Similarly, **Bulgaria** had a systemic lack of digital tools and infrastructure, which it identified as a major obstacle to implementing STEM education across schools. This led to the Building a School STEM Environment programme, funded through the National Recovery and Resilience Plan ([102]).

The reports from **Croatia** and **Slovakia** point to challenges in upgrading outdated facilities and equipping schools for modern STEM delivery. **Hungary** and **Lithuania** also report infrastructure disparities, with schools in rural areas being particularly disadvantaged. In **Romania**, the lack of basic science equipment and weak laboratory infrastructure are cited as a barrier to aligning STEM education with national goals. **Estonia** and **Greece** similarly mention gaps in connectivity and access to digital tools, especially for students in lower-resourced areas. **Portugal**, despite recent national investments, continues to face persistent infrastructure challenges, particularly in rural areas, that hinder equal access to high-quality STEM learning environments.

**France** highlights regional disparities in STEM infrastructure, especially between urban and rural areas, despite increased national investment following the COVID-19 pandemic. In **Latvia**, a lack of laboratory space and inadequate digital tools are frequently cited by schools in remote areas. In **Sweden**, while urban municipalities often have high-quality infrastructure, rural schools report delays in technology upgrades that hinder implementation of STEM curricula.

**Italy** has launched multiple investment schemes targeting digital infrastructure in schools, while the **Netherlands** and **Slovenia** continue to align infrastructure planning with national STEM strategies. **Spain's** country report similarly stresses the need for sustained investment, noting that one-off infrastructure improvements without systemic planning risk widening existing gaps.

Across these cases, a common pattern emerges. **Infrastructure development is often project based, reactive and fragmented, rather than systemic and strategic.** Few countries report regular audits of school infrastructure or long-term capital investment plans tied to STEM education goals. Without such planning, physical and digital limitations will continue to restrict the scalability, inclusiveness and pedagogical quality of STEM reform efforts.

([102]) European Commission, 'STEM centres and innovation in education', European Commission website, https://reforms-investments.ec.europa.eu/projects/stem-centres-and-innovation-education_en?utm_source=chatgpt.com; Ministry of Education and Science (Bulgaria), 'Investment project 1 "STEM centres and innovation in education"', Ministry of Education and Science website, https://sf.mon.bg/?go=page&lang=en&pageId=549?utm_source=chatgpt.com https://stem.mon.bg/.

### 5.1.2.4. STEM teacher shortages, professional development and professional support

A sustainable and effective STEM education system depends critically on the recruitment, preparation and ongoing support of teachers. The country reports consistently highlight systemic issues related to teacher supply, initial education and training, and continuous professional development (CPD). These issues are particularly acute in STEM subjects, where teacher shortages are widespread and teaching demands are evolving rapidly. Four key challenge areas were identified, namely:

- STEM teacher shortages and recruitment difficulties;
- gaps in initial teacher education (ITE) for STEM;
- limited access to continuous professional development (CPD);
- weak institutional support for teacher induction and retention.

#### STEM teacher shortages and recruitment difficulties

Most countries report **persistent shortages of qualified STEM teachers, particularly in rural or disadvantaged areas**. These shortages are linked to broader labour market competition from industry, low rates of entry into ITE and high attrition.

In **Germany**, the shortage of qualified STEM teachers is a long-standing concern, with reports citing an insufficient number of applicants for teacher training programmes in mathematics, physics and computer science. The situation is particularly acute in eastern regions. In **Belgium**, teacher shortages vary by region and subject but are notable in STEM, especially in vocational pathways. **Portugal** provides an explicit example of rural schools facing difficulty in attracting and retaining science and mathematics teachers, leading to uneven access to qualified educators. In **Lithuania** and **Slovakia**, limited career progression contributes to the challenge of attracting young professionals into STEM teaching careers.

The stakeholder consultations through focus groups corroborate persistent STEM teacher shortages and capacity gaps, particularly at the primary education level. Participants highlighted that many primary teachers come from non-science backgrounds and often lack confidence in teaching subjects such as mathematics and science, sometimes due to their own negative experiences as learners. This dynamic creates a generational barrier to adopting innovative STEM teaching approaches and underscores the need for targeted professional development and support for primary school educators.

These examples suggest that teacher recruitment challenges are embedded in labour market structures and broader workforce conditions. Training and working

as a STEM teacher is often perceived as quite demanding, with the perception of there being alternative, better-paid career opportunities outside education. Unless governments offer competitive incentives, more flexible entry pathways or targeted recruitment for underserved regions, the shortages will persist.

The Pokropek report ([103]) echoes these findings on shortages of qualified teachers and deepens the analysis with specific reference to professional development needs, particularly in science and engineering. It also supports calls for career-long support systems. Surveys show that many educators lack specialised training and report high demand for professional development, especially in applying inquiry-based methods and integrating digital technologies (see the next section for more details).

### Gaps in initial teacher education for STEM

ITE systems in many countries do not adequately prepare STEM teachers for the interdisciplinary and digital nature of modern classrooms. There is often a **lack of specialised STEM pathways within ITE programmes and insufficient alignment between theoretical training and practical classroom demands**.

In **Ireland**, concerns have been raised about the limited availability of STEM-specific pedagogical modules within teacher training courses, while in the **Netherlands** few trainee teachers choose inquiry-based learning options. In **Romania**, the initial education of teachers remains overly focused on theoretical content, with limited attention given to practical classroom experience. Although STEM pedagogical modules are included, these are often treated as a formality and poorly integrated with school-based practice. As a result, many graduates enter the profession without meaningful exposure to real teaching environments. In **Bulgaria**, while universities are the main ITE providers, the system suffers from insufficient curricular focus on contemporary STEM methods, with few programmes offering pedagogical tools for interdisciplinary or digitally enabled instruction. Similarly, in **Croatia**, ITE was noted as overly theoretical, with minimal emphasis on applied learning, particularly in science and technology.

Improving ITE for STEM requires better alignment with school realities, increased integration of interdisciplinary and technology-enhanced teaching methods, and close collaboration between universities and schools. National strategies that define standards for STEM ITE and fund partnerships between teacher training institutions and schools can address this gap.

([103]) Pokropek, A., *STEM Competencies, Challenges, and Measurements: A literature review*, Publications Office of the European Union, Luxembourg, 2024, JRC138618.

### Limited access to continuous professional development

A review of the country reports reveals **significant disparities in the availability, accessibility and relevance of continuous professional development (CPD) for STEM teachers**. Although professional development is widely acknowledged as crucial for implementing STEM reform, CPD provision remains uneven and underdeveloped across much of Europe.

Many countries report systemic weaknesses in CPD for STEM educators. In **Bulgaria** and **Cyprus**, training is often project based or externally funded, leading to fragmented provision and limited long-term impact. Similarly, in **Slovakia**, the absence of structured programmes and inadequate school-level funding limit both access and relevance. In **Sweden**, although national programmes such as *Lärarlyftet* exist to support in-service training, participation has declined in recent years, suggesting barriers to teacher engagement and/or structural uptake.

Even in countries with formal CPD systems, disparities persist. Reports from **France** and **Hungary** do not provide detailed accounts of CPD access, but broader regional inequalities and resource constraints may affect rural provision. In **Romania**, while CPD structures exist, available information does not confirm the presence of a coordinated national approach specifically for STEM. In **Germany**, variations in state-level (*Land*) policies lead to inconsistencies in CPD quality and focus, contributing to regional imbalances. In **Spain**, while CPD is offered through regional education ministries, participation is not systematically monitored and STEM-specific opportunities are limited, especially in rural areas. In **Italy**, CPD is increasingly promoted through national strategies (e.g. *Piano Nazionale Scuola Digitale*), but local implementation remains inconsistent and often lacks follow-up measures.

A recurring issue is that **CPD is rarely linked to career progression or incentivised in a way that fosters sustained participation**. Teachers may lack time, funding or institutional support, especially in countries where CPD remains optional or disconnected from broader professional advancement structures.

Despite these challenges, several countries offer promising practices. **Estonia** has established robust CPD partnerships between universities and educational technology providers, supporting teachers in adopting digital and interdisciplinary pedagogy. **Austria** and **Finland** have nationally mandated frameworks that promote structured, sustained STEM-related CPD. In these systems, professional development is embedded in wider strategies to modernise teaching and ensure coherence with curricular reforms. The mismatch between curriculum aspirations and teacher readiness is evident in countries such as **Belgium** and **Lithuania**, where inquiry-based or integrated STEM pedagogy is encouraged in policy but under-supported in practice. Teachers frequently cite a lack of concrete guidance and training tools, underscoring the urgent need to align pedagogical innovation with accessible, high-quality CPD.

CPD for STEM teachers remains one of the weakest links in Europe's STEM education ecosystem. Expanding access, embedding CPD in teacher career frameworks and fostering school-level cultures of continuous learning will be essential to ensure that reforms translate into classroom practice. Effective CPD systems require national leadership, sustainable financing and incentives for teacher participation. Policies that embed CPD in teacher career progression and ensure regional equity in provision are essential for systemic impact.

### Weak institutional support for teacher induction and retention

In addition to recruitment and training, **effective systems also require mechanisms for supporting early-career teachers and retaining experienced STEM educators**. Yet many countries report weak or inconsistent mentoring systems, poor induction experiences and little institutional follow-up. These gaps are especially acute in the early stages of teachers' careers, contributing to attrition and undermining efforts to build a sustainable STEM teaching workforce.

In **Portugal**, retention is discussed in the context of broader community engagement programmes that aim to stabilise staffing in rural and disadvantaged areas. However, systemic challenges in teacher allocation and working conditions continue to undermine long-term retention, particularly in STEM fields. **Malta** presents a clear case of national concern regarding teacher supply and retention. The Ministry for Education, Sport, Youth, Research and Innovation has recognised high turnover and workforce instability, prompting a new sectoral agreement aiming to improve working conditions and support structures to retain qualified educators. In **Lithuania**, retention concerns are linked to broader issues of workforce renewal, including the ageing teacher population and difficulties in attracting and retaining young professionals in STEM teaching roles. Although reform efforts are under way, long-term planning for retention remains underdeveloped. In **Hungary**, the Teachers' Democratic Trade Union has voiced its concern regarding working conditions and resource allocation, which contribute to attrition and difficulties in retaining experienced teachers.

In **Denmark**, national initiatives to improve teacher retention include mentoring and team-teaching strategies, but there is limited STEM-specific focus in induction structures. In **Croatia**, despite overall improvements in teacher working conditions, rural STEM teacher retention remains a concern due to a lack of support services and career progression clarity. Together, these examples show that workforce stability depends on both addressing structural working conditions and improving targeted support for STEM teachers.

A related issue is the lack of clear **career pathways or formal professional recognition frameworks for STEM teachers**. While isolated references to teacher career development or prestige appear in countries such as the **Netherlands**, **Poland**, **Portugal** and **Slovenia**, these mentions are often vague,

embedded within broader educational reform narratives, and rarely specific to the STEM teaching profession. Few systems provide clearly defined advancement opportunities or incentives that distinguish STEM educators or reward continued professional growth. The lack of visible career progression routes, combined with limited recognition of professional expertise, contributes to long-term retention challenges and undermines efforts to attract high-quality STEM teachers. More explicit, sector-specific frameworks could help elevate the status of STEM teachers and support workforce stability across school systems.

International bodies echo these concerns. The OECD emphasises that strengthening teacher professionalism through career progression, autonomy and status is crucial for attracting and retaining excellent teachers ([104]). Its report suggests that education systems should design and establish career paths encouraging established teachers to become mentors to support early-career teachers, through incentives such as salary progression and professional recognition. Similarly, the European Commission's STEM Education Strategic Plan highlights the need for more policy efforts and research to address challenges in STEM education, including the development of structured career pathways for teachers.

These findings point to a clear need for stronger, sustained and equity-focused approaches to teacher induction and retention. Successful models would include **structured mentoring, reduced workloads for early-career teachers, clear progression routes and integrated support systems** that extend beyond the first year of employment. Without addressing these foundational issues, efforts to improve STEM teaching quality and workforce stability will remain fragmented and limited in impact.

**Box 10. Good practice examples of trends in STEM teacher recruitment, education, professional development and support**

Policy choices and governance frameworks play a pivotal role in shaping outcomes for STEM teacher supply and professional development. Countries that have implemented coherent, cross-ministerial strategies and long-term workforce-planning frameworks tend to face fewer recruitment and retention problems, according to the country reports. For example, in **Finland**, despite some variation in uptake, a nationally mandated CPD framework supports consistent professional growth. Ireland has invested in STEM education strategies that include teacher recruitment goals, CPD subsidies and school partnerships with higher education institutions.

Specific highlights are outlined below.

- Finland is widely recognised for its **highly selective and research-informed teacher education system**. All teachers, including those in STEM fields, must hold a master's degree, and ITE integrates subject expertise with advanced pedagogical training. CPD is embedded in the professional culture, supported by **national frameworks and local autonomy**. Early-career support is well structured and teacher retention is high, thanks in part to **respect for the profession and good working conditions**.
- France has improved the structure of its ITE programmes by merging academic and pedagogical tracks within teacher education institutes. STEM teachers benefit from

([104]) OECD, 'Reinforcing and innovating teacher professionalism for a changing world', *OECD Education Policy Perspectives*, No 56, 2022.

| | |
|---|---|
| | **national content standards and CPD pathways**, with additional support provided through digital platforms (albeit not equally across the regions). While challenges exist in some rural areas, the country has made significant investments in mentoring and peer collaboration to support new teachers and reduce attrition. |

*Source:* Country reports.

### 5.1.2.5. STEM learning support and equity

Despite widespread recognition of the need for inclusive and high-quality STEM education, many countries face persistent challenges in providing adequate learning support and ensuring equitable participation. This section explores how different groups, particularly disadvantaged learners, experience structural barriers in accessing enriched STEM learning environments. It draws on country report findings related to non-formal and informal learning (as equity tools), targeted gender measures, learning support mechanisms, financial incentives and career guidance.

Educational data reveal high underachievement rates in mathematics and science among disadvantaged groups. These disparities underline the urgent need for equity-driven interventions in curricula, infrastructure and support services ([105]).

Six major areas presenting challenges in accessing learner support to increase equity emerge from the country reports, namely:

- limited access to non-formal STEM education opportunities;
- insufficient informal STEM learning and public engagement;
- lack of targeted gender support in STEM;
- insufficient learning support for disadvantaged groups;
- underdeveloped career advice and mentorship programmes;
- limited access to scholarships and financial incentives.

#### Limited access to non-formal STEM education opportunities

Non-formal STEM education, including through after-school clubs, science camps, competitions and makerspaces, plays a crucial role in expanding student engagement and interest beyond the classroom. However, country reports reveal that **access to these opportunities remains highly uneven across Europe, with many education systems lacking coordinated strategies or sustained investment**.

([105]) Pokropek, A., *STEM Competences, Challenges, and Measurements: A literature review*, Publications Office of the European Union, Luxembourg, 2024, JRC138618.

In several countries, non-formal STEM education is heavily dependent on temporary projects or external funding. **Slovakia** describes an ecosystem in which enrichment activities are limited to specific schools or regions, often driven by EU-funded initiatives without long-term integration into national or regional education strategies. These programmes risk closing once the funding ends, leaving students, especially those in disadvantaged areas, without meaningful access to extracurricular STEM engagement beyond the core curriculum. A key challenge for the sustainability of and equitable access to non-formal STEM education in **Romania** lies in the sector's heavy reliance on private sponsors and non-governmental organisations (NGOs). For instance, while the Romanian-American Foundation has played a catalytic role in advancing non-formal STEM and STEAM education through long-term programmes in areas such as rural access, teacher training, hands-on learning and curriculum innovation, the dependence on philanthropic or donor-driven support raises concerns about continuity and national coverage ([106]). Without structural integration into public education policy and stable public funding, such initiatives risk remaining fragmented, geographically limited or vulnerable to shifts in donor priorities, ultimately constraining their long-term impact and inclusiveness.

**Geographical and socioeconomic inequality** is a recurring theme. Geographical and socioeconomic disparities further limit equitable access to non-formal and informal learning. In rural or marginalised regions, long distances to science centres and limited public transport reduce participation. Digital alternatives, while promising, are rarely part of coordinated outreach strategies. In **Lithuania** and **Poland**, the country reports highlight that students in rural or economically marginalised communities are much less likely to have access to science fairs, technology laboratories or summer STEM programmes. The absence of systemic provision exacerbates existing disparities in STEM attainment and career aspirations.

Few national strategies explicitly integrate non-formal learning into broader STEM education policies. Where coordination exists, such as structured STEM outreach programmes in **Ireland** or cross-sectoral engagement in **Portugal**, it remains the exception rather than the norm. Without sustained planning, infrastructure and teacher support, the potential of non-formal education to expand participation and motivation remains underutilised.

Overall, country reports suggest that building inclusive and aspirational STEM learning ecosystems will require stronger integration of non-formal opportunities into national strategies, supported by targeted funding, school–community partnerships and clear policy frameworks.

([106]) Romanian-American Foundation initiatives in Romania include formal and non-formal learning. This section focuses on the non-formal aspects.

### Insufficient informal STEM learning and public engagement

Informal STEM education, through science museums, exhibitions, public science events, media campaigns and family-oriented activities, offers valuable opportunities to inspire interest and build societal awareness of STEM. However, the country reports show that engagement in informal STEM education to support learning and equity is underdeveloped.

In several countries, informal learning opportunities rely heavily on the initiative of NGOs, cultural institutions or civil society. This results in patchy provision and dependence on local leadership or temporary partnerships. For instance, **Slovenia** and **Slovakia** reference community-based science activities and informal networks, but these are not systematically embedded in national STEM frameworks.

Some countries, such as **Germany** and **Ireland**, host STEM festivals. However, these are not always integrated into formal education pathways, and participation may depend on school leadership, parental initiative or geographical proximity. Teachers often lack the time, funding or policy support to facilitate student access to these opportunities. **Spain** offers additional insight: while a strong network of science museums and popular science media exists, there is limited systematic alignment with school education. Public engagement in STEM remains event driven.

The role of families and the wider public in STEM learning is often overlooked. While informal and non-formal learning environments (see the section above) are well placed to bridge schools and communities, few countries treat this as a strategic policy priority. Where positive examples exist, such as cross-sectoral partnerships in **France** and **Finland**, they remain the exception.

To build more STEM-literate societies, **informal education should not be treated as a peripheral supplement**. Investments in infrastructure, outreach programmes and community engagement frameworks will be vital to realising the potential of informal STEM learning for inclusion, aspiration and public awareness.

### Lack of targeted gender support in STEM

Despite widespread recognition of gender imbalances in STEM education and careers ([107]), targeted support for girls and under-represented genders remains limited across much of the EU. While some countries have introduced pilot programmes and awareness campaigns (see Section 5.1.3.6), **few have**

([107]) Evagorou, M., Puig, B., Bayram, D. and Janečková, H., *Addressing the gender gap in STEM education across educational levels – Analytical report*, Publications Office of the European Union, Luxembourg, 2024, accessed 29 July 2025, https://op.europa.eu/en/publication-detail/-/publication/5c74b478-3ffe-11ef-865a-01aa75ed71a1.

**implemented sustained, system-wide interventions to address persistent gender gaps in STEM participation**. These persistent disparities in learning support and gender participation in STEM run counter to EU-wide commitments under the **European Pillar of Social Rights** ([108]) and the **EU Gender Equality Strategy for 2020–2025** ([109]), both of which call for inclusive, high-quality education systems that promote equal opportunities regardless of socioeconomic background or gender. Strengthening equity measures in national STEM strategies is essential to achieving these broader EU objectives.

Several country reports, such as those from **Belgium**, **Germany**, **Estonia**, **Lithuania**, **Poland** and **Slovakia**, highlight the under-representation of girls in physics, engineering and technology pathways. These gaps are frequently attributed to gendered stereotypes, a lack of visible female role models and biased curricular materials that fail to engage diverse learners. However, comprehensive strategies to counteract these barriers are largely absent.

**Where initiatives exist, they are often fragmented or rely on NGOs.** For example, **Estonia** and **Slovakia** mention isolated efforts to promote girls' interest in technical fields, such as science camps or female mentorship programmes, but these are typically localised and not integrated into national education plans. In **Belgium**, while there is recognition of gender disparities as an educational challenge, there is limited evidence of coordinated initiatives in this area, which hampers scale and sustainability.

Some countries have taken initial steps through awareness campaigns and the inclusion of gender in strategic frameworks. For instance, **Cyprus** launched a national STEAM promotion campaign to highlight women role models in science and technology. However, such campaigns often lack accompanying policy mechanisms, such as targeted funding, teacher training in inclusive pedagogy or monitoring systems to track progress.

Importantly, gender equity in STEM is not limited to access. Reports point to deeper cultural and structural factors, including the early streaming of students into gendered pathways, limited gender-sensitive career guidance and insufficient engagement with families and communities around STEM futures. Without interventions that address these root causes, participation disparities are likely to persist.

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([108]) European Commission, 'European Pillar of Social Rights', European Commission website, accessed 29 July 2025, https://employment-social-affairs.ec.europa.eu/policies-and-activities/european-pillar-social-rights-building-fairer-and-more-inclusive-european-union_en.

([109]) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Gender equality strategy 2020–2025: A union of equality, COM(2020) 152 final of 5 March 2020, accessed 29 July 2025, https://commission.europa.eu/strategy-and-policy/policies/justice-and-fundamental-rights/gender-equality/gender-equality-strategy_en.

Only a handful of countries, such as **Ireland**, **France**, **Finland** and **Sweden**, stand out for embedding gender equity as a core objective in national STEM strategies. These strategies include actions such as gender-sensitive curriculum reviews, targeted teacher training, mentorship programmes for girls and public campaigns to combat stereotypes. For instance, Finland embeds gender equity across multiple components of its STEM strategy (including curriculum reviews, pedagogical development and career guidance), while Ireland's STEM education policy includes specific measures to encourage girls' participation in science and technology.

Finally, countries such as **Spain**, **Croatia**, the **Netherlands** and **Portugal** show emerging practices that support gender inclusion, often through regional programmes or NGO-led initiatives. These may include STEM clubs for girls, local scholarships or media campaigns to promote women in science. However, such actions are not yet embedded in national education policies and are vulnerable to funding fluctuations.

Overall, the country reports indicate that, while gender gaps in STEM are well documented, **policy responses remain partial, fragmented and uneven**. A shift from isolated initiatives to comprehensive national action plans is needed to create inclusive STEM ecosystems that support the aspirations and talents of all learners.

### Insufficient learning support for disadvantaged groups

**Disadvantaged learners, such as those from low-income backgrounds, rural areas or ethnic minorities, or with special educational needs, often face structural barriers that limit their full participation and achievement in STEM education.** Country analyses consistently highlight that these groups are under-supported by national systems, with targeted interventions either absent or inconsistently applied.

In countries such as **Bulgaria** and **Romania**, support for disadvantaged students in STEM is largely project based, relying on temporary initiatives rather than long-term strategies embedded in national education policies. These initiatives, often supported by EU funding, lack continuity and therefore potential sustainability, and rarely address deeper systemic inequities in access to qualified teachers, modern infrastructure or tailored pedagogical support.

Other countries, including **Ireland**, **Italy** and **Hungary**, acknowledge the needs of disadvantaged learners but report that STEM-specific support remains limited. While these systems may offer general inclusion frameworks, they rarely include targeted STEM interventions such as adapted curricula, differentiated instruction or additional learning time in science and mathematics.

In **Poland**, rural schools face compounding barriers to equitable STEM learning: not only a shortage of qualified teachers but also limited tailored support for

diverse learners. These challenges are intensified by rigid assessment frameworks that do not allow sufficient flexibility for contextualised instruction. In **Portugal**, resource constraints intersect with centralised curricula and exam pressures, disproportionately affecting students with additional learning needs. These examples illustrate how inequities in STEM education are rooted not solely in the absence of facilities or equipment but also in broader aspects of education system design, such as adequate staffing, curriculum flexibility and assessment practices, which collectively shape access, inclusion and outcomes for disadvantaged students.

Equity concerns are also evident in the treatment of students with disabilities and those requiring learning accommodations. **Greece**, **Croatia** and **Cyprus** note a lack of inclusive teaching resources or STEM materials adapted to different learning styles. Moreover, few countries offer teacher training in inclusive STEM pedagogy or conduct systemic data collection to track learning outcomes for these groups.

In the focus group on assessment, participants expressed concern that current STEM assessment tools often fail to accommodate vulnerable learners, including those with special educational needs or from diverse cultural and socioeconomic backgrounds. They advocated the development of inclusive, sensory-based and non-verbal assessment methods that empower marginalised students to demonstrate their competences fully. Such approaches are critical to reducing barriers and ensuring equity in STEM education ([110]).

As will be evident from the overview of existing instruments supporting equity and inclusion in STEM education across Member States (see Section 5.1.3.6), the vast majority of targeted interventions are intended to increase the participation of women and girls. In contrast, there is a **notable lack of dedicated support schemes addressing the needs of other disadvantaged groups, such as learners from lower socioeconomic backgrounds, those from rural or remote areas, migrant students and students with disabilities**. While these groups face well-documented structural barriers to STEM engagement and achievement, interventions targeting their specific challenges are less common. As a result, there is a risk that current equity-focused STEM initiatives may overlook or inadequately address broader dimensions of inclusion beyond gender. This imbalance suggests a need for more comprehensive and intersectional approaches to inclusive STEM education – that is, approaches that not only promote gender equality but also address the overlapping barriers faced by students who experience multiple forms of disadvantage.

Some promising practices are reported. **Finland** and **Sweden** integrate equity-focused strategies within their national STEM frameworks, including early intervention, school counselling and tailored allocation of resources to schools

([110]) Focus group on assessment, April 2025.

depending on their needs. However, these remain outliers in a landscape where most national STEM strategies are not systematically equity oriented.

In summary, while many education systems express a rhetorical commitment to inclusion, STEM-specific support for disadvantaged learners remains a significant gap in practice. Addressing this requires comprehensive policy frameworks that integrate equity across curriculum design, teacher deployment, funding allocation and monitoring systems.

### Underdeveloped career advice and mentorship programmes

Robust career guidance and mentorship are essential to help students navigate STEM education pathways and envisage future professional trajectories. However, across the country reports, it was reported that **career advice remains generic and poorly aligned with STEM-specific opportunities, while structured mentorship programmes are limited in scale and scope**.

In many systems, career guidance is delivered sporadically or by staff without specialised training in STEM labour market trends. **Germany**, **Ireland** and **Cyprus** note that, although guidance services are available, they are often disconnected from wider STEM approaches (and strategies, where they exist) and lack targeted content tailored to technical, engineering or digital professions. Students receive broad advice that fails to reflect the diversity or dynamism of STEM-related careers.

Several countries, such as **Lithuania** and **Poland**, report that mentorship opportunities are largely confined to NGO initiatives or temporary projects. These schemes, while impactful at the local level, often lack long-term funding, integration with formal education or visibility among the students who could benefit most. For example, Poland's Girls Go Tech programme and Lithuania's donor-supported outreach schemes illustrate this reliance on external partners in lieu of systemic provision.

In **Belgium** and **Hungary**, promising practices exist in particular regions, but there is no coherent national approach to mentorship for STEM learners. The decentralised governance structure in Belgium also contributes to fragmented provision, with differing approaches across linguistic communities.

Another gap identified in multiple country reports is the **limited exposure students have to STEM professionals and role models**. This is particularly acute for girls and students from under-represented groups. Without structured mechanisms to connect learners with diverse professionals working in STEM fields, schools struggle to dispel stereotypes or cultivate sustained interest.

Positive exceptions include **Finland**, where career guidance and mentoring are integrated into national STEM efforts, including early exposure to industry and structured school-to-work pathways. In **France**, there are initiatives to strengthen

students' orientation towards STEM careers, such as partnerships between schools and higher education institutions and industry. These activities are linked to broader educational and equality policies. France promotes early-career guidance and supports mentoring schemes, such as *Elles Bougent*, to encourage girls to pursue technical and engineering careers.

Overall, the lack of systematic career guidance and mentorship represents a missed opportunity to support students' STEM engagement. Embedding this support within national strategies, linked to curriculum content, industry collaboration and equity goals, would better equip students to confidently make informed decisions about their futures in STEM.

### Limited access to scholarships and financial incentives

Financial support is a key enabler of equitable participation in STEM education, particularly for students from low-income backgrounds or underserved communities. However, the country reports indicate that **access to scholarships and financial incentives in STEM remains limited across much of the EU and is often fragmented or under-targeted**.

There are few national-level financial aid programmes specifically aiming to promote STEM participation among disadvantaged students. Where scholarships do exist, they are often offered at the higher education level, missing the opportunity to incentivise earlier engagement during secondary education.

**Hungary** and **Slovakia**, for example, highlight that financial support is primarily linked to university admission or academic excellence, rather than social equity goals. This approach may reinforce existing inequalities, as students who would benefit most from early financial encouragement, such as rural learners or those in lower-income families, are less likely to meet competitive criteria without prior support.

In **Germany**, some *Länder* provide state-level scholarships, but national coherence is lacking. These programmes may be well intentioned but they are reported to suffer from low visibility or administrative barriers that discourage uptake among the target groups. Similarly, **Croatia** and **Cyprus** report that financial aid in STEM is rarely tied to systemic inclusion efforts or labour market needs.

By contrast, **Ireland** has introduced targeted bursaries and support mechanisms to increase diversity in technology and engineering programmes, particularly in higher education. While these initiatives align with broader inclusion goals, they are not currently embedded within a dedicated national STEM strategy (the STEM Education Policy Statement for 2017–2026). Such examples of targeted financial support remain the exception across Europe.

The lack of targeted scholarships and financial incentives not only limits individual opportunity but also weakens national efforts to address STEM skills shortages. Well-designed funding mechanisms, linked to inclusion criteria, educational progression and emerging labour demands, could be a powerful tool for improving both equity and outcomes in STEM education.

Moving forward, **national STEM strategies should prioritise financial inclusion as a structural lever**. This includes designing scholarships that reach under-represented groups early, simplifying application processes and aligning financial incentives with broader goals for participation, retention and progression in STEM learning pathways.

Equity remains an under-addressed dimension of STEM education policy. While gaps in terms of gender, geography, socioeconomic background and ability are widely recognised, systemic and sustained responses remain limited. The lack of access to enrichment opportunities, inclusive learning resources, targeted support and financial incentives continues to marginalise under-represented learners. Embedding equity into national STEM strategies, through structural support, inclusion measures and public engagement, will be vital to building more inclusive and resilient STEM learning ecosystems.

#### 5.1.2.6. Integration of non-formal and informal STEM learning and the whole-school approach

While Section 5.1.2.5 explored non-formal and informal learning as important equity tools, this section shifts the focus to their **systemic integration** within schools and national strategies. It also considers how **whole-school approaches** can embed STEM culture across teaching, leadership and community engagement. Under this approach, the school community – involving school leaders, all school staff, learners and parents – engages in collaborative action involving strong cooperation with external stakeholders and the community at large (see Section 5.1.3.2). Despite growing interest, such opportunities remain poorly connected to mainstream education, limiting their pedagogical and systemic impact.

Non-formal and informal STEM learning opportunities are increasingly recognised for their potential to boost engagement and real-world relevance. Yet across most countries they remain marginal and disconnected: programmes are often short-term, fragmented and dependent on external funding or individual champions, with limited links to curricula, teacher training or school development planning. As a result, their reach and sustainability are restricted ([111]).

Country examples illustrate this pattern. In **Spain**, although initiatives such as digital competence centres and extracurricular programming workshops are

([111]) Focus group on the whole-school approach, March 2025.

active, they are rarely embedded within the formal curriculum or supported by national monitoring mechanisms. Similarly, **Slovakia** features examples of schools engaging with industry partners and NGOs, yet such efforts are typically isolated, with no overarching policy or incentive structure encouraging systemic adoption.

In **Poland**, the NGO STEAM Polska is actively engaged in supporting schools and teachers through training in STEAM methodologies and interdisciplinary projects. While impactful in specific regions, its influence is not supported by a strategic mechanism to integrate non-formal content into teaching programmes or school development planning.

The **whole-school approach is similarly underdeveloped**. This model envisages schools as dynamic, interdisciplinary environments where STEM is not confined to specific lessons or departments, but shapes the ethos, teaching and community engagement.

In practice, this approach is often limited to isolated schools or relies on the initiative of individual school leaders. In **Slovenia**, while some schools embed sustainability or innovation principles into their ethos, the specific application to STEM education remains ad hoc. In **Hungary** and **Poland**, efforts to build interdisciplinary and collaborative STEM cultures within schools are hampered by curricular rigidity and assessment systems that reinforce discipline-specific teaching. In **Cyprus**, for instance, school-level innovation in STEM depends heavily on individual initiative, with limited institutional mechanisms to foster or sustain whole-school approaches.

These structural constraints, including limited time for collaborative planning, weak cross-disciplinary teacher training and rigid evaluation frameworks, mirror those described earlier and throughout this section.

Moreover, there is **a lack of evaluation and evidence gathering on the impact of whole-school STEM strategies**. Without systematic monitoring and visibility in national reporting, these types of approaches risk being treated as supplementary rather than essential components of high-quality STEM education.

In summary, while non-formal and informal STEM activities can enhance engagement and deepen learning, their impact remains constrained unless supported by coherent, school-wide strategies and policy alignment. Similarly, the whole-school approach offers a promising framework for embedding STEM across teaching, leadership and partnerships, but it is rarely implemented at scale.

### 5.1.2.7. Data availability and research on promoting STEM education in schools

Data collection, monitoring and evaluation are essential to understanding the effectiveness and equity of STEM education systems. Yet, across many countries, gaps in the availability of high-quality, disaggregated data and systematic evaluation of STEM education initiatives continue to hinder evidence-based policymaking. **This limits countries' capacities to track progress and adjust policies effectively.**

The country-level mapping highlights **persistent and systemic limitations in the availability, granularity and utility of monitoring and evaluation data related to STEM education in schools**. These weaknesses affect both assessments at the national policy level and the evaluation of individual programmes.

#### Limited availability of data and monitoring systems

Many countries continue to rely primarily on **international large-scale assessments such as PISA and the Trends in International Mathematics and Science Study (TIMSS) as proxies for STEM education performance**. While these tools provide valuable benchmarking data and facilitate international comparisons, they are limited in their capacity to assess the specific impact of national reforms or contextualised interventions. Crucially, they offer only periodic, high-level snapshots and do not support real-time policy learning or disaggregated analysis of local practices, implementation fidelity or differential outcomes across student subgroups.

The country reports reveal **significant weaknesses in the availability, integration and use of data related to STEM education**. In **Ireland**, while initiatives such as Smart Futures and SciFest are evaluated, there is no centralised framework for tracking participation or progression. In **Germany**, decentralisation fragments data across *Länder*, impeding national coordination. **Lithuania** and **Romania** lack robust systems for disaggregated monitoring, while in **Poland** and **Portugal** available data are underutilised and rarely linked to accountability or resource planning.

Focus group participants identified significant gaps in the collection, integration and use of STEM education data across countries. They highlighted the importance of participatory monitoring models that involve educators and learners in shaping meaningful, context-sensitive indicators that go beyond academic performance to capture STEM competences and experiences ([112]). Positive examples are rare, but **Belgium** (Flemish Region), **Estonia** and **Finland** demonstrate how comprehensive education data infrastructures with STEM-

([112]) Focus group on assessment, April 2025.

specific indicators can inform strategy, guide resource allocation and support continuous improvement.

To strengthen STEM education governance, **countries should develop integrated monitoring systems that disaggregate participation and outcomes by key equity dimensions, enable international comparability and support adaptive policy responses**. Greater collaboration between education ministries, statistical offices and research institutions will be critical to achieving this goal.

### Inadequate research on the promotion and effectiveness of STEM initiatives

Evidence-based policymaking in STEM education depends not only on strong data systems but also on a robust body of applied research. However, the country reports reveal that **many Member States lack sufficient national research to evaluate the design, implementation and impact of STEM-related initiatives**. This weakens the feedback loop between policy intent and classroom reality.

As outlined in the mapping of instruments supporting STEM education in schools, most evaluations focus on short-term, easily quantifiable outputs, such as numbers of teachers trained or materials distributed, rather than on deeper indicators of pedagogical change, learner progression or educational equity. For instance, evaluations in countries such as **Cyprus** and **Romania** often prioritise the reporting of participation numbers or self-reported satisfaction rather than robust outcome measures. In Cyprus, the country report highlights that most STEM-related activities are not evaluated systematically and evidence of impact is scarce.

**Longitudinal research, essential in the STEM education context due to the cumulative and developmental nature of skills acquisition, is notably scarce.** The scarcity of such studies reflects broader structural and resource constraints, including insufficient funding, limited institutional capacity and a lack of technical expertise. These constraints are particularly acute for NGOs and local actors, which often lead grassroots STEM initiatives but lack the infrastructure to undertake rigorous, long-term evaluation. As a result, many potentially impactful programmes remain under-analysed, limiting the transfer of lessons learned and the potential for scaling up successful models.

As noted in the report from **Ireland**, while there is research supporting national strategies, a coordinated approach to evaluating the long-term impact of STEM initiatives on learner outcomes is still emerging. In **Germany**, despite a broad landscape of STEM innovation at the state (*Land*) level, there is little evidence in the country report of a unified national framework to evaluate or synthesise results from these diverse efforts. Fragmentation hinders the ability to scale up promising practices or align them with broader policy frameworks. Similarly, **Spain** lacks evaluation tools specifically focused on monitoring the impact of

digital STEM programmes or outreach activities. The country report highlights that, although inclusion and innovation are policy goals, systematic research into whether such interventions affect student participation or achievement is limited. Some positive practices exist and, as highlighted above, **Belgium** (Flemish Region), **Estonia** and **Finland** are among the few countries with advanced education research infrastructures. In Estonia, a strong digital ecosystem supports real-time data collection and experimentation in STEM education reforms.

However, across most of the EU, research on STEM education tends to be project specific, with limited mechanisms for policy learning or knowledge transfer. Reports commonly note a lack of institutionalised collaboration between ministries, researchers and schools. Moreover, findings from pilot initiatives are not consistently disseminated or used to inform national planning.

#### 5.1.2.8. Impact of the COVID-19 pandemic

The COVID-19 pandemic significantly disrupted education systems across Europe, with substantial effects on the teaching and learning of STEM subjects. School closures, shifts to remote learning and wider social and economic instability exposed and deepened structural inequalities in access to high-quality STEM education. Several country reports reflect on these disruptions and the challenges they created, both during and after the crisis.

##### Disruptions to teaching and learning in STEM

The sudden transition to remote and online learning during the pandemic disrupted the continuity of STEM education, particularly in practical subjects, such as science and technology, that rely on laboratory work and physical interaction. The **German** country report highlights a loss of practical laboratory experience and a general decline in the quality of STEM education due to emergency online provision. In **Ireland**, while teachers adapted with digital tools, science teachers found it especially difficult to translate practical activities into virtual formats. Similarly, in **Lithuania**, the country report explicitly notes that school closures had a negative effect on student motivation and achievement in STEM, particularly in rural areas, where remote learning infrastructure is weaker. In **Portugal**, similar rural–urban divides in access to STEM learning during the pandemic are highlighted. Teachers in **Belgium** and **Austria** stated that they had experienced difficulties in adapting science subjects to online formats, with reports of diminished student engagement and inconsistent instruction across schools. In **Czechia**, hands-on learning in STEM subjects was significantly affected by the shift to online education, particularly in disadvantaged schools, which lacked the resources to replicate laboratory-based instruction remotely. In **Croatia**, students and teachers struggled with the absence of practical experiments in subjects such

as chemistry, biology and physics, leading to decreased academic performance and confidence in STEM learning.

The reliance on practical, hands-on learning in STEM subjects made them particularly vulnerable to disruption during remote schooling. Countries with weak digital readiness and limited teacher training faced greater learning losses in STEM.

### Widening of digital and social inequalities

The COVID-19 pandemic acted as a **stress test for digital equity in STEM education**. Countries such as **Bulgaria** and **Romania** reported stark disparities in access to devices and reliable internet, especially among low-income and rural students, leading to prolonged disruption in STEM learning. In **Slovakia**, the transition exposed gaps in digital competences among both teachers and students, with students with special educational needs being particularly affected. In **Hungary**, remote teaching platforms were available, but digital literacy and infrastructure varied, affecting consistency. In **Greece** and **Italy**, teacher shortages and varying levels of technological preparedness created inconsistent learning experiences. The **Czech** country report highlights that schools in socially disadvantaged areas were less equipped for online STEM instruction. In **Finland**, the country report noted that low-achieving students suffered greater setbacks in mathematics during distance learning, with reduced parental support.

These disruptions revealed how existing digital inequities are deeply tied to broader structural vulnerabilities within education systems.

### Delays in assessment and progression

Several countries reported **interruptions to standardised assessments and school transitions**, particularly for upper-secondary STEM students preparing for higher education. In **Germany**, school-leaving exams were modified or postponed, impacting STEM students' preparation for university entry. In **Ireland**, concerns were raised about the fairness of calculated grades for STEM subjects, which usually depend heavily on exam performance. In **Lithuania**, national assessments in mathematics and science were interrupted, affecting academic progression. **Poland** reported cancelled or delayed extracurricular STEM activities such as science fairs and competitions, which play a key role in student development and access to higher education. In **Spain**, the disruption to STEM enrichment activities such as science Olympiads and technical competitions removed key motivators for high-achieving students. There was concern that this would negatively influence STEM university applications and student confidence.

Interruptions to assessment and progression pathways may have long-term effects on student confidence and STEM career aspirations. Recovery plans need to incorporate targeted support for transition years.

### Acceleration of digital innovation but inconsistent implementation

Some countries used the **crisis as a catalyst to expand digital learning infrastructure and accelerate teacher training**. In **Poland** and **Portugal**, investments in digital devices and platforms continued after the pandemic, with expanded access to online STEM content. **Germany** and **Ireland** introduced national platforms for blended learning, although implementation was uneven. **Belgium** and **Austria** launched emergency teacher training programmes in digital pedagogy, but the quality and uptake varied widely.

The pandemic spurred innovation but also revealed the need for more coordinated national strategies on digital STEM education. Post-pandemic recovery plans offer an opportunity to embed digital skills more systematically across STEM curricula.

**Box 11. Comparative reflection: pre- and post-pandemic system conditions**

While no Member State was entirely immune to the challenges posed by the COVID-19 pandemic, several demonstrated strong strategic responses that mitigated disruption and supported long-term digital transformation.

- **Finland** leveraged its existing digital infrastructure and teacher autonomy to maintain continuity in STEM education, with rapid shifts to online learning facilitated by prior investments in digital pedagogy.
- **Ireland** introduced a National Digital Strategy for Schools, with targeted support for disadvantaged students, a boost in teacher training for online delivery and expanded online STEM content.
- **Portugal** rapidly scaled up device distribution, strengthened broadband access and launched digital resources aligned with the national STEM curriculum. It also supported teachers with emergency CPD programmes.

**These examples illustrate that systems with pre-existing investments in digital learning and inclusive infrastructure were well positioned to adapt and sustain STEM education through the crisis.**

*Source:* Country reports.

The COVID-19 pandemic magnified existing structural vulnerabilities in STEM education, particularly around digital access, pedagogical resilience and equity. It disrupted practical learning, widened digital divides and exposed the fragility of progression pathways. However, it also catalysed innovation and investment in digital infrastructure in some education systems. Moving forward, recovery strategies must build on these shifts by embedding digital readiness, resilience and inclusivity into the core of national STEM education agendas.

## 5.1.2.9. Other challenges

While the preceding sections capture the major structural and policy challenges in STEM education across European school systems, a review of all the country

reports also reveals a set of additional cross-cutting issues that, although less commonly reported, are significant in shaping the context and effectiveness of STEM reform. These other challenges include barriers related to education system governance, strategic vision, stakeholder involvement and educational values.

## Fragmented ecosystems and the need for cross-sectoral coordination in STEM education

A major structural challenge in many European countries is the **lack of cross-sectoral collaboration and policy coherence in STEM education**. Education policies are often developed in isolation from broader strategies for labour market development, digital transformation, innovation and industrial modernisation. This disconnect weakens the capacity of STEM education to respond to national priorities and emerging economic needs.

Despite emerging collaborative frameworks across ministries and sectors, many systems have yet to embed meaningful stakeholder engagement in the **design and implementation of STEM reforms**. This disconnect highlights the need for inclusive, participatory governance models that reach beyond institutional partnerships to empower school-level actors.

Several reports note that STEM approaches are designed without sufficient input from key stakeholders, including teachers, school leaders, parents, students and industry partners. In **Croatia** and **Slovakia**, stakeholder consultation has often been ad hoc or restricted to formal actors, resulting in strategies that lack school-level buy-in and practical feasibility. In both Member States, engagement with schools, teachers and industry tends to occur through externally funded pilot programmes, rather than through national policy planning. Inclusive policy design is critical for legitimacy and implementation. Mechanisms for co-creation, feedback and participatory governance help ensure that STEM strategies reflect local needs and capacities.

In **Bulgaria** and **Romania**, weak interministerial coordination has led to inconsistent messages and overlapping mandates. In **Germany**, the country report notes that the decentralised system (*Länder*) often leads to fragmented STEM policies, reducing coherence with economic strategies. **Ireland** also reports fragmented coordination between education, innovation and enterprise policies.

This policy-level fragmentation is mirrored at the implementation level in the **weak and inconsistently supported partnerships between schools, communities and industry**. While strong school–community and industry engagement is critical for delivering contextualised, future-oriented STEM education, such collaborations remain underdeveloped across much of Europe.

In many countries, including **Croatia**, **Cyprus** and **Austria**, partnerships with businesses, universities, NGOs and community institutions are typically informal, short-term and highly dependent on individual school leadership or teacher initiative. While motivated educators may cultivate valuable collaborations, there is little structural support or policy guidance to scale up these efforts systemically.

Several reports, including those from **Lithuania** and **Slovakia**, highlight the existence of university–school links, especially in urban centres, but note that these rarely extend to the wider education system or reach rural schools. Without national frameworks or incentives, the benefits of these partnerships are unevenly distributed and fail to reduce structural gaps in access to innovation and career development.

The lack of formalised, scalable partnership models limits schools' abilities to offer contextualised, inquiry-driven STEM learning. In countries such as **Italy** and **Portugal**, the lack of central coordination mechanisms means that even promising local practices struggle to gain visibility or long-term support (although, in the case of Portugal, *Ciência Viva* plays an important intermediary role by supporting extracurricular STEM activities and outreach). As a result, schools miss opportunities to enrich their curricula with interdisciplinary, applied learning experiences that reflect the rapidly changing nature of STEM jobs.

Strengthening school–community and industry engagement requires a shift from ad hoc collaboration to embedded practice. This entails developing **national strategies that outline partnership principles, allocate dedicated resources, support intermediary organisations and provide incentives for sustained cooperation**. Without such frameworks, STEM education risks becoming disconnected from the broader ecosystems that can inspire, inform and prepare students for the future.

### Institutional inertia and reform fatigue

Several European countries face persistent **institutional inertia** and **reform fatigue**, which significantly hinder the implementation and sustainability of STEM education reforms. These challenges often arise when **top-down initiatives** lack adequate consultation, ownership or continuity at the school and teacher levels.

For example, in **Austria** and **Slovakia**, STEM-related reforms have largely been driven by central government directives. While these initiatives were well intentioned, they have struggled to gain traction in practice. In Austria, the lack of cross-sectoral coordination and insufficient support for bottom-up innovation have limited the systemic uptake of interdisciplinary or competence-based approaches. Similarly, in Slovakia, fragmented implementation and a reliance on prescriptive curricula have stifled local-level engagement and adaptation.

Other countries show similar patterns. In **Romania**, frequent changes in policy direction and limited teacher involvement have led to reform fatigue, reducing

trust in long-term STEM policy frameworks. **Malta** and **Portugal** both exhibit signs of slow or inconsistent implementation, with top-level initiatives often failing to become embedded in classrooms. **Belgium** and **Croatia** also highlight fragmented reform efforts, with pilot programmes or innovation projects lacking integration into mainstream policy or practice.

These examples underline the need for more **inclusive, participatory and sustained approaches** to reform. Building trust and ownership among educators, ensuring policy coherence and allowing sufficient time and support for meaningful change are essential to overcoming structural inertia in STEM education systems.

### Lack of focus on transversal skills and innovation competences

A recurring structural challenge across European STEM education systems is the **limited integration of transversal skills and innovation competences within school-level curricula and pedagogical practices**. Despite increasing global recognition of the importance of competences such as **critical thinking, collaboration, creativity and entrepreneurship**, national reports reveal a persistent focus on discipline-specific knowledge and conventional learning outcomes.

Content analysis of the 27 country reports shows that terms associated with transversal skills and innovation competences are either **entirely absent** or **only marginally addressed**. For example, countries such as **Estonia**, **Spain**, **Hungary** and **Finland** make little reference to transversal skills, innovation competences or related 21st-century skill sets in their discussion of STEM education challenges. In **Cyprus** and **Portugal**, curricula are content heavy, leaving little space for interdisciplinary or project-based approaches ([113]). Moreover, even in countries where such skills and competences are mentioned, they are rarely framed as **core components** of STEM teaching and learning. Instead, references to skills such as creativity, problem-solving or the use of interdisciplinary approaches are often peripherally treated as aspirational rather than operational elements of curriculum design or teacher training. **Lithuania's** frameworks, for example, reference competences but indicate a lack of supporting implementation tools. This absence suggests that these areas are not yet considered structural priorities in national reform agendas.

This gap has implications for the alignment of STEM education, once again, with labour market needs and societal challenges. The lack of systemic integration of transversal skills in STEM education represents a structural barrier to developing a future-ready workforce and limits the broader educational mission of fostering agency, curiosity and civic engagement through STEM.

([113]) Recent reforms in Portugal under the 'profile of the student' curriculum framework are addressing these issues.

### 5.1.3. Overview of the identified instruments promoting STEM education and their results

While the preceding sections highlighted a range of deep-rooted structural challenges that continue to hinder the effective implementation of STEM education in many Member States, it is equally important to recognise the substantial efforts under way to address these barriers. Indeed, the landscape is marked by a dynamic interplay between systemic constraints and proactive, often innovative responses. The following section turns to national-, regional- and, in some cases, local-level instruments and initiatives, revealing a diverse array of policy tools, programmes and practices that have been deployed to promote STEM education – many with demonstrable impact. Examining these instruments allows for a greater appreciation of how policy ambitions can be translated into tangible actions on the ground and how localised solutions can serve as scalable models of how to overcome the obstacles previously identified. This juxtaposition underscores the importance of aligning structural reform with educational innovation and highlights the potential for coherence and synergy across different levels of the education system.

It is important to note that the instruments and initiatives presented in this section do not represent an exhaustive inventory of all STEM-related policies and programmes across the analysed countries. These examples were primarily drawn from country-level research and expert interviews conducted during the study and supplemented by targeted desk research. Thus, the focus is on illustrative and representative initiatives that capture emerging trends, evidence-based practices and innovative approaches to promoting STEM education, rather than providing a comprehensive catalogue of all actions undertaken across Europe.

The analysis categorises the identified instruments based on their objectives, target groups, delivery mechanisms and other relevant criteria. The mapped instruments include, for instance, formal curriculum-based reforms, non-formal and informal learning initiatives, teacher training schemes, public–private partnerships and digital education initiatives. Particular attention is paid to the instruments' alignment with national policy goals, their degree of innovation and scalability and their reported or measured outcomes.

Importantly, this section identifies key success factors associated with different types of interventions – such as integrated teaching approaches, industry partnerships or inclusive outreach models – providing insights into what tends to work in specific national or educational contexts. In addition, selected good practice examples are highlighted in more detail, offering a deeper understanding of innovative and impactful initiatives that can serve as models to be replicated or adapted by Member States.

While the number and scope of such initiatives vary significantly across countries, the analysis also reveals persistent challenges in their implementation –

particularly in relation to equity, inclusiveness and the lack of systematic impact monitoring. This section therefore serves as both a mapping of existing practices and a critical reflection on the conditions that support or hinder their effectiveness.

#### 5.1.3.1. STEM education curriculum, pedagogy and assessment

Cross-analysis of the country reports from the EU-27 revealed that over the last 10 years a wide array of **programmes and initiatives** has been deployed to strengthen STEM education in schools. These initiatives target different facets of education – from **curriculum reforms** and **competence frameworks** to **innovative teaching methods**, **integrated STEAM approaches** and **new assessment methods** – with the common goal of improving students' STEM skills and engagement.

##### Actions to modernise STEM curricula and pedagogy

Some Member States have begun to confront the structural barriers identified in the previous section – curriculum rigidity, fragmented governance and uneven access to qualified teachers or high-quality infrastructure – through ambitious curriculum reforms. While the majority of countries still operate within traditional, discipline-based frameworks (as shown in the policy typology, where cluster 2 countries predominate), evidence gathered for this study indicates a gradual, if uneven, shift towards modernising STEM learning over the past decade ([114]). Reform momentum is most visible among countries in cluster 1 (interdisciplinary and policy integrated) and cluster 3 (innovation and technology driven), which are redesigning curricula to emphasise interdisciplinarity, applied digital skills and real-world relevance. These initiatives exemplify a broader recognition that overcoming systemic challenges requires rethinking teaching and learning approaches and aligning educational outcomes more closely with labour market and societal needs. **The reforms include introducing new STEM courses and integrating disciplines, updating learning goals towards competences, and aligning school programmes with real-world and industry developments and needs**. A common thread in these curriculum initiatives is a shift from rote learning towards developing problem-solving, critical thinking and digital skills. The following section explores how these emerging competence-based frameworks and curriculum updates are being operationalised to foster transversal skills in STEM, illustrating both the promise and the limits of current reform efforts to build more inclusive and future-oriented education systems.

Some countries have been or are revising their national curricula, **particular by updating learning objectives to place greater emphasis on applied skills and interdisciplinarity in STEM education**. In 2024, **Poland** introduced a new

([114]) See Section 5.1.1.1 for more information on the clusters.

general education curriculum ([115]) explicitly incorporating STEM/STEAM elements, with a special emphasis on interdisciplinarity and the practical application of knowledge. This reform reduced theoretical content by about 20 % to allow deeper coverage of key topics and increased the use of digital tools in teaching. By 2026, Poland plans to have **integrated formerly separate science subjects** (biology, chemistry, physics and geography) into a single integrated science course for grades IV–VI, reflecting a push towards more holistic science education. Similarly, in **Greece**, model and experimental schools ([116]), originally launched in 1929 and revised in 2020, serve as platforms for piloting educational innovations and new teaching methods. These schools create a flexible environment that supports interdisciplinary, inquiry-based learning. Students and teachers often collaborate in small groups, sometimes outside regular hours, on thematic projects rooted in, for example, environmental science, astronomy or the arts. These projects can include STEM-focused experimentation.

**Italy** has likewise modernised its curriculum. The National Guidelines for the Curriculum set out by the Ministry of Education, provide a competence-based framework that emphasises applying knowledge in real-world contexts. In 2023, Italy adopted new STEM-specific guidelines ([117]) encouraging innovative, inquiry-based and inclusive practices in the teaching of STEM subjects. This reform was partly driven by concern over international assessments (e.g. PISA) revealing weaknesses in students' scientific literacy, prompting a shift towards more engaging methods and a stronger STEM foundation from an early age.

Revised curricula in several countries explicitly encourage cross-curricular connections and hands-on learning. For example, **Finland**'s 2016 National Core Curriculum introduced **phenomenon-based learning (PhBL)** ([118]) as a nationwide approach, requiring every school to implement at least one interdisciplinary, project-based learning module each year (see Box 12). Instead of teaching subjects in isolation, Finnish schools now explore real-world phenomena through multiple disciplines in these modules, which has fostered student-centred learning and collaboration. Early evidence from Finland suggests this approach helps students build broader 21st-century skills, though it also requires significant teacher collaboration and new pedagogical strategies.

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([115]) Ministry of National Education (Poland), 'Podstawa programowa kształcenia ogólnego' ['National core curriculum'], Zintegrowana Platforma Edukacyjna [Integrated Educational Platform], accessed 29 July 2025, https://zpe.gov.pl/podstawa-programowa.

([116]) Aikaterini Valari *Τα Πρότυπα Πειραματικά Σχολεία: Αριστεία και Κοινωνικές Διασυνδέσεις*, [*The Model Experimental Schools: Excellence and Social Dimensions (2011-2015)*], doctoral thesis, Aristotle University of Thessaloniki, 2017, GRI-2017-18290, https://ikee.lib.auth.gr/record/287060/files/GRI-2017-18290.pdf.

([117]) Ministry of Education and Merit (Italy), *Linee guida per le discipline STEM*, No 184, Rome, 2023. c9144007-9a2b-3424-acf0-8995165b7ac2.

([118]) Drew, C., 'What is Finland's phenomenon-based learning approach?', *Teacher Magazine*, 3 March 2020, accessed 29 July 2025, https://www.teachermagazine.com/au_en/articles/what-is-finlands-phenomenon-based-learning-approach.

**Box 12. Good practice example: phenomenon-based learning – Finland**

**Approach**. **A 2016 national curriculum reform mandated interdisciplinary PhBL as part of basic education.**

**Objectives**. By modernising teaching methods and breaking down traditional subject silos, students should be better prepared for 21st-century complexities. PhBL aims to develop critical thinking, collaboration and problem-solving by studying real-world themes (e.g. climate change, urbanisation) through multiple subject lenses.

**Target groups**. The reform affected all Finnish primary and lower-secondary schools. PhBL is implemented school-wide, involving students of various ages depending on the phenomenon project.

**Activities**. Each school must run at least one multidisciplinary project module per year. In these modules, students investigate a real-world phenomenon (e.g. climate change) through integrated activities spanning science, technology, mathematics, social studies, etc., rather than separate lessons by subject. Students work in teams to formulate questions, conduct research and present findings, while teachers from different subject areas plan and facilitate the module collaboratively.

**Results/impacts**. The reform has been implemented nationwide, institutionalising project-based STEM learning. It has reportedly enhanced student engagement and improved the development of transversal skills, such as teamwork and inquiry-based problem-solving. All Finnish schools now provide opportunities for applied interdisciplinary STEM learning each year – an unprecedented scale-up of curricular integration. While quantitative outcomes (e.g. PISA scores) are being monitored, PhBL is widely seen as a cultural shift in Finnish education towards more integrative and student-centred STEM learning.

Several countries have introduced **new STEM subjects or modules** within their curricula, focusing on digital technologies. For instance, **Denmark** piloted a compulsory course in technology comprehension at the lower-secondary level (international standard classification of education – ISCED2) in 2017, to build students' understanding of digital technology and programming as part of the core curriculum. In 2024, it was decided to implement technology comprehension in all schools from 2027/2028 as an integral part of existing subjects, as well as an optional subject at the lower-secondary level ([119]). In **Romania**, a 2017 curricular reform ([120]) made informatics (coding and computer science) a required subject in grades 5–8, acknowledging the need to build digital skills; however, this created an urgent demand for trained ICT teachers, which Romania addressed through parallel upskilling programmes.

**Better alignment with industry needs** has been another aspect of curriculum development in the Member States over the last few years. In the **Netherlands**, this has taken shape through the Technology Pact (*Techniekpact*), a comprehensive national strategy launched in 2013 to better connect education

([119]) Rambøll Management Consulting, *Forsøg med teknologiforståelse i folkeskolens obligatoriske undervisning – Slutevaluering*, Børne- og Undervisningsministeriet Rapport, Copenhagen, 2021, https://www.uvm.dk/-/media/filer/uvm/aktuelt/pdf21/okt/211004-slutevaluering-teknologoforstaaelse.pdf.

([120]) European Commission / EACEA / Eurydice, *Recommended annual instruction time in full-time compulsory education in Europe – 2017/18 – Eurydice – Facts and figures*, Publications Office of the European Union, Luxembourg, 2018, https://eurydice.indire.it/wp-content/uploads/2018/06/Instruction-Time-2017-18-Final-report.pdf.

with labour market demands ([121]). As part of this pact, curricula are being revised to include more practical technical skills and work-based learning, ensuring that graduates have the relevant skills for the high-tech economy. Early outcomes of the pact include stronger collaboration between schools and industry, increases in technical subjects' enrolment and progress in addressing teacher shortages and gender imbalances in technical education (see Box 13 for more details).

**Box 13. Good practice example: Technology Pact (*Techniekpact*) – Netherlands**

**Approach.** The *Techniekpact* is a comprehensive national strategy to reinforce the entire technical education continuum and respond to evolving STEM challenges. Launched in 2013, the pact was designed to tackle pressing issues, such as teacher shortages, rapid technological change and the persistent mismatch between education and labour market needs. It brings together a broad coalition of over 60 stakeholders, including government ministries, educational institutions, industry partners and civil-society organisations.

**Objectives.** The overarching aim of the *Techniekpact* is to increase the number of students enrolling in and completing technical and STEM education, while simultaneously ensuring that these educational pathways are aligned with the dynamic needs of the labour market. The pact addresses the full educational continuum, starting from primary education and extending through secondary and vocational education into adult upskilling and lifelong learning, making it one of the most comprehensive instruments of its kind in the EU.

**Target groups.** The *Techniekpact* targets primary/secondary/VET students, teachers and industry.

**Activities.** One of its core focuses has been the revision and adaptation of curricula to reflect the technical skills increasingly demanded by employers. Educational programmes have been updated to include more applied, hands-on learning and to integrate practical, technical competences, helping to make learning more relevant and responsive to labour market developments. Alongside curriculum innovation, the pact has supported a range of initiatives aimed at making technical education more attractive to young people. These include regional campaigns, interactive workshops and school–industry engagement projects designed to spark student interest in technical careers from an early age.

**Results/impacts.** Evaluation ([122]) indicates a slight increase in enrolment in technical and STEM education pathways, suggesting that the pact's activities are effectively stimulating interest and uptake. Furthermore, regional collaboration between education providers and businesses has improved, leading to stronger local ecosystems for technical education and training. Investment in vocational education has expanded, and new training opportunities have been developed, improving the alignment between classroom learning and real-world technical competences. Notably, the pact has also succeeded in modestly increasing the participation of women in technical education at both the secondary and higher levels, addressing long-standing gender disparities in the sector.

In recent years, several Member States have developed national STEM competence frameworks, competence-based curricula or STEM policy frameworks, emphasising the importance of competence-based teaching and learning. These frameworks serve as reference models, specifying the knowledge, skills and attitudes students should develop in STEM disciplines.

([121]) Platform Talent voor Technology is the Netherlands' national STEM platform; see https://www.ptvt.nl.

([122]) Ter Weel, B., Zegel, S., Oomens, I., Vervliet, T. and Vlaanderen, M., *Evaluerend advies Techniekpact 2013–2020: evaluatie en advies over het Techniekpact voor een toekomstig kabinet*, SEO Economisch Onderzoek and Technopolis, Amsterdam, 2020, https://www.seo.nl/wp-content/uploads/2020/09/2020-49-Evaluerend-advies-Techniekpact-2013-2020.pdf.

- **Germany** has used nationally agreed educational standards (*Bildungsstandards*) as a competence-based curriculum framework in STEM since 1997 ([123]), ensuring that, core STEM competences are uniformly defined and assessed across *Länder*.
- **Latvia** launched the *Skola2030* reform ([124]) in **2018**, establishing a national competence-based curriculum. This reform is built around a cross-disciplinary model that outlines key STEM and 21st-century skills, such as critical thinking, creativity and digital literacy. It marks a fundamental shift from content-focused instruction to skills-oriented, interdisciplinary STEM education.
- In **Romania**, the development of a competence-based curriculum has been significantly advanced by the 2023 School Education Law (Law 198/2023) ([125]), which builds on the Educated Romania initiative. The law introduces a competence-based curriculum aimed at equipping students with key skills, including those used in STEM fields, to meet labour market and societal needs. It promotes interdisciplinary, project-based learning by integrating STEM with the arts, humanities and social sciences, encouraging critical thinking and creativity. Complementing this, the 2019–2030 Action Plan for Education in Romania ([126]) prioritises the development of STEM competences, curricular updates and modern teaching practices to align education with national and European priorities, further supporting the integration of digital skills and problem-solving across subjects.
- In **Ireland**, the development of a competence-based curriculum is supported by national curriculum reforms and shaped by alignment with EU education priorities. The Primary Curriculum Framework ([127]), adopted in 2023, promotes interdisciplinary learning by integrating STEM subjects into the curriculum to develop key competences. A new primary STEM curriculum was successfully piloted ahead of a full roll-out in September

([123]) Standing Conference of the Ministers of Education, Science and Cultural Affairs, 'Mathematik, Informatik, Naturwissenschaften, Technik (MINT)', Standing Conference of the Ministers of Education, Science and Cultural Affairs website, accessed 29 July 2025.

([124]) National Centre for Education of Latvia, 'Skola2030 – Competence-based curriculum and learning approach for general education', Skola2030 website, 2021–2025, accessed 29 July 2025, https://www.skola2030.lv/.

([125]) Parliament of Romania, Legea educației naționale nr. 198/2023 privind învățământul preuniversitar, official gazette No 614, 5 July 2023, Article 1(1), Bucharest, 2023, https://legislatie.just.ro/Public/DetaliiDocumentAfis/271896.

([126]) Ministry of Education (Romania), *Planul de acțiune pentru educație 2019–2030*, approved by ministerial order No S 387 of 5 August 2019, Bucharest, 2019, (steamonedu.eu, portalînvățământ.ro).

([127]) National Council for Curriculum and Assessment (Ireland), *Primary Curriculum Framework for Primary and Special Schools*, Department of Education, Dublin, 2023, accessed 29 July 2025, https://curriculumonline.ie/getmedia/84747851-0581-431b-b4d7-dc6ee850883e/2023-Primary-Framework-ENG-screen.pdf.

2025. At the post-primary level, the 2014 junior cycle reform mandated the inclusion of key skills and STEM-related subjects, such as coding, reinforcing the focus on future-oriented competences. National legislation, including the 2012 Education (Amendment) Act ([128]), and strategic directives from the Department of Education provide the legal and policy framework for these changes. Additionally, the integration of STEM and ICT education is guided by Ireland's commitment to the EU Digital Education Action Plan, ensuring coherence with broader European educational objectives.

- **Denmark** has developed subject-specific competence frameworks relevant to STEM education. The Mathematical Competence Framework ([129]) and a Digital Competence Framework ([130]) were developed to guide curriculum and instruction in mathematics and digital education, respectively. While Denmark does not have a unified STEM competence framework, these two serve as reference models for relevant domains within STEM. The Mathematical Competence Framework dates from the early 2010s, and Digital Competence Framework was implemented between 2017 and 2019.
- In 2019, the Flemish community in **Belgium** reformed its curriculum to include STEM learning goals within minimum attainment standards. These standards function as a de facto competence framework, specifying what students should be able to do in STEM subjects (e.g. apply the scientific method, integrate scientific and technological knowledge to solve problems) and guiding integrated STEM teaching ([131]).
- In **Finland**, the development of competence frameworks in STEM education is anchored in the national core curriculum ([132]) for primary and lower-secondary education. The current curriculum, implemented progressively from 2016, embeds transversal competences across subjects (including STEM subjects), with a strong emphasis on ICT, well-being and real-world skills. The 2019 upper-secondary reform reinforced this with a curriculum that integrates inquiry-based, interdisciplinary and

([128]) Government of Ireland, Education (Amendment) Act 2012, Dublin, 2012, https://www.teachingcouncil.ie/assets/uploads/2023/07/education-amendment-act.pdf.

([129]) Niss, M. A. and Højgaard, T. (eds), *Competences and Mathematical Learning: Ideas and inspiration for the development of mathematics teaching and learning in Denmark*, Roskilde University, Roskilde, 2011.

([130]) Ministry of Children and Education (Denmark), 'Fokus på digitale kompetencer i gymnasiet', EMU website, accessed 29 July 2025, https://www.emu.dk/stx/det-digitale/fokus-paa-digitale-kompetencer-i-gymnasiet.

([131]) https://onderwijsdoelen.be/.

([132]) Finnish National Agency for Education, 'National core curriculum for primary and lower secondary (basic) education', Finnish National Agency for Education website, 2014, accessed 29 July 2025, https://www.oph.fi/en/education-and-qualifications/national-core-curriculum-primary-and-lower-secondary-basic-education. The national core curriculum was introduced in grades one to six on 1 August 2016 and was gradually rolled out up to grade nine by 2019.

hands-on learning approaches, reflecting national priorities like sustainability and digital transformation.

In addition to developing national frameworks and localised innovations, some Member States are increasingly drawing on **internationally recognised pedagogical practices to address common, persistent challenges** in STEM education, one of which is mathematics anxiety. This phenomenon, affecting learners of all ages, is widely acknowledged as a major barrier to engagement and achievement in mathematics. Students who experience mathematics anxiety often struggle to develop confidence and fluency, leading to avoidance behaviours and lower performance, which can perpetuate achievement gaps and discourage progression into STEM fields. Recognising this, some Member States are beginning to adopt evidence-based international programmes that explicitly address such issues through alternative instructional models. These models often emphasise structured support, incremental learning and emotional safety, particularly in mathematics teaching. A notable example comes from **Bulgaria**, where the Institute for Progressive Education ([133]), a public benefit association, has been promoting educational innovation since 2011. Among its most impactful initiatives is the JUMP Math programme, an internationally developed instructional system designed to reduce math anxiety and foster mathematical confidence (see Box 14).

**Box 14. Good practice example: JUMP Math – Bulgaria**

**Approach.** The Institute for Progressive Education, a public benefit association established in 2011, works to improve education in Bulgaria by offering affordable, innovative teaching methods and global best practices to teachers, students and parents. One of its flagship initiatives is the implementation of JUMP Math, an international structured and inclusive mathematics teaching programme designed to support all learners, reduce mathematics anxiety and build essential mathematical skills through active learning and small-step instruction.

**Objectives.** The programme seeks to make mathematics accessible and engaging for every child, regardless of background or ability. Its goals include reducing anxiety around learning mathematics, fostering critical thinking and problem-solving skills, and supporting teachers with effective methodologies that promote inclusive and high-quality instruction.

**Target groups.** JUMP Math targets primary and kindergarten students, particularly those who struggle with traditional approaches to learning mathematics. It also supports teachers by providing them with structured lesson plans, training and pedagogical tools. The programme is inclusive of resource-assisted learners and aims to benefit a wide range of learning needs.

**Activities.** The programme breaks down complex mathematical concepts into small, manageable steps, allowing students to gradually build understanding and confidence. It encourages active student participation, immediate feedback and guided practice. Teachers receive dedicated training to implement the programme effectively and adapt it to their classes' needs. Lessons are designed to promote independent thinking while ensuring a supportive learning environment for all students.

**Results/impacts.** Since its introduction in Bulgaria in 2011, JUMP Math has reached over 24 000 children. Annually, around 2 000 students from 100 classes across 50 schools and kindergartens participate in the programme. More than 1 900 teachers have been trained in its

([133]) https://progresivno.org/.

methods ([134]). While national-level impact data remain limited, international evidence supports its effectiveness; for example, a study in Barcelona showed that 85 % of students improved their mathematics scores after one year of using the programme. In Bulgaria, JUMP Math has been credited with improving student confidence, motivation and interest in mathematics, while also equipping teachers with strategies for inclusive, engaging instruction ([135]).

Country-level research also shows that some Member States have **adopted STEM education standards that define expected teaching and learning practices and serve to incentivise schools to implement these innovative approaches**. In **Austria**, for example, the Ministry of Education launched the MINT *Gütesiegel* ([136]) (STEM Quality Seal) in 2016 as a nationwide quality framework and certification for schools excelling in STEM (see Box 15).

**Box 15. Good practice example: MINT *Gütesiegel* (STEM Quality Seal) – Austria**

**Approach.** The MINT *Gütesiegel* is a national STEM school certification initiative and quality label introduced by the Ministry of Education in 2016. The seal is awarded to schools that demonstrate high-quality STEM provision, with certification levels valid for three years.

**Objectives.** The aim of the seal is to provide clear criteria defining excellence in STEM education and incentivise schools to meet these standards. The framework aims to improve the quality of STEM teaching, promote interdisciplinary learning and align school programmes with industry and research needs. It also seeks to increase the visibility of STEM in schools and encourage continuous improvement through a recurring certification cycle.

**Target groups.** Schools at all levels (from kindergartens to upper-secondary and VET schools) can voluntarily participate.

**Activities.** Schools self-assess and apply for the seal by documenting their STEM activities against the framework's criteria (e.g. evidence of interdisciplinary projects, use of inquiry-based methods, partnerships with STEM industries or universities, initiatives to engage girls in STEM, etc.). Submissions are evaluated by a national jury. Qualifying schools receive certification and join a network for peer exchange. The programme operates in three-year cycles, after which schools can reapply, fostering an ethos of ongoing innovation.

**Results/impacts.** The MINT *Gütesiegel* has achieved a wide reach. As of 2023, over 690 schools (including kindergarten, primary, secondary and vocational institutions) have been awarded the seal. This indicates widespread adoption of the framework and integration of its criteria into everyday schooling. The initiative has built a nationwide community of practice – certified schools benefit from networking, best-practice sharing and increased public recognition.

Country-level mapping shows a growing trend across Europe towards dismantling the traditional disciplinary silos in STEM education. Increasingly, efforts are being made to connect core STEM subjects (e.g. natural sciences, mathematics, technology and engineering) with the arts, humanities and social sciences, reflecting a broader shift towards **integrated STEAM education**. Several countries have revised their core curricula to include cross-subject STEAM activities. While many such initiatives remain concentrated in non-formal

([134]) Institute for Progressive Education (Bulgaria), 'JUMP Math – innovative system for teaching mathematics in Bulgarian schools with students from vulnerable groups', Institute for Progressive Education website, 2023, accessed 29 July 2025, https://progresivno.org/jump-math/.

([135]) JUMP Math Canada, 'History & milestones of *JUMP Math'*, JUMP Math website, accessed 29 July 2025.

([136]) State Department for Education and Science (Austria), 'MINT Gütesiegel: Initiative zur Förderung innovativen Lernens in Mathematik, Informatik, Naturwissenschaft und Technik', MINT school website, 2025, accessed 29 July 2025, https://www.mintschule.at/.

education and are delivered by NGOs (as further discussed in subsequent sections), there are also notable examples of STEAM integration in formal education settings. In **Finland**, the 2014 core curriculum introduced phenomenon-based learning, enabling teachers to combine subjects, such as science, mathematics, economics, sociology, the humanities and arts, to explore real-world themes. Pilot and local-level STEAM initiatives have also been identified elsewhere. In **Slovenia**, Ledina High School (Gimnazija Ledina) in Ljubljana ([137]) stands out as a best-practice school in STEM education, particularly in chemistry and environmental science. The school engages students aged 15–19 in hands-on projects that link scientific inquiry with sustainability and the arts. A notable example is the award-winning Strip (photographic stories) project, which merged chemistry and artistic expression and won first place in a competition marking the 150th anniversary of the publication of Mendeleev's periodic table.

Emerging good practices from focus group discussions include innovation laboratories, makerspaces, STEAM integration through the arts, open schooling models and peer-led teacher networks. Participants also emphasised the importance of aligning whole-school STEM initiatives with broader EU frameworks, such as the forthcoming STEM competence framework and Teacher Agenda, to enhance coherence and sustainability at the national and regional levels ([138]).

### Assessment practices and innovations

Study findings indicate a **gradual shift in how STEM subjects are assessed** across Europe, reflecting broader educational transitions towards competence-based learning and transversal skills development. While traditional assessment methods, primarily focused on theoretical knowledge and factual recall, remain prevalent in many education systems, innovative practices observed across Member States feature examples of more holistic approaches. These include continuous and formative assessment practice, the integration of assessment formats that better capture students' problem-solving skills, project-based work and the applied understanding of STEM concepts.

Some of the novel assessment practices **emphasise interdisciplinary and competence-based learning** in STEM, which in turn drive innovation in assessment. In line with modern curricula that emphasise 21st-century skills, some European countries are reorienting assessments to measure competences – practical skills, problem-solving and the application of knowledge – rather than just the recall of content. In **Denmark**, a 2013 reform introduced a joint final exam for lower-secondary natural science subjects (biology, geography and physics/chemistry). The new format combines a cross-

([137]) https://www.ledina.si/.

([138]) Focus group on whole-school approach, March 2025; focus group on assessment, April 2025.

disciplinary oral exam with subject-specific computer-based tests. Throughout grades 7–9, students complete at least six interdisciplinary projects focused on problem-solving and practical application. Evaluation findings suggest increased student motivation, better learning outcomes and greater collaboration among teachers across disciplines ([139]) (see Box 16). **Poland**'s forthcoming integrated science curriculum for middle schools implies a future single exam covering multiple areas of science and assessing interdisciplinary competences.

**Box 16. Good practice example: joint science ninth-grade exam – Denmark**

**Approach.** The introduction of an interdisciplinary final exam in natural sciences at the end of lower secondary (ninth grade). This one **integrated exam**, covering physics/chemistry, biology and geography, replaced separate subject exams. The exam consists of a multidisciplinary **oral exam** based on a student project and **computer-based tests** in each science subject.

**Objectives.** By examining students on integrated sciences, the policy aims to break subject silos and emphasise the interconnectedness of scientific disciplines, thus encouraging cross-curricular learning and problem-solving skills in science. It also seeks to boost student engagement by using project-based learning as a core element of assessment.

**Target groups.** The exam is targeted at lower-secondary school students (approximately 15–16 years old).

**Activities.** During grades 7–9, students complete at least **six cross-disciplinary science projects** that involve applying biology, physics/chemistry and geography knowledge to real problems. For the exam, each student team draws a thematic scenario (e.g. the impact of climate change) and has to formulate a problem and investigative questions spanning all three sciences, which they then research and present orally. This oral exam (with experiments or demonstrations) is evaluated by teachers / external examiners. In addition, students sit brief computer-based tests in each science subject to individually validate core knowledge. Extensive teacher training and new curriculum guides accompanied the roll-out so that teachers could design interdisciplinary modules and coach students in project work.

**Results/impacts.** An evaluation of the joint exam format found **notable benefits**. Both students and teachers reported that the interdisciplinary project work improved learning: students felt they understood scientific concepts better and could make connections between fields. Teachers observed **higher motivation** and collaboration among students, and they themselves began coordinating more across subjects (e.g. aligning curricula so that a biology topic coincides with the relevant chemistry content). The new exam thus succeeded in changing classroom practices and student experiences in lower-secondary science.

However, the broader impact on STEM is mixed – the evaluation did **not find an increase in students choosing science in upper secondary** as a direct result. This suggests that, while the quality of science learning improved, other factors may also influence students' career choices.

Some recent examples show that **competence-based assessments are increasingly used not only for certification but also for guidance and diagnostic purposes**. A prime example can be found in **Belgium**'s Flemish Region. Introduced in 2013, the *Ijkingstoets* is a diagnostic positioning test for STEM university entrants (see details in Box 17 below). While not a graded exam, it evaluates incoming students' competences in mathematics and science and gives personalised feedback. Its purpose is to guide students towards addressing skill gaps before starting university.

**Box 17. Good practice example: positioning tests – Belgium (the Flemish Region)**

([139]) Rambøll, *Slutevaluering af den fælles prøve i fysik-kemi, biologi og geografi*, Ministry of Children and Education, Copenhagen, 2024.

**Approach.** A mandatory but non-selective positioning test was implemented for all incoming STEM higher education students in the Flemish Region. Known as the ***Ijkingstoets***, this is a diagnostic assessment of mathematics and science competences that prospective students must take before enrolling in many STEM bachelor's degree programmes. The test is standardised across Flemish universities and is taken after secondary school graduation (typically in the summer). Importantly, there is **no pass or fail:** students cannot be denied admission based on the score, but taking the test is compulsory for certain STEM fields.

**Objectives.** The primary aim is to guide students in their study choices and help them prepare for STEM higher education. In the Flemish Region's open-access system (any secondary school graduate can enrol in university), a challenge has been that students embark on STEM programmes unprepared and risk failing first year. The ***Ijkingstoets*** addresses this by giving students a clear sense of whether their level of competence in mathematics/science meets the expected standard for their chosen programme. It thus helps identify gaps early and encourages students to fill them (e.g. through remedial courses or self-study) before or during the first year. A broader objective is to reduce dropout rates in STEM higher education and improve **matching** between student abilities and programme demands, all without introducing an exclusionary entrance exam.

**Target groups.** The *Ijkingstoets* is for all prospective university students enrolling in STEM-related bachelor's degrees (e.g. engineering, sciences, mathematics, etc.) in the Flemish Region.

**Activities.** The ***Ijkingstoets*** is developed collaboratively by Flemish universities, ensuring alignment with first-year curricula. It usually consists of multiple-choice questions tailored to the discipline (e.g. an engineering test covers advanced mathematics, physics and applied problem-solving). Students receive detailed individual feedback: their scores are compared with the requirements of the programme and with peers' scores. For example, students might learn that they scored in the bottom quartile on calculus questions, signalling a need for improvement. Universities use the aggregated results to offer targeted bridging courses or tutoring in weak areas at the start of the academic year. Communication campaigns make it clear that the test is obligatory but **non-elitist**: its slogan could be 'measure to better prepare'. It does not aim to exclude. **By 2024, over** 10 000 students **were registering annually for positioning tests across various fields**.

**Results/impacts.** The ***Ijkingstoets*** system has shown promising results. Although the test does not block enrolment, studies found that the scores are predictive of first-year success and eventual diploma **attainment** in STEM programmes. This validates the test's content and the notion that it measures relevant competences. As an impact, many students who perform poorly use the feedback to adjust: some undertake refresher courses over the summer, while others reconsider their study path (occasionally switching to a less mathematics-intensive field before they invest time and tuition). University data indicate a positive trend of **slightly improved first-year pass rates** in programmes where the test is mandatory, though it is too early to attribute causality. Importantly, student feedback on the *Ijkingstoets* is positive: participants perceive the test as fair and useful for understanding their own level of competence. This acceptance is crucial for its continued implementation ([140]).

There is a growing emphasis on **formative assessment methods in STEM education**. Rather than relying only on high-stakes exams at the end of a course, many instruments promote ongoing evaluation that supports learning (this is known as assessment for learning). This shift is often driven by the recognition that STEM competences (e.g. experimentation, design thinking and analytical reasoning) are best developed with iterative feedback. Several countries have

([140]) Vanderoost, J., Van Soom, C., Langie, G., Van den Bossche, J., Callens, R. et al., 'Engineering and science positioning tests in Flanders: Powerful predictors for study success?', in: *Proceedings of the 43rd Annual SEFI Conference, Orléans, 29 June–2 July 2015*, pp. 1–8; Vlaamse Interuniversitaire Raad, *Slotevaluatierapport verplichte deelname aan de ijkingstoets voor burgerlijk ingenieur en burgerlijk ingenieur-architect 2018: Interpretatieve nota*, Leuven and Brussels, 2019, https://www.vlir.be/wp-content/uploads/2019/08/OW-en-KZ-Ijkingstoets-nota-Evaluatierapport-Interpretatieve-Nota-NaWG_Onderwijs.pdf.

made formative assessment an official component of national exams or qualifications.

In **Ireland**, the junior cycle (lower-secondary) reforms introduced two **classroom-based assessments** in 2015 ([141]), which are essentially project tasks undertaken in the second and third years of junior cycle. These are assessed by the students' own teachers using common rubrics, and the results (along with a response to a self-reflection task) are reported alongside the final exam grade. This innovation ensures that a student's investigative skills and ability to apply the scientific method are formally recognised, not just their performance on a written science exam. The change has been significant in Ireland's education system: it required developing new assessment guides for teachers and training them to reliably evaluate projects, representing a broader move towards blending **summative and formative** evaluation. Furthermore, Ireland implemented another incentive for continuous effort: students who take **higher-level mathematics** receive **25 bonus points** on their university entrance score if they score 40 % or above. This policy, introduced to encourage more students to challenge themselves in advanced mathematics, has shown positive results: there was an **increase** in higher-level mathematics participation from 2019 to 2021. These outcomes suggest that strategic changes in assessment weighting (in this case, an incentive in the scoring system) can influence student choices and address under-representation in key STEM areas.

Some countries are implementing more formative assessment practices in earlier grades to build STEM competences. While Malta, for instance, has traditionally relied on content-heavy summative exams, recent changes promote more frequent, low-stakes assessments throughout the school year. The Maltese reform introduced smaller, more frequent tests and problem-solving tasks in classroom assessments, aiming to reduce student stress and actively engage learners.

In addition to the emerging examples of more innovative assessment practices in the Member States, the cross-analysis also shows a **more general trend towards summative exit exams to raise proficiency in STEM-related disciplines in some countries**. One example is the introduction of mandatory exams in STEM subjects. In **Lithuania**, since 2016, students seeking state-funded higher education places have been required to pass the mathematics *matura* exam, except those entering arts programmes ([142]). From 2025, this requirement extends to all higher education applicants, whether for state-funded or non-state-funded places (except for those studying the arts). Consequently, mathematics *matura* exam results directly affect graduates' access to higher

([141]) Department of Education and Skills (Ireland), *A Framework for Junior Cycle*, Dublin, 2015, https://www.ncca.ie/media/3249/framework-for-junior-cycle-2015-en.pdf.

([142]) Minister of Education and Science of the Republic of Lithuania, Implementation of Article 70(4) of the Law on Education, adopted under the authority of the Seimas (TAD/082ba540412d11e59cf1cfda14b526c5), Vilnius, https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/082ba540412d11e59cf1cfda14b526c5/asr.

education in Lithuania. Similarly, from 2025/2026, **Latvia** mandates that students take at least one science subject exam (physics, chemistry or integrated science) as part of their centralised upper-secondary exams, and a successful result is required for university entry. To strengthen earlier diagnostics in STEM-related disciplines, countries like **Croatia** have introduced new exams at the **primary and secondary levels**. Croatia piloted national exams in grade 8 in 2023, expanding to grade 4 in 2024. These standardised tests in mathematics and other core subjects serve to monitor and benchmark student achievement in STEM-related disciplines and other areas. Notably, Croatia's primary school exams are descriptive and low-stakes – results do not affect student grades or high school admission. Instead, they function as a system-level instrument to identify learning gaps and inform improvements in curriculum and instruction.

The examples from Member States analysed in this section reveal that successful reforms in STEM curricula and teaching practices are underpinned by **several recurring factors** that enhance both the quality and the inclusivity of STEM education. These reforms and actions collectively reflect a shift away from traditional content-heavy instruction towards more applied, interdisciplinary and student-centred learning models.

- A key success factor is the integration of interdisciplinary and applied learning into national curricula. Reforms that encourage real-world, cross-subject exploration – such as Finland's Phenomenon-Based Learning (PhBL) or Poland's forthcoming integrated science curriculum – demonstrate the potential of project-based, inquiry-driven education to foster critical thinking and deepen student engagement. These approaches succeed in making STEM education more relevant and motivating, particularly when they connect theoretical knowledge to concrete societal or environmental challenges.
- Competence-based curricula and policy frameworks are another enabler of curricular innovation. Countries such as Germany, Ireland, Latvia and Romania have adopted national standards that define essential STEM-related knowledge, skills and attitudes, promoting pedagogies that prioritise problem-solving, collaboration and digital fluency. These frameworks provide both structure and flexibility, guiding educators while allowing adaptation to local contexts.
- Reforms are also more effective when accompanied by system-level support, including teacher training and collaborative interdisciplinary work planning to coordinate across subjects and align teaching strategies. Interventions like Denmark's interdisciplinary science exam or Austria's MINT *Gütesiegel* show that providing incentives for school-level innovation, coupled with structured guidance and peer networks, can accelerate the uptake of integrative teaching methods.
- Furthermore, alignment with labour market needs enhances the relevance and sustainability of curriculum reforms. The Dutch Technology Pact

stands out for bridging education and industry through curriculum updates, joint projects and early exposure to careers, ensuring that students acquire competences aligned with emerging economic sectors.

- Initiatives such as Bulgaria's JUMP Math programme underscore the importance of inclusive teaching methodologies that support all learners. Tackling barriers, like mathematics anxiety, through structured, low-stress pedagogy helps broaden access to STEM education and counteract early disengagement.
- Innovative STEM assessment practices often move beyond rote recall to emphasise real-world problem-solving, interdisciplinary learning and continuous feedback. Successful examples from across the EU – such as Denmark's integrated science exam, the Flemish Region's diagnostic *Ijkingstoets* and Ireland's project-based junior cycle tasks – highlight key factors: aligning assessment with 21st-century competences, combining formative and summative elements and providing actionable insights for both learners and educators. These approaches are often supported by teacher training, system-level reforms and strategic incentives, creating assessments that not only evaluate but also enhance STEM learning outcomes.

#### 5.1.3.2. School governance and infrastructure

Adequate basic infrastructure is a prerequisite for high-quality STEM education. Evidence stemming from cross-analysis of country reports and other data sources indicate that many Member States, especially those with historically under-resourced school facilities have invested heavily in upgrading **school buildings, utilities and learning spaces** in recent years. These efforts often leverage EU structural and recovery funds to renovate classrooms, improve heating/ventilation and expand capacity in rapidly growing topic areas, such as robotics.

Many countries – but primarily those in central, eastern and southern Europe – note ageing or inadequate facilities, especially in rural or disadvantaged areas, and have launched targeted investment programmes or initiatives to **renew and upgrade the school infrastructure, including laboratory equipment**. A common focus across these programmes has been the enhancement of digital and technological capacities in schools. This includes the provision of modern equipment, such as robotics kits, 3D printers and laboratory tools, and expanded access to ICT resources, like computer laboratories, tablets and educational software. Among recent initiatives, investment in ICT and robotics infrastructure has emerged as the most prevalent area of intervention. Countries such as Estonia, France, Italy, Poland and Portugal have made notable progress in modernising their schools with technologies that enable more hands-on, inquiry-based STEM learning.

- Poland's Future Labs ([143]) is a large-scale, state-funded initiative aimed at equipping all primary and comprehensive art schools with modern technical equipment to develop students' practical and future-oriented competences, including in STEM, as well as creativity, teamwork and problem-solving. With a budget of approximately PLN 1.2 billion, the programme has provided every primary school in the country with tools, such as 3D printers, supported by a centralised equipment catalogue ([144]) – a national list of pre-approved, standardised technological tools and learning resources curated by the Ministry of Education to ensure good quality, interoperability and cost efficiency. To further support implementation, the Mobile Future Labs initiative deploys 16 specially equipped buses across all the Polish regions, offering interactive workshops and hands-on learning opportunities. In the 2022/2023 school year alone, the mobile programme reached 2 077 schools, engaged around 125 000 students and delivered 17 000 hours of STEAM-based instruction. Together, these programmes have significantly enhanced Poland's school infrastructure and student engagement in technical education.
- Germany's *Digital Pakt Schule* (Digital Pact for Schools) ([145]), launched in 2019, is a five-year initiative, costing over EUR 5 billion, co-funded by federal and state governments to equip schools with high-quality digital technology (e.g. campus Wi-Fi, interactive displays, tablets). By 2025, this programme aimed to connect all 40 000+ schools and give students and teachers access to up-to-date devices and software, substantially improving the digital infrastructure for STEM learning.
- In Estonia, launched in 2012, the ProgeTiger national programme aimed to develop digital and STEM competences from pre-primary to upper-secondary education. It supports hands-on learning in programming, robotics and 3D modelling, while offering teacher training and funding for digital equipment. By 2021, 98 % of schools had joined. The initiative has produced 100 digital resources and funded over 1 100 tools. A 2023 evaluation confirmed its effectiveness, driven by strong government support and wide adoption (see Box 18 for more details).
- In Italy, the School 4.0 ([146]) programme, a part of the National Recovery and Resilience Plan, focuses on digital transformation, creating student-

([143]) Ministry of Education and Science (Poland) and GovTech Centre, 'Future Labs projects', Polish government website, https://www.gov.pl/web/future-labs.

([144]) Ministry of Education and Science (Poland) and GovTech Centre, 'Katalog wyposażenia' ['Equipment catalogue'], Polish government website, https://www.gov.pl/web/laboratoria/katalog-wyposazenia2.

([145]) https://www.digitalpaktschule.de/index.html.

([146]) *Piano Scuola 4.0: Innovative learning environments and digital STEM labs for Italian schools*, adopted by Decreto Ministeriale No 161 of 14 June 2022, Missione 4 – Componente 1 – Investimento 3.2, Brussels/Rome, 2022, https://pnrr.istruzione.it/wp-content/uploads/2022/07/PIANO_SCUOLA_4.0_VERSIONE_GRAFICA.pdf.

centred learning environments and enhancing teacher training. With an investment of EUR 2.1 billion, the programme aims to convert traditional classrooms into innovative learning environments and establish laboratories focused on future digital professions.

- Portugal's 2023/2024 Digital Education Laboratories programme ([147]) equipped secondary schools with advanced technology (e.g. 3D printers, STEM kits, renewable energy laboratories) to boost digital literacy and STEM integration. It aimed to install 1 300 laboratories nationwide, 1 for every 500 students, under the Secretariat-General for Education and Science's oversight.

**Box 18. Good practice example: ProgeTiger national programme – Estonia**

**Approach**. Launched in 2012, ProgeTiger is Estonia's flagship national initiative aimed at embedding digital competence and technological literacy throughout the education system, from the pre-primary to the upper-secondary level. It reflects a systemic approach to digital education, integrating teacher training, digital resources and infrastructure investment. The programme focuses on fostering essential 21st-century skills, problem-solving, creativity and critical thinking, through hands-on engagement with programming, robotics and 3D design.

**Objectives**. ProgeTiger seeks to equip all students with a strong foundation in digital literacy from an early age, ensuring that they are capable and confident users and creators of technology. Its goals are closely aligned with Estonia's broader education and digital strategies, promoting equity in access and preparing students for active participation in a digitally driven economy and society.

**Target groups**. The programme targets both students and teachers across all general educational levels, with particular emphasis on early years and pre-primary education. Recognising that teacher capacity is key to meaningful digital integration, ProgeTiger places professional development and educator support at the centre of its approach.

**Activities**. ProgeTiger offers extensive training and support for teachers to strengthen their digital pedagogical skills, backed by professional networks that promote the sharing of practices and resources. Schools receive funding to purchase robotics kits, coding tools and ICT equipment, and to develop or access curriculum-aligned digital teaching materials. Since 2014, the programme has supported the development of over 100 digital resources and the distribution of more than 1 100 technology kits. Digital competence has also been formally integrated into the national curriculum, including at the pre-primary level.

**Results/impacts**. ProgeTiger has had a wide-reaching and lasting impact. As of 2021, 98 % of general education schools and 99 % of pre-primary institutions were participating. The early integration of digital skills into the curriculum, especially at the pre-primary level, has helped build a strong foundation for lifelong digital learning. Schools report improved infrastructure and more engaging, hands-on STEM education. Teachers have gained confidence in using technology effectively, and students show increased digital fluency, creativity and problem-solving ability. A 2023 evaluation ([148]) confirmed the programme's strong relevance and effectiveness, with 90 % of experts endorsing its impact. Supported by stable government funding and institutional coordination, ProgeTiger stands out as a sustainable, scalable model

([147]) https://erte.dge.mec.pt/laboratorios-de-aprendizagem.

([148]) Õunapuu, T., Raun, M., Lauringson, D. and Vint, G., *ProgeTiigri programmi tegevuste tulemuslikkuse hindamine: toimitud Haridus- ja Noorteameti poolt*, LevelLab OÜ, commissioned by the Education and Youth Board, Tallinn, 2023, https://harno.ee/sites/default/files/documents/2023-08/ProgeTiigri%20l%C3%B5ppraport%202023.pdf.

for national digital educational reform and is widely regarded as a leading example internationally.

In some cases, recent national investments have been specifically targeted at improving **students' and teachers' access to digital technologies, such as laptops and tablets**. **Poland** has launched two major national initiatives, Laptops for Teachers ([149]) and Laptops for Students ([150]), to enhance digital infrastructure in schools and foster digital competences among educators and learners. The laptops for teachers initiative, implemented by the Ministry of Digitalisation, provides public school teachers with vouchers worth PLN 2 500 to purchase a laptop, with the option to upgrade by covering the price difference. This flexibility allows teachers to choose devices tailored to their professional needs, supporting more dynamic lesson delivery, effective curriculum implementation and the development of students' digital skills. Simultaneously, the laptops for students programme aims to equip every fourth-grade student in public and non-public primary schools with a free laptop to support learning and the development of digital competences. The initiative supports the distribution of approximately 400 000 laptops, with the first phase – launched in September 2023 – starting with 4 000 laptops.

In several countries, the support for STEM infrastructure and equipment have been integrated into broader support schemes that also address other STEM aspects (e.g. teacher training, curriculum development, informal/non-formal training). For example, in the **Netherlands**, the Strong Technical Education programme (*Sterk Techniekonderwijs*) ([151]), launched in 2018, provides comprehensive support to technical and vocational education, including significant investment in infrastructure. This includes funding for modern laboratories, up-to-date equipment and facility upgrades, alongside curriculum development with industry partners, teacher training and student engagement activities. Evaluations report modest growth in enrolment and the increased appeal of technical education, partly due to visible improvements in school infrastructure.

A notable emerging trend across several Member States is the **integration of STEM infrastructure development within broader strategic efforts to establish national, regional and local STEM centres**. These centres function as interconnected hubs that not only modernise physical learning environments but also foster systemic collaboration among key stakeholders, including schools, students, educators, higher education institutions, industry NGOs and local authorities. Sometimes supported by EU-level funding instruments such as the Recovery and Resilience Facility and Structural Funds, these initiatives reflect a

([149]) Ministry of Education and Science (Poland) and GovTech Centre, 'Laptop dla nauczyciela', Polish government website, 2023–2025, https://www.gov.pl/web/laptop-dla-nauczyciela.

([150]) Ministry of Education and Science (Poland) and GovTech Centre, 'Laptop dla ucznia programme – free distribution of laptops to fourth-grade pupils as part of the National Recovery Plan', Digital Skills website, https://laptopdlaucznia.gov.pl/.

([151]) https://www.sterktechniekonderwijs.nl/.

shift towards more holistic, ecosystem-based approaches to advancing STEM education and innovation capacity. This approach typically includes dedicated support for training educators to effectively utilise new technologies and facilities, alongside creating opportunities for students to engage with the infrastructure, often through non-formal and informal learning activities that complement the formal curriculum.

- **Croatia's** Regional Science Centres (RSCs) ([152]), launched under the local development and poverty reduction programme and funded by EUR 22.27 million from the European Economic Area and Norway grants, represent a comprehensive approach to strengthening STEM education through infrastructure and regional coordination. Inspired by the Norwegian model, the initiative established four centres in different regions, each serving as a hub that connects schools, students, teachers, universities and local stakeholders, including municipalities and NGOs. These centres support STEM learning by equipping schools with modern tools, offering teacher training and delivering extracurricular and community-based activities, such as science camps and workshops. Designed as inclusive, participatory learning spaces, Regional Science Centres aim to make STEM education more dynamic and hands-on, while addressing regional disparities by prioritising less developed areas.
- In **Lithuania**, the development of STEM infrastructure has been strategically embedded within a broader effort to build a coordinated national ecosystem for STEAM education. Following a 2015 government-commissioned study on international best practices, the Ministry of Education, Science and Sport launched the STEAM Centre initiative, a multilevel network of regional centres, co-funded by EU Structural Funds, municipalities and research institutions. Operational since 2021, the network currently comprises seven regional STEAM centres and three methodical centres in the country's largest cities. These centres serve as innovation hubs, offering modern laboratories in biology, chemistry, physics, engineering, information technology (IT) and robotics as well as specialised facilities tailored to regional economic profiles. The centres are designed to engage students in practical, inquiry-based learning and to strengthen links between schools, universities and industry. Importantly, teachers' professional development is a central component, with the centres offering accredited training programmes, workshops and in-service support, particularly in regions where such opportunities were previously limited. Activities span both formal and non-formal education, including support for science clubs, camps and curriculum-aligned laboratory sessions. The methodical centres also develop educational content and serve as national coordination points, linking Lithuania's

([152]) Ministry of Regional Development and European Union Funds (Croatia), 'Support to future bilateral collaborations for regional science centres in Croatia, Norway and Latvia', EEA grants website, 2024, https://eeagrants.hr/en/support-to-future-bilateral-collaborations-for-regional-science-centres-in-croatia-norway-and-latvia/.

STEAM efforts with international networks. Early evidence highlights strong engagement and growing impact: for instance, the Tauragė centre involved over 5 000 students and 1 000 teachers in one school year, while the Telšiai and Utena centres delivered thousands of research projects and training sessions. Stakeholders widely recognise the STEAM network as a strategic and effective investment in building regional STEM capacity, enhancing curriculum delivery and supporting teacher development at scale.

- In **Bulgaria**, the Building a School STEM Environment programme, launched in 2020 and funded by EUR 270 million from the National Recovery and Resilience Plan, aims to create a national STEM education ecosystem through infrastructure and pedagogical innovation. It includes one national and three regional STEM centres that develop and pilot teaching models and support equitable access, alongside the establishment of 2 200 school-level STEM centres by 2026. These centres feature robotics halls, digital laboratories and flexible learning spaces, promoting hands-on, technology-rich STEM education across all state and municipal schools. A key feature of the programme is combining the investment in STEM infrastructure with the training provided to educators on using the equipment (see Box 19).

Further to the examples above, the analysis shows that over the past 10 years other Member States have adopted similar schemes comprising the coordinated development of STEM centres (that embed STEM infrastructure development) and access into a wider ecosystem, providing opportunities for basic training and practical use of the equipment. These include **Germany**, **Latvia**, **Luxembourg**, **Austria**, **Romania**, **Slovakia**, **Finland** and **Sweden**.

**Box 19. Good practice example: Building a School STEM Environment programme – Bulgaria**

**Approach**. Launched in 2020 by the Ministry of Education and funded by EUR 270 million from the National Recovery and Resilience Plan, Bulgaria's **Building a School STEM Environment** programme is a transformative national initiative aimed at overhauling the physical and pedagogical landscape of STEM education. At its core, the programme seeks to establish modern, technology-rich environments that enable hands-on, student-centred learning in science, mathematics and technology. With a three-tiered model that includes national, regional and school-level centres, the programme positions infrastructure as a central driver of educational innovation and systemic change.

**Objectives**. The primary aim of the programme is to create a comprehensive STEM education ecosystem that supports inquiry, creativity and applied learning across Bulgaria's public school system. By embedding advanced STEM infrastructure into everyday teaching environments, the initiative is designed to make STEM learning more engaging and relevant, while also addressing equity gaps by providing all students, regardless of location or background, access to high-quality facilities. Importantly, the programme recognises that the success of new infrastructure depends on the capacity of teachers to use it effectively, and it therefore links physical transformation with professional development.

**Target groups**. The programme targets students and teachers in all state and municipal schools across Bulgaria. While the investment in infrastructure benefits all learners, particular attention is given to ensuring that vulnerable and underserved groups gain equal access to modern STEM education. Teachers are a key target group for capacity-building efforts, with

39 000 educators expected to be trained by 2027 to operate within and make full use of the new STEM environments.

**Activities**. The programme is building a nationwide network of STEM centres at three levels. At the top is the National STEM Centre, which serves as a hub for developing and testing integrated content, methodologies and tools. It is equipped with advanced laboratories and is also used to train elite student teams and educators. Three regional centres are being established as research-oriented environments that help distribute expertise and ensure inclusive access to innovative STEM education. Most significantly, at the school level, approximately 2 200 centres will have been rolled out across the country by 2026. These centres feature robotics halls, digital workshops, programming laboratories and reconfigurable learning spaces equipped with multifunctional furniture, adaptive lighting and specialised flooring. Funding is scaled according to school size, ensuring that all institutions, from small rural schools to large urban ones, can participate meaningfully. The programme is not only providing hardware and classroom modernisation but also investing in the full integration of these environments into the learning process by training teachers to use the new tools and spaces effectively. This dual focus ensures that infrastructure does not remain underutilised and that pedagogical practice evolves alongside physical transformation.

**Results/impacts**. As of 2023, over 250 school-level STEM centres had opened, with visible impact on the quality and appeal of STEM education. Stakeholder feedback highlights a marked increase in student interest in technical subjects, driven by the opportunity to engage in real-world, practice-oriented learning. The introduction of modern, flexible classrooms has helped shift teaching away from traditional lecture-based formats towards more collaborative, interactive approaches. The coupling of infrastructure investment with teacher training has proven critical. Educators are being equipped with not only new tools but also the confidence and knowledge to integrate those tools into daily instruction. This alignment is helping schools maximise the value of their new STEM environments and foster a culture of innovation in teaching and learning. While challenges remain, including the need for a more clearly defined STEM curriculum and broader dissemination of effective methodologies, the programme has laid a strong foundation for sustained improvement. It represents one of the most comprehensive infrastructure-focused educational reforms in the region and serves as a model for how physical transformation, when paired with educator empowerment, can drive meaningful change in STEM education.

The above examples show that some countries have moved beyond individual school upgrades to build ecosystem-based STEM centres that integrate infrastructure, teacher training and curricular innovation. These initiatives reveal that successful STEM infrastructure programmes share several features: alignment with national strategies, integration of professional development, sustained funding and attention to regional equity. They demonstrate that infrastructure investment, when coupled with pedagogical innovation and stakeholder collaboration, can be a powerful catalyst for improving STEM education outcomes at scale. The key enabler is investment in infrastructure as a pedagogical tool, rather than just a technical upgrade. Bulgaria's STEM environment programme (see also below as an example of a whole-school approach model) ties every investment in laboratories and equipment to structured teacher training, ensuring that new resources translate into improved learning outcomes. This dual focus allows even remote schools to benefit from high-quality STEM education.

#### 5.1.3.3. The whole-school approach in STEM education

The STEM centres highlighted in the previous section reflect a broader trend towards expanding instruments that foster cross-sectoral cooperation – among

schools, local authorities, universities, businesses, NGOs and museums – through a **whole-school approach** to STEM education. This approach involves the coordinated engagement of all stakeholders – students, educators, administrators, parents and community partners – to embed STEM principles throughout the school's culture, practices and partnerships. This includes integrating STEM topics across various subjects, promoting inquiry-based learning and establishing partnerships with external organisations to provide real-world contexts for STEM education. Such an approach aligns with the European Commission's emphasis on fostering excellence in STEM through collaborative frameworks that bridge education and industry sectors ([153]).

The whole-school approach is not a fixed model but rather a flexible framework that reflects how schools mobilise leadership, teaching practices, partnerships, infrastructure and values to make STEM relevant, inclusive and engaging. Its manifestation depends on the local context ([154]), governance structure and educational goals, as can be seen in the examples detailed in this section ([155]). Consequently, there is no single, universally accepted definition that captures the instruments that promote a whole-school approach to STEM education. However, emerging evidence points to a number of recurring characteristics that are typically present in implementations. These characteristics do not always appear in full or in the same configuration across contexts; rather, they form a flexible set of elements that can be adapted to local needs and systemic conditions.

- The key feature of the instruments related to the whole-school approach is that they often involve partnerships between schools and other stakeholders – such as industry, higher education and wider community actors (parents, researchers, local authorities, NGOs, museums, etc.) – as a means of enriching student experiences and aligning learning with real-world applications.
- Infrastructure and resources, including access to modern equipment and digital tools, play a foundational role in supporting these efforts. In particular, the abovementioned partnerships provide easier access to, sharing and development of the infrastructure that enriches STEM education.

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([153]) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A STEM Education Strategic Plan: skills for competitiveness and innovation, COM(2025) 89 final of 5 March 2025, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52025DC0089&qid=1773666053423.

([154]) Holmes, K., Mackenzie, E., Berger, N. and Walker, M., 'Linking K–12 STEM pedagogy to local contexts: A scoping review of benefits and limitations', *Frontiers in Education*, Vol. 6, 693808, 2021, https://doi.org/10.3389/feduc.2021.693808.

([155]) Mathie, R. G., 'A whole school approach: a synthesis of interconnected policy, practice, and research conceptualisations', in: Wals, A. E., Bjønness, B., Sinnes, A. and Eikeland, I. (eds), 'Whole school approaches to sustainability', *Sustainable Development Goals series*, Springer, Cham, 2024, pp. 9–13, https://doi.org/10.1007/978-3-031-56172-6_2.

- Analysis suggests that such approaches are commonly underpinned by integrated and interdisciplinary curricula, which help break down traditional subject silos and promote real-world problem-solving.
- Collaborative teaching practices and continuous professional development for educators are also critical, enabling teachers to work across disciplines and adopt innovative pedagogies. Active engagement and partnerships with universities very often function as a catalyst of these teacher training practices.
- Innovative curriculum development and teacher training are frequently driven by close collaboration between schools, universities and research institutions, ensuring that educators remain informed about the latest advancements in STEM education research and pedagogy.

These characteristics, which intersect and reinforce each other, are neither exhaustive nor prescriptive. Rather, they mirror varied European contexts, highlighting the importance of a systemic, coordinated approach to advancing STEM education at the school level. Indeed, many national and regional examples illustrate how multiple dimensions are enacted simultaneously, where partnerships and cooperation between schools and other local actors engender innovative teacher training, STEM curriculum development, exposure to real-life problem-solving, inclusiveness and other strategic goals.

### Regional and national STEM coordination hubs and centres

This multifaceted and context-specific nature of whole-school approaches is particularly evident in **regional and national STEM coordination hubs and centres** that act as multistakeholder coordination platforms. While these types of initiatives have already been partly addressed in this report in the context of the support for STEM infrastructure (see Section 5.1.3.2), they usually have much broader scopes and objectives. These centres are often based at universities or science museums and are explicitly designed to connect schools, teachers, researchers, businesses and other actors. These coordination hubs illustrate how national/regional centres can foster partnerships at multiple levels. They provide a formal structure for stakeholder collaboration. Whereas funding is usually provided by ministries or public grants, the implementation involves cross-sector governance. Several reports note that such centres help to standardise teacher training, adopt innovative STEM curricula practices and direct resources to targeted areas. In practice, these centres become focal points where schools, universities and companies co-design projects. By integrating at the regional or national level, these hubs ensure that all local schools can tap into expertise and infrastructure that individual teachers or schools could not achieve alone.

- For example, LUMA Centre Finland ([156]) is a university-linked network of five regional STEM centres. Each LUMA centre functions as a local STEM hub – offering after-school science clubs, laboratory visits, equipment loan services and teacher workshops – to promote hands-on STEM engagement (for more details, see Box 21 below). Similarly, Swedish science centres, coordinated by the Swedish Association of Science Centres, promote STEM engagement through interactive theme-based learning aligned with national education standards. With 20 certified centres attracting around 2 million visitors annually, including over 350 000 students and 20 000 teachers, they support both student learning and teachers' professional development. Initiatives like *Energijakten* link classroom learning to real-world contexts and actively foster gender inclusivity, particularly engaging girls. These centres also contribute to school development and curriculum implementation. Regulated state funding (10 % of revenue) helps ensure high-quality programming and strong partnerships.
- The *Engineering i Skolen* ([157]) (Engineering in Schools) programme in Denmark is a collaborative whole-school initiative that brings engineering principles into primary and lower-secondary STEM education. Launched in 2017 and supported by Engineer the Future, a national technology alliance comprising around 50 companies, educational institutions and interest groups, the programme is built on strong cross-sectoral cooperation. This alliance works to enhance technological and scientific literacy, improve young people's competences and help secure a skilled future workforce. A key feature of the programme is its strong cooperative foundation: it partners with municipalities to tailor implementation to local contexts and ensure sustainability.
- Germany's *MINTvernetzt* ([158]) is a national initiative in Germany aimed at fostering cooperation and innovation in STEM (*MINT*) education through a systemic networked approach. Funded by the Federal Ministry of Education and Research, it serves as a central platform connecting schools, civil-society organisations, educational institutions and businesses to strengthen STEM learning. The initiative promotes collaboration by supporting cross-sectoral partnerships, professional development for educators and the sharing of best practices and resources.
- The Millennium Schools programme ([159]) in Lithuania exemplifies a cooperative whole-school approach to enhancing STEM education by empowering municipalities to lead tailored improvements in local schools.

([156]) https://www.luma.fi/en/.

([157]) https://engineerthefuture.dk/.

([158]) https://www.mint-vernetzt.de/.

([159]) https://tukstantmeciomokyklos.lt/en/home/.

Launched in 2022, the programme integrates national goals with community-level decision-making, allowing municipalities to plan and implement investment in infrastructure, equipment, teacher training and educational activities that address specific needs. By fostering collaboration between local and national actors and embedding STEM development within broader school improvement strategies, the Millennium Schools programme strengthens local ownership, ensures more equitable access to resources and supports systemic upgrades across all schools. This decentralised model enhances educational quality and inclusiveness, while promoting sustained engagement with STEM across school communities (see Box 20).

**Box 20. Good practice example: Millennium Schools programme – Lithuania**

**Approach**. Launched in 2022 by Lithuania's Ministry of Education, Science and Sport and supported by the European Social Fund Agency, the **Millennium Schools programme** (**Tūkstantmečio mokyklų programa**) is a large-scale national initiative aimed at transforming school systems through decentralised planning, municipal empowerment and integrated investment in STEM education. Its core mission is to eliminate educational disparities and upgrade learning environments across all municipalities by 2030. The programme prioritises both physical modernisation and systemic change by supporting municipalities to lead school development based on local needs, while aligning with national strategic education objectives. Through infrastructure upgrades, STEM laboratories, professional development and school networking, the programme advances a whole-school and whole-system approach to equity and excellence.

**Objectives**. The programme's overarching aim is to create modern, inclusive and high-quality learning environments that support improved learning outcomes, particularly in STEM subjects. It seeks to reduce achievement gaps between schools and regions by strengthening local ownership and enabling tailored investment in infrastructure, tools and pedagogical capacity. The initiative also encourages municipalities to view their schools as interconnected systems, fostering collaboration and resource sharing across educational institutions.

**Target groups**. The Millennium Schools programme targets all Lithuanian municipalities, schools and learners, with particular emphasis on improving opportunities for students in under-resourced regions. School leaders and teaching staff are central to the programme's implementation, as their continuous professional development is a key lever for ensuring that investment in infrastructure and equipment leads to meaningful pedagogical change.

**Activities**. The programme supports five key investment areas: infrastructure renovation, acquisition of up-to-date STEM equipment and digital tools, continuous professional development for educators, enhanced access to educational resources and student-focused educational activities. A notable innovation of the programme is the decentralised model that empowers municipalities to plan and implement local strategies, including the development of school networks; shared STEM laboratories; and mechanisms to ensure access, such as transport and technical coordination. For example, municipalities can choose to pool STEM resources into specialised schools or distribute STEM laboratories across several institutions, supported by dedicated coordination and logistics. As of 2024, over 800 out of 1 154 planned actions under stream 1 ([160]) were completed or under way in 22 participating municipalities.

**Results/impacts**. Early monitoring shows promising results: average mathematics scores among 10th-graders rose significantly (from 23.8 in 2022 to 43.5 in 2023), and the reliance on

([160]) In Lithuania, the Millennium Schools programme has been implemented in two phases. Stream I (2023–2025) served as a pilot, involving 22 municipalities and 93 schools, focusing on testing new approaches in STEAM education, infrastructure upgrades and teacher capacity building. Stream II (2024–2026) expands the programme to 36 additional municipalities and 177 schools, scaling up the practices proven effective in stream I.

combined classes decreased, improving the quality of instruction. Stakeholder interviews highlight increased teacher engagement, improved infrastructure and strengthened school collaboration. An interim evaluation confirmed the programme's alignment with national education goals and its early effectiveness in fostering more equitable and higher-quality education. Despite challenges, such as teacher fatigue and inter-school competition, the Millennium Schools programme's strategic emphasis on municipal autonomy, school networking and alignment with Lithuania's broader STEM ecosystem marks it as a strong example of how coordinated investment and decentralised governance can drive systemic educational change ([161]).

**Box 21. Good practice example: LUMA centres – Finland**

**Approach**. Launched in 2013 and mandated by Finland's Ministry of Education and Culture, LUMA Centre Finland is a national STEM education network coordinated by 11 research universities. The network adopts a systemic and research-informed approach to improving STEM education at all levels, from early childhood to higher education, by integrating pedagogical research, teacher education, community engagement and national curriculum alignment. LUMA Centre Finland's strategy is anchored in long-term sustainability, institutional cooperation and community embedding, making it a model of structural rather than project-based reform. Its operations include research-driven teacher development, curriculum co-design, regional science hubs and inclusive outreach, all implemented through enduring partnerships among universities, schools, municipalities and other stakeholders.

**Objectives**. LUMA Centre Finland aims to raise the quality and appeal of STEM education by strengthening pedagogical capacity, improving curriculum relevance and building long-term collaboration between universities and school systems. A key objective is to ensure that pedagogical innovation not only is informed by research but becomes embedded in practice through teacher training, school leadership engagement and regional science centres.

**Target groups**. The programme targets learners from early childhood to secondary education, pre-service and in-service teachers, school communities and students' families. Special attention is given to equipping teachers at all stages of their careers with the tools to deliver engaging, evidence-based STEM education. The programme also supports principals, education administrators and the broader public through public science events and multilingual outreach, ensuring relevance across diverse contexts.

**Activities**. LUMA Centre Finland delivers a broad range of activities, including:

- the integration of STEM-focused modules in university-based teacher education programmes;
- project-based teacher training where future teachers design and deliver science learning experiences;
- in-service training for approximately 4 300 education professionals annually;
- the management of 13 regional science centres offering workshops, lending laboratories and equipment, and community events (e.g. Children's Saturdays);
- the development of curriculum-aligned teaching materials and publication of over 50 scientific articles per year.
- multi-year collaboration with 66 school communities to co-develop and test educational approaches embedded in local education systems.

**Results/impacts**. Between 2017 and 2020, LUMA Centre Finland reached over 600 000 people annually. Regional centres alone, like the Tampere LUMA centre, served 20 000

([161]) Ministry of Education, Science and Sport of the Republic of Lithuania and Visionary Analytics, *Implementation Progress Evaluation of the Millennium Schools' Programme – Summary of the final evaluation report*, Vilnius, 2025, https://smsm.lrv.lt/public/canonical/1740140546/6423/S%CCC%8CMSM_TU%CC%84M_galutine%CC%87s%20ataskaitos%20santrauka_EN.pdf.

participants in 2023. Evaluation evidence and interviews show that LUMA has successfully created a self-sustaining national system that builds local ownership while maintaining strong alignment with national strategies. Teachers, including kindergarten educators, have been central to the programme's impact, actively shaping local STEM practices through collaboration with university experts. The model is considered an example of best practice in systemic reform due to its integration of scientific research, curriculum development and professional learning. LUMA also represents Finland in EU-level cooperation (e.g. EU STEM Coalition), contributing to knowledge sharing and policy exchange across Europe.

### Partnerships between schools and industry/business organisations

While the above instruments illustrate whole-school approach schemes that integrate multiple objectives and features – such as teacher training, strengthening links between STEM education and research, infrastructure development and sharing, and support for informal and non-formal STEM learning – the country reports also highlight a growing trend towards more targeted whole-school approach initiatives with specific, focused features.

**Instruments promoting partnerships between schools and industry/business partners** are particularly relevant in the context of promoting STEM education. These instruments aim to expose students to authentic workplace contexts, support the development of practical and transversal skills, and encourage STEM-oriented career choices. Analysis across the Member States indicates that school–industry collaboration takes several forms. In many cases, industry professionals engage directly with students by mentoring them, delivering in-class sessions or hosting school visits at their premises. Work-based learning opportunities are also common, with secondary-level students participating in internships, company-led projects or integrated dual education formats. Businesses often support STEM events, acting as sponsors or active collaborators in national and regional competitions or STEM days. Additionally, some companies contribute equipment and technical expertise to schools, donating laboratory kits and software tools or taking part in hands-on activities, such as hackathons and maker fairs. These initiatives frequently target lower- and upper-secondary students, aiming to build motivation and clarify future study or career paths. Some programmes also involve STEM teachers, providing them with technical upskilling via industry placements or joint pedagogical design.

Countries such as Belgium, Germany, the Netherlands and Sweden provide examples of schemes that help students gain real-world exposure to STEM careers and work contexts, while also aligning STEM teaching, learning practices and curricula with labour market needs.

- In the Flemish Region, Regional Technological Centres ([162]) exemplify this approach through their exclusive focus on technical and vocational

([162]) RTC Oost-Vlaanderen, 'Regional Technological Centre of East Flanders: Strengthening STEM competences in technical and vocational secondary education through teacher training, project support, and innovation labs', RTC Oost-Vlaanderen website, 2025, https://www.rtcoostvlaanderen.be/.

education. Each Flemish province hosts a Regional Technical Centre, which acts as a bridge between schools and companies to strengthen the STEM competences of both students and teachers. The 2023 annual report from the East Flanders Regional Technical Centre illustrates strong engagement with the regional school network, with 64 % of the targeted schools participating in 53 initiatives delivered over the year. Remarkably, 87 % of these activities were implemented in collaboration with industry partners or sector federations, underlining the clear emphasis on aligning education with practical labour market needs.

- A similar philosophy underpins the Jet-Net initiative ([163]) in the Netherlands. Launched in 2002 in response to growing shortages of university-trained technologists, Jet-Net connects secondary schools with leading technology companies, enabling students to encounter real-world technological applications through site visits, workshops, guest lectures and career events. By offering industry-informed teaching materials and supporting educators, Jet-Net not only enhances STEM teaching but also makes scientific and technological career paths more tangible for and appealing to students. The initiative has been praised for its strategic alignment between education and economic needs and has received recognition at the European level ([164]) as a best practice example of business–education collaboration (see Box 22).
- Sweden's *Teknikcollege* initiative ([165]), coordinated by the Swedish Industry Council (Industrirådet), offers another strong example of aligning education with labour market needs through structured regional cooperation. The initiative connects over 170 schools with 3 000 companies across 24 certified regions and promotes STEM engagement by offering industry-certified training grounded in quality criteria. According to its 2023 activity report, *Teknikcollege* not only strengthens vocational pathways but also promotes diversity, with targeted programmes for young women, such as mentorships and summer schools. Certification ensures alignment with labour market needs, and strong local partnerships enable students to develop practical skills through real-world projects and internships.

([163]) https://jet-net.nl/jet-net-technet-en/.

([164]) https://jet-net.nl/jet-net-technet-en/.

([165]) https://www.teknikcollege.se/.

- Austria's vocational schools ([166]) similarly integrate schools and industry through their dual education model (*duale Ausbildung*). Students combine formal instruction in vocational schools with extensive on-the-job training in companies, often in high-demand sectors such as robotics, renewable energy, electronics and IT. Technical secondary schools further strengthen this system by embedding project-based collaboration with private sector firms directly into the curriculum. Around 80 % of students' training occurs in real workplace settings, ensuring they develop relevant and transferable skills while fostering career readiness. This model has proven particularly effective in providing equitable pathways to STEM professions for students not pursuing traditional academic routes, and it supports career progression through further vocational or tertiary studies. By designing curricula in close cooperation with industry partners, Austria's dual and technical school systems demonstrate how institutionalised collaboration can ensure STEM education remains responsive, applied and aligned with evolving economic demands ([167]).
- In Germany, the decentralised *MINT-Regionen* (STEM regions) initiative plays a vital role in embedding STEM within local contexts. With over 150 regional networks active across 16 federal states ([168]), *MINT-Regionen* fosters partnerships between schools, businesses, associations and providers of early years education. These networks offer students practical, hands-on experiences through workshops, mentorships, extracurricular laboratories and career orientation programmes. Importantly, they address disparities by tailoring support to local needs, promoting gender inclusion and creating structured pipelines to STEM careers. According to the Körber Foundation's 2019 report, most networks prioritise workforce development and career guidance, with over 70 % operating student laboratories or similar facilities ([169]).

**Box 22. Good practice example: Katapult programme – Netherlands**

**Approach**. Launched by Platform Talent voor Technologie, the **Katapult programme** ([170]) is a national initiative in the Netherlands designed to strengthen the alignment between education

([166]) Federal Ministry for Economy, Energy and Tourism (Austria), 'Apprenticeships and vocational training', Federal Ministry for Economy, Energy and Tourism website, 2025, https://www.bmaw.gv.at/en/Topics/Vocational-Training-and-Skills/Apprenticeshipsandvocationaltraining.html; Federal Ministry Economy, Energy and Tourism (Austria), 'Dual vocational training and skills in Austria', Federal Ministry for Economy, Energy and Tourism website, 2025, https://www.bmaw.gv.at/en/Topics/Vocational-Training-and-Skills.html.

([167]) Agency for Education and Internationalisation (Austria), 'The education system', Agency for Education and Internationalisation website, https://bildungssystem.oead.at/en/.

([168]) https://www.mint-regionen.de/.

([169]) Körber Foundation, *Auf dem Weg zur MINT-Region: Kurzleitfaden zur Gründung eines regionalen Netzwerks für MINT-Bildung*, Hamburg/Berlin, 2019.

([170]) https://www.wijzijnkatapult.nl/.

and the labour market through structured public–private partnerships. The programme fosters sustainable collaboration between educational institutions and the business sector, particularly in technical and vocational education. Central to Katapult's model are **centres of expertise** and **learning communities**, where students, teachers and industry professionals co-develop solutions to real-world challenges. These spaces serve as innovation hubs that blend education, applied research and workforce development.

**Objectives.** *Katapult*'s main objective is to close the gap between the evolving demands of the labour market and the content and delivery of vocational and professional education. The programme aims to ensure that curricula are responsive to technological advances and regional economic needs, while also enhancing the relevance of learning for students. A secondary objective is to stimulate regional innovation ecosystems by anchoring education institutions more deeply within local business networks.

**Target groups.** The programme targets a broad range of stakeholders, including students in vocational and applied higher education, teachers and educators, and companies, particularly in technical fields. Teachers benefit from professional development supported by industry partners, while companies contribute expertise, resources and work-based learning opportunities.

**Activities.** *Katapult* supports the development of **over 450 public–private partnerships**, encompassing **more than 12 000 companies**, **124 000 students** and **9 000 educators**. Activities include co-creation of curriculum content, student internships, teacher placements in industry and collaborative research projects. Centres of expertise provide platforms where industry and education co-develop training materials, organise innovation workshops and conduct applied research relevant to both parties. The programme also promotes mutual learning through national networks and facilitates the exchange of best practices across sectors and regions.

**Results/impacts**. *Katapult* has demonstrated a measurable impact on educational quality, employability and regional innovation. Independent evaluations ([171]) show that students involved in public–private partnerships under *Katapult* gain relevant, hands-on experience and are better prepared for careers in technical fields. Educators report improved understanding of current industry trends, which translates into more effective teaching. The partnerships also support regional economic development, helping businesses address skill shortages and innovate more rapidly. The programme has fostered a **culture of structural cooperation**, where knowledge exchange between education and industry is institutionalised rather than project-based. This sustainable model of partnership has become a cornerstone of the Dutch approach to workforce and innovation policy and serves as a reference for other Member States seeking to integrate vocational education with economic development.

## Teacher-oriented whole-school approaches

Another type of **whole-school-approach-related instrument involves schemes where the key feature is teacher empowerment**, based on the idea that teachers are the primary drivers of change, through local community engagement. While these schemes often include support for teachers' continuous professional development (CPD) (for more details on teacher-oriented schemes, see the next subsection), they frequently go further by embedding teacher training within collaborative networks and partnerships. A common approach is to form local or thematic school networks that promote collaboration, typically between schools and universities but sometimes also involving other stakeholders, such as government bodies or teachers' associations. In some cases, in these school-based networks, municipalities provide venues and subsidies, while non-profits and universities contribute

([171]) https://www.wijzijnkatapult.nl/.

expertise or materials. This ensures that STEM education planning transcends individual classrooms or schools and that teaching practices are embedded within wider community strategies and knowledge systems.

- The Teacher Education Forum (2024–2027) is a national initiative in Finland aimed at strengthening and innovating teacher education in line with the Teacher Education Development Programme and the Finnish National STEM Strategy. Coordinated by the University of Helsinki and funded by the Ministry of Education and Culture, the forum brings together a wide range of stakeholders, including universities, applied science institutions, government bodies, educator associations, LUMA Centre Finland and others. The Teacher Education Forum has significantly improved **dialogue, coherence and collaboration** across Finland's teacher education ecosystem. According to evaluations, the forum has enabled higher education institutions to align their strategies more closely with national priorities, particularly in integrating **STEM-focused pedagogies** and digital competences. It has also established more **systematic and enduring structures for stakeholder cooperation**, allowing for continuous exchange between researchers, educators and policymakers.
- Latvia offers a strong example of how collaborative leadership can drive meaningful change in education, particularly through the *Skola2030* competence-based reform. By giving schools and teachers more autonomy, this reform has encouraged innovation from the ground up. In physics education, this has led to a successful model where teachers, researchers and university students work together to develop and test new teaching methods. Their collaboration has produced a comprehensive set of 245 lesson plans, laboratory guides and support materials, now freely available online. Key organisations, like the Latvian Physics and Science Association, have played a crucial role in coordinating these efforts, ensuring both high quality and long-term sustainability.
- France's *La main à la pâte* network of classes and laboratories ([172]) connect clusters of primary schools with a central university team. These networks function as regional hubs of excellence; **university professors and inspectors train local teachers** and support them in piloting inquiry-based science lessons (for more details, see Box 23).

**Box 23. Good practice example: *La Fondation La Main à la Pâte* – France**

**Approach.** *La Fondation La Main à la Pâte*, founded in 1995 by the Nobel laureate Georges Charpak, is a nationally recognised French initiative dedicated to transforming science and technology education in primary and secondary schools. Drawing inspiration from US hands-on learning models, the foundation serves as a long-standing laboratory of pedagogical innovation. It supports teachers through classroom resources, multimedia training and sustained professional development, promoting science education that is inquiry based, interdisciplinary

([172]) https://fondation-lamap.org/.

and connected to real-world societal issues. The foundation operates through a decentralised, cooperative network structure, engaging local actors, academic institutions and industry experts, to address schools' specific needs and foster bottom-up improvement.

**Objectives.** The primary aim is to enhance the quality and attractiveness of STEM education by equipping teachers with the tools, knowledge and partnerships needed to deliver engaging, inquiry-driven lessons. By embedding scientific practices into classrooms and fostering collaboration with the research and business sectors, the initiative works to demystify science, boost students' motivation and improve teaching capacity, especially in under-resourced or remote schools.

**Target groups.** The programme primarily targets primary and lower-secondary teachers and school leaders, with additional benefits for school students, university science students and professional researchers. Special focus is given to teachers in rural or priority education zones, where support for science teaching is often limited.

**Activities.** *La Fondation La Main à la Pâte* operates through several flagship initiatives.

- Science Partners for the Classroom places university science students in primary classrooms to assist teachers and model inquiry-based instruction. It provides both pedagogical support and exposure to scientific thinking ([173]).
- Maisons pour la science (Houses for Science), 12 regional centres based at universities, offer structured, research-informed professional development, pilot school networks and co-designed classroom projects with engineers, researchers and educators.
- Collèges La main à la pâte foster cross-sectoral collaboration in lower-secondary schools, involving laboratories, companies and teachers in interdisciplinary, project-based learning.

**Results/impacts.** The foundation has established itself as one of France's most respected STEM education actors. Between 2011 and 2015, 3 300 classrooms were supported by the Science Partners initiative; in 2022–2023 alone, 1 250 classrooms participated. The programme is highly regarded for reducing teacher isolation and improving confidence in delivering experimental science. As of 2025, the foundation annually supported around 725 000 students (approximately 6 % of French schoolchildren) and 8 200 teachers through its science centres ([174]). According to evaluations, 97 % of participating teachers would recommend the training, and 88 % plan to apply it in their teaching.

A randomised impact evaluation found short-term gains in student motivation through inquiry-based practices. However, the positive effects diminished over time without continued teacher support, highlighting the importance of sustained engagement and structural alignment. The evaluation also pointed to difficulties in scaling up hands-on approaches across curricula. Despite these challenges, the foundation's model demonstrates that deep institutional cooperation, embedded professional development and localised support can catalyse meaningful change in science education ([175]).

([173]) Cavaillès, A., Julien, S., Minault, B., Moreau-Fauvarque, C., Paitel, E. et al., *La sensibilisation et la formation à la démarche scientifique de l'école élémentaire au doctorat*, IGÉSR Rapport No 21-22-099A, General Inspectorate of Education, Youth and Sports, Paris, 2023.

([174]) Michelin Corporate Foundation, 'Awakening the scientific spirit in young people', Michelin Corporate Foundation website, 16 May 2025, https://fondation.michelin.com/en/awakening-the-scientific-spirit-in-young-people.

([175]) Académie des sciences and Académie des technologies, *Science et technologie à l'école primaire: un enjeu décisif pour l'avenir des futurs citoyens – Rapport de l'Académie des sciences et de l'Académie des technologies sur la pratique et la formation en sciences et technologie des professeurs de l'école primaire*, Paris, 2020, https://www.academie-sciences.fr/pdf/rapport/202011_science_techno_ecole_primaire.pdf.

### Challenge-driven whole-school approaches

Country-level mapping of STEM-oriented instruments across the EU-27 reveals the emergence of **whole-school approaches, focusing on specific challenges**. These initiatives are based on the assumption that complex issues – such as inclusion, gender equality and sustainability – are more effectivelyaddressedas part of STEM education when grounded in local contexts and supported by diverse community actors. Key features of these whole-school-approach-based instruments include collaboration with networks of academic institutions, industry, NGOs and other local stakeholders to complement and extend the capacity of schools. Several examples show how whole-school-approach-based instruments can address cross-cutting challenges by linking schools with external expertise and resources.

- In Malta, the National STEM Community Fund ([176]), managed by Esplora and Xjenza Malta, offers annual grants for community-led STEM initiatives. Schools, NGOs and local councils co-develop projects with STEM professionals to ensure both educational relevance and scientific rigour. Examples include biodiversity-focused school gardens, inclusive environmental mapping and gender equity campaigns in engineering. The fund strengthens ties between schools and local communities, encouraging more context-responsive STEM learning.
- In Slovakia, Aj Ty v IT  (You too in IT) ([177]) supports female participation in ICT through coding workshops, mentoring and summer schools targeting students and adult learners. Operating nationwide since 2012, the programme works with schools, companies and international partners to deliver practical training and promote gender-inclusive pathways into technology fields. Thousands of participants have taken part, and the initiative continues to support broader awareness and institutional collaboration around gender equity in STEM.

Based on the rich set of examples provided, several **key success factors** can be identified for effective whole-school-approach-based instruments that promote STEM education in schools. These factors are not stand-alone but function as interconnected pillars that reinforce each other in practice.

- A key success factor is the **integration of multistakeholder partnerships**. Programmes like Lithuania's Millennium Schools and Finland's LUMA Centre show how structured collaboration between municipalities, universities and industry creates a dynamic ecosystem that supports schools with infrastructure, expertise and pedagogical support. These partnerships not only enable access to cutting-edge equipment but

([176]) Esplora Interactive Science Centre, 'The National STEM Community Fund 2024 – Introduction and applications (call now closed)', Esplora website, 2024, https://esplora.org.mt/the-national-stem-community-fund-2024-introduction-and-applications-call-now-open/.

([177]) https://ajtyvit.sk/.

also contextualise learning in real-world applications, strengthening relevance and motivation.

- Equally important is the **empowerment of teachers as agents of change**. Initiatives such as France's *La main à la pâte* and the Finnish Teacher Education Forum embed professional development within collaborative networks, ensuring that educators are equipped to adopt innovative, inquiry-based methods. These efforts go beyond conventional training by linking teachers directly with researchers and practitioners, enabling sustained pedagogical transformation.
- Notably, effective whole-school-approach initiatives are often **decentralised in implementation but centrally coordinated**. Lithuania's model empowers municipalities to design local solutions within a coherent national strategy, improving equity and responsiveness while maintaining quality standards. This balance between autonomy and alignment is key to reaching underserved areas.
- Sustainability and impact also depend on **institutional anchoring and long-term policy support**. Programmes like LUMA Centre Finland and the *Katapult* network in the Netherlands are embedded in broader education and innovation strategies, allowing for continuity, scaling-up and systemic reform beyond short-term funding cycles.

#### 5.1.3.4. STEM teacher recruitment, professional development and support

As was emphasised in Section 5.1.2.4 above, many Member States experience challenges related to teacher recruitment, professional development and support that are particularly pertinent in STEM. An ageing teacher workforce, chronic shortages of STEM teachers, the need to attract and prepare new talent, the importance of ongoing professional growth and the value of peer support and networking are common challenges that require systemic and targeted measures.

Across the EU-27, Member States have introduced a range of instruments to support STEM teachers at all stages of their careers and to respond to common challenges. This section analyses four main types of teacher-oriented instruments found in country reports, highlighting key trends, the diversity of approaches and commonalities among countries, namely:

- schemes addressing teacher shortages, recruitment and retention – initiatives to attract new STEM teachers and keep them in the profession,
- Initial teacher education and training (ITE) – reforms and programmes in the pre-service preparation of STEM teachers,
- Continuous professional development (CPD) – structured in-service training programmes to enhance STEM teaching skills,

- support services and networks for STEM teachers – communities of practice, resource centres and online platforms that facilitate peer learning and support.

### Instruments to address shortages of (STEM) teachers

The most direct responses to STEM teacher shortages involve **mechanisms to attract and retain qualified teachers** in mathematics, physics, chemistry, ICT and other related disciplines. These instruments typically reflect labour market urgency rather than educational reform. However, their design often intersects with broader workforce planning and career development strategies. The primary policy logic is to provide additional incentives for young people to choose this professional path and to expand entry pathways into teaching while ensuring adequate preparation.

Several analysed Member States provide examples of schemes that support fast-track or alternative pathways into (STEM) teaching. Though very often not exclusively focusing on STEM, this type of schemes is often particularly relevant in addressing mathematics and natural science teacher shortages, which are the most pressing in many countries.

- In **Lithuania**, the I Choose to Teach! ([178]) programme recruits motivated graduates into two-year teaching placements, offering intensive training and continuous support. It has proven effective in addressing teacher shortages, particularly in STEM, while also contributing to school improvement and changing perceptions of the teaching profession (see Box 24).
- In **Croatia**, the Scientific (STEM/STEAM) Education from Early Childhood programme aims not only to nurture scientific curiosity and 21st-century skills from a young age but also to address shortages of STEM educators at lower education levels by training teachers without formal STEM backgrounds and introducing modern, interdisciplinary teaching methods ([179]).
- **Poland** supports teachers to acquire additional qualifications, including postgraduate studies enabling them to teach a second subject (e.g. qualifying a mathematics teacher to teach physics), alongside targeted

([178]) https://www.renkuosimokyti.lt/.

([179]) University of Zagreb, Faculty of Science, 'HFD STEAM: Znanstveno (STEM/STEaM) edukacijski program za djecu, nastavnike i odgajatelje od vrtića do srednjih škola', University of Zagreb, Faculty of Science website, https://www.pmf.unizg.hr/phy/hfd-steam/. The programme was launched in 2018 and has been coordinated nationally by Fizikalno društvo – Split since 2021.

workshops and training initiatives run by universities and foundations, such as the Wawelberg Foundation ([180]) and STEAM Polska ([181]).

**Box 24. Good practice example: I Choose to Teach! (*Renkuosi mokyti!*) – Lithuania**

**Approach**. I Choose to Teach! is a national education initiative launched in Lithuania in 2008 with the goal of bringing motivated and creative graduates into the teaching profession. It offers an alternative pathway into teaching that combines intensive training with practical classroom experience. The programme focuses on introducing innovative, student-centred teaching methods, and aims to foster a new generation of educators who can contribute to positive change within the education system.

**Objectives**. The programme seeks to address persistent teacher shortages in Lithuania, particularly in STEM subjects, while ensuring that every child, regardless of social or economic background, has the opportunity to succeed in school. Beyond simply filling vacancies, it aims to promote inclusive and high-quality education, support school-level transformation and elevate the teaching profession to have a social impact and drive progress.

**Target groups**. The initiative targets recent university graduates and young professionals who demonstrate a commitment to education and social equity. It also serves schools that are in need of fresh perspectives and motivated teachers, especially those serving diverse or disadvantaged student populations.

**Activities**. Each year, between 20 and 30 participants are selected to join the programme and commit to teaching in schools for two years. Before entering the classroom, participants undergo an intensive summer training course that equips them with pedagogical and psychological knowledge. During their two-year teaching period, they receive ongoing support through professional mentoring and additional training opportunities. Many participants also lead school transformation projects aimed at improving teaching practices, student engagement and the overall learning environment.

**Results/impacts**. By 2023, the programme had produced around 300 alumni, newly qualified teachers who had completed the two-year commitment. On average, 75 % of participants continue working in the education sector, either as teachers or in related roles, after completing the programme. Evaluation findings ([182]) show that the initiative has had a meaningful impact not only on staffing but also on student outcomes. Students **demonstrated** notable improvements in their social and emotional development, particularly in communication and interpersonal skills. Parents observed a stronger focus on inclusive education, and teachers reported positive changes in school culture. Over time, I Choose to Teach! has expanded its influence by building an active alumni network that continues to advocate better education policies and practices. By empowering teachers as change-makers, the programme has significantly contributed to a more dynamic, equitable and forward-thinking education system in Lithuania.

In a few countries, **financial incentives and career advancement measures have been introduced to increase the attractiveness of STEM teaching**, particularly in regions with acute shortages. For instance, the Croatian employment service regularly identifies critical gaps in the supply of mathematics, computer science and physics teachers ([183]). To address this, Croatia's Ministry

([180]) Wawelberg Foundation, 'Science teachers', Wawelberg Foundation website, https://wawelberg.org/nauczyciele-przedmiotow-scislych/.

([181]) https://www.steampolska.org/.

([182]) Agnelli Foundation, *Highlighted research from across the Teach For All network*, Turin, 2022, https://www.fondazioneagnelli.it/wp-content/uploads/2023/10/highlighted_research_of_the_teach_for_all_network_march_2022.pdf.

([183]) Croatian Employment Service, *Preporuke za obrazovnu upisnu politiku i politiku stipendiranja za 2025. godinu* [*Recommendations for education enrolment and scholarship policy, 2025*], Zagreb, 2024.

of Education has proposed a range of solutions and in 2022, under its Recovery and Resilience Plan , introduced new scholarships for students pursuing STEM teaching careers. These scholarships – offering EUR 600 per month, twice the amount of non-teaching STEM scholarships – are conditional on graduates committing to work as STEM teachers in their regions, thereby also tackling territorial disparities ([184]). Bulgaria has also implemented measures to attract future teachers through tuition fee exemptions and scholarship schemes for education students. These efforts have contributed to a 31 % increase in enrolment in bachelor's programmes in education between 2019 and 2024. However, despite this progress, challenges remain, as many graduates do not ultimately enter or remain in the teaching profession ([185]).

### STEM teachers' initial teacher education and training

As the demand for well-prepared STEM teachers continues to grow, **initial teacher training** (ITE) has increasingly come into focus, not just as a pipeline for recruitment but as a key lever for reform. Effective ITE must strike a balance between cultivating deep subject knowledge and developing the pedagogical agility required to engage diverse learners in inquiry-based, digitally enriched and socially relevant STEM education.

While continuous professional development (CPD) initiatives are widespread across Europe, offering innovative pathways for in-service STEM teachers to enhance their competences, there are **fewer examples of innovative or systemic reforms in ITE**, especially those that integrate cutting-edge STEM content, interdisciplinary approaches and practical classroom readiness from the outset. Furthermore, the few existing examples from Member States refer to university-level initiatives and not efforts to reform ITE at the system level.

- One such example is the master of science in STEM teaching course at the University of Copenhagen ([186]), developed in partnership with the University of Southern Denmark. This part-time programme is tailored to educators seeking to strengthen their practice across STEM subjects. Its hybrid design, combining online coursework with in-person sessions, allows for professional flexibility, while its curriculum focuses on linking scientific content with contemporary societal issues, such as sustainability and gene technology. In doing so, the programme not only enhances

([184]) Office for Gender Equality of the government of the Republic of Croatia, *Comprehensive National-level Review: The Republic of Croatia*, UN Women website, 2024, https://www.unwomen.org/sites/default/files/2024-09/b30_report_croatia_en.pdf.

([185]) European Commission: Directorate-General for Education, Youth, Sport and Culture, *Education and training monitor 2024 – Bulgaria*, Publications Office of the European Union, 2024, https://data.europa.eu/doi/10.2766/058373.

([186]) The University of Copenhagen launched its master of science degree in STEM teaching in 2024. The course is offered in collaboration with the University of Southern Denmark and is delivered in Danish and online.

individual teaching capacity but also enables participants to contribute to broader educational initiatives within schools or municipalities.

- Across the 39 public universities offering primary teacher degrees in Spain, interdisciplinary and contextual approaches to science and mathematics are becoming more common. However, only one institution, the University of Lleida, offers a dedicated STEM track within its primary education programme ([187]).

**Box 25. Good practice example: the natural science – environmental studies teacher training – Hungary**

**Approach.** The natural science – environmental studies teacher training, known as the **Z Study programme**, is an innovative initiative launched in 2013 in Hungary to modernise science education through interdisciplinary and sustainability-focused teacher training. Coordinated by Eötvös Loránd University in collaboration with seven other universities, it replaces traditional dual-subject science teacher education with an integrated model that blends scientific knowledge with creative pedagogy and ecological awareness.

**Objectives.** The programme aims to prepare future teachers to deliver engaging, inquiry-based STEM education in grades 5–8 and in vocational secondary education (grades 9–12). It addresses Hungary's need for modern, adaptable science educators by equipping them with interdisciplinary knowledge, a sustainability mindset and skills for innovative and inclusive teaching.

**Target groups.** The programme targets prospective science teachers, including students with backgrounds in both the humanities and sciences, with the goal of making STEM education more accessible, creative and applicable to real-world contexts.

**Activities.** The curriculum is divided into three core components: 60 % is dedicated to natural sciences (biology, chemistry and physics), 30 % to developing visual communication and creative knowledge transfer skills and 10 % to pedagogy and psychology, including teamwork and problem-solving. The programme also incorporates extensive fieldwork and practical exercises to ensure real-world application and active learning. By integrating subjects such as geography, pedagogy and visual communication, the programme promotes holistic, cross-disciplinary teaching strategies.

**Results/impacts.** By 2023, over 200 graduates had completed the programme, many of whom are actively contributing to STEM education reform in Hungary. The Z Study programme has received recognition for fostering sustainability and innovation in science education and has influenced the development of similar frameworks in other institutions. Graduates are expected to play leadership roles not only in education but also in fields like environmental conservation and research. While the programme has expanded its reach, challenges remain in scaling it nationally and ensuring long-term policy and institutional support. Nonetheless, it stands as a model of how interdisciplinary, sustainability-driven teacher education can enhance the quality and relevance of STEM learning for future generations ([188]).

## Support for STEM teachers' continuing professional development

In response to the growing expectations of STEM education, many Member States have developed targeted instruments to support **STEM teachers' continuous professional development (CPD)**. CPD is widely acknowledged as a key lever for improving both instructional quality and teacher retention,

([187]) University of Lleida, 'Bachelor's degree in primary education', Faculty of Education, Psychology and Social Work website, https://www.educacioprimaria.udl.cat/ca/pla-formatiu/pla-estudis-guies-docents/.

([188]) https://zeeszak.hu/index.php/erettsegizoknek/.

especially in a rapidly evolving field like STEM, where new content knowledge and pedagogical methods frequently emerge. Cross-country analysis reveals that CPD schemes for STEM teachers are present in nearly all Member States, though they vary widely in their design, focus and implementation. These schemes reflect different national priorities and systemic needs, resulting in a diverse landscape of approaches tailored to support teacher growth and advance STEM education objectives.

Some countries provide relevant examples of modular and course-based CPD programmes that are usually **closely integrated with academic and research institutions, reflecting a systemic approach that links teacher learning to pedagogical research and curricular reform**. These initiatives are often designed to be flexible in duration and intensity, typically allowing teachers to participate in self-paced or semester-structured learning paths. A common feature is their academic affiliation; they are often delivered in partnership with or directly by universities or pedagogical institutes, enabling the CPD to offer formal recognition through continuing education credits or microcredentials. They frequently emphasise theoretical grounding in subject content alongside applied pedagogical methods, which supports deeper conceptual understanding as well as practical classroom adaptation. Such programmes aim to ensure alignment with curricular reforms and promote instructional coherence across school levels. They also allow greater autonomy for teachers in choosing learning pathways suited to their experience levels and subject focus.

In the context of STEM education, this model is particularly effective for enhancing subject-specific expertise and pedagogical and content knowledge. These programmes allow teachers to deepen their understanding of mathematical reasoning, scientific inquiry or technological integration in a systematic and theory-informed manner. Such modular programmes are particularly suitable for STEM because they enable sustained, content-rich learning, essential in disciplines where conceptual precision and curriculum alignment are critical. Their academic structure also allows for the integration of recent scientific knowledge, thereby reducing the lag between disciplinary advances and classroom practice.

- An illustrative case is the **STEM-ProNeD** ([189]) initiative in Germany. Launched in 2023 under Germany's National Recovery and Resilience Plan and funded by the Federal Ministry of Education and Research, the initiative exemplifies how modular CPD is being deployed to respond to the twin challenges of digitalisation and pedagogical innovation in STEM. STEM-ProNeD brings together nine teacher education universities and three research institutes from Baden-Württemberg, Bavaria and Rhineland-Palatinate. It operates through three interdisciplinary networks that focus, respectively, on professional development, curricular advisory services and innovation in STEM classrooms. The initiative supports the

([189]) https://mint-proned.de/startseite/.

development of modular, research-based CPD courses across all STEM disciplines and education levels, with explicit attention to digital integration, process-based learning and emergent technologies, such as AI and immersive environments.

- In Finland, the **LUMATIKKA** ([190]) and **LUMATIKKA+** programmes coordinated by LUMA Centre Finland exemplify a high-impact, research-informed, modular CPD model. These nationally recognised online courses, offering up to 15 European credit transfer and accumulation system (ECTS) credits, target mathematics teachers across educational levels (see Box 26 below for more information).
- The **Danish Academy of Science Education (NAFA)** ([191]) provides a complementary example of how course-based CPD is embedded within a longer-term national science education reform. While NAFA also addresses teacher preparation and research, one of its key pillars is the development of **scalable and sustainable professional development models** in science subjects. It supports the integration of updated scientific and didactic knowledge into teacher training and in-service learning for primary and lower-secondary educators. The programme operates with extensive collaboration from Danish university colleges and research institutions, ensuring that CPD content remains grounded in both pedagogical research and practical classroom relevance.
- Another noteworthy example is Hungary's **physics education doctorate programme** ([192]) at Eötvös Loránd University, which launched in 2007. This advanced training pathway targets experienced secondary school physics teachers and is distinguished by its focus on pedagogical research rather than pure subject-based inquiry. By integrating recent scientific developments with applied teaching strategies, the programme addresses the long-standing disconnect between physics research and classroom application. It also adopts an interdisciplinary methodology, preparing teachers to navigate the complex, evolving nature of modern STEM instruction. Despite facing sustainability challenges, such as limited public funding and an ageing faculty, the programme has made a significant contribution to elevating the quality of physics education and teacher training in Hungary.

**Box 26. Good practice example: LUMATIKKA – Finland**

**Approach**. LUMATIKKA, coordinated by LUMA Centre Finland, is a nationally recognised professional development programme designed to improve the quality of mathematics teaching

([190]) LUMA Centre Finland, 'LUMATIKKA – Continuing professional development in mathematics teaching', LUMA Centre Finland website, https://www.luma.fi/.

([191]) https://nafa.nu/about-nafa.

([192]) This research-oriented programme was launched in 1994, lasts for eight semesters (48 months) and is delivered in English; see https://study-in-hungary.com/eotvos-lorand-university/physics-phd/.

in the Finnish education system, from early-childhood education to upper-secondary school. First launched in 2018 and now extended through its successor initiative LUMATIKKA+ (2024–2025), the programme offers high-quality, flexible, research-informed training for educators. It is grounded in Finland's strong university-based teacher education system and leverages the LUMA network's national reach and expertise in science and mathematics education.

**Objectives**. The programme aims to strengthen teachers' pedagogical and mathematical content knowledge, support inclusive and equitable mathematics instruction and enhance students' motivation and conceptual understanding. It also addresses systemic challenges in mathematics education by promoting innovative teaching practices aligned with national curriculum priorities, such as real-world problem-solving, interdisciplinary learning and transversal skills development.

**Target groups**. LUMATIKKA serves mathematics educators at all levels of schooling in both Finnish- and Swedish-speaking communities. Its modular design allows teachers to select course content that matches their teaching level and professional needs, ensuring relevance across a diverse teaching workforce.

**Activities**. Delivered as a free, modular online course series worth up to 15 ECTS credits, LUMATIKKA combines supervised online learning with interactive activities. Participants can choose from tailored modules that integrate themes such as learner diversity, differentiated instruction and equity. The programme also provides extensive digital learning resources, including instructional videos, lesson plans and teaching materials. In 2022, all educational materials were made publicly available, contributing to the initiative's long-term impact and accessibility through platforms like the Finnish library of open educational resources and YouTube.

**Results/impacts**. LUMATIKKA has demonstrated wide national engagement. In 2022, nearly 3 000 teachers participated in its training activities that year alone, with over 7 000 educators engaged across the full duration of the programme. Approximately 10 % completed the full 15-credit training pathway. Evaluations show high satisfaction, particularly among primary educators, who reported increased confidence in teaching mathematics, exposure to innovative teaching methods and improved collaboration across education levels. Its digital resources have received over 100 000 views, and the initiative has generated strong interest and discussion within teacher networks and social media. The programme's continuation as LUMATIKKA+ introduces updated content and new modules, addressing emerging challenges in mathematics education and reinforcing the programme's role as a cornerstone of national professional development in Finland ([193]).

Across Europe, an increasingly important form of STEM-focused CPD for teachers is **emerging outside formal education systems. These targeted, short-term training schemes, typically led by non-formal education providers** – such as NGOs, companies, foundations and specialised STEM organisations – offer flexible practice-oriented opportunities for teachers to enhance their skills. Rather than functioning as conventional academic courses, these initiatives often combine teacher training with student-facing programmes, leveraging non-formal learning environments to deliver hands-on, innovative educational experiences.

Unlike traditional CPD programmes, these schemes are often integrated into broader informal education offers, such as robotics competitions, maker activities or digital literacy campaigns, and provide educators with focused workshops, teaching materials, digital platforms and access to educator networks. Many also include massive open online courses, workbooks and open-source teaching resources, enabling long-term use and wider dissemination. These initiatives often respond directly to gaps in national curricula or systemic challenges in

([193]) https://www.luma.fi/download/luma-suomi-yhdessa-olemme-enemman/.

STEM teaching, especially around digital tools, cross-curricular integration and student engagement.

- In Poland, the STEAM Education in Schools programme, run by Centralny Dom Technologii ([194]), offers a prime example. Teachers take part in an intensive, three-day training course focusing on active STEAM teaching, lesson design and collaboration strategies. The programme also includes full logistical support (accommodation, travel, meals), mentoring by experts from Poland and Norway and entry into a wider network of teachers, who continue to share practices and implement educational projects in schools. Participants receive certification and gain access to a community of educators using technology to enhance both formal and non-formal student learning.
- In Croatia, the Institute for Youth Development and Innovation (IRIM) ([195]) exemplifies this approach through its Croatian makers movement, which launched in 2015. While the initiative is best known for its wide reach among students, its impact on teacher development is equally significant. IRIM has trained over 4 500 teachers through short, targeted workshops embedded in larger extracurricular STEM programmes. These training sessions equip educators with practical skills in coding, robotics and digital literacy, often using tools like micro:bit devices or 3D printers. Delivered through a mix of in-person workshops, mentoring and open-access online resources, IRIM's CPD model is highly accessible and responsive to local needs, especially in underserved areas. It not only strengthens teachers' technical and pedagogical capacities but also fosters a community of practice that bridges formal and non-formal education.
- In Slovakia, *ExpEdícia – Skús, skúmaj, spoznaj* ([196]) is another strong example. Since 2016, this national programme has promoted constructivist and inquiry-based learning in science subjects for lower-secondary education. It offers teachers practical tools, such as workbooks and subject-specific materials for biology, physics, chemistry and geography, aligned with the national curriculum. Through workshops, pilot programmes and seminars, the initiative provides ongoing CPD for teachers, supporting them in shifting to more student-centred, hands-on instruction. Many participating schools have reported higher student engagement and improved conceptual understanding as a result.

([194]) PFR Foundation, 'STEAM education', PFR Foundation website, https://fundacjapfr.pl/edukacja-steam.

([195]) https://croatianmakers.hr/en/home/.

([196]) Indícia, 'ExpEdícia: skús, skúmaj, spoznaj – prírodné vedy konštruktivisticky' ['ExpEdícia: Try, explore, discover – Constructivist natural sciences'], Indícia website, https://www.indicia.sk/aktivity/expedicia/.

- In Romania, the Romanian-American Foundation and the non-profit organisation Aspire Teachers ([197]) have become the key drivers of innovative CPD for STEM teachers (see Box 27).

**Box 27. Good practice example: Aspire Teachers – Data Math Lab – Romania**

**Approach.** Aspire Teachers – Data Math Lab is a practice-oriented professional development initiative launched in 2021 to improve mathematics instruction in Romanian lower-secondary schools, with a specific focus on data literacy and real-world mathematical reasoning. Developed by the non-profit association Asociatia the Teacher Lab and supported by the Romanian-American Foundation, the programme combines a research-informed CPD model with open-access teaching resources. It provides a structured online learning pathway that helps mathematics teachers shift from traditional, abstract instruction to more student-centred, contextualised teaching. The programme integrates real-life data, formative assessment strategies and metacognitive approaches into everyday classroom practice.

**Objectives**. The initiative addresses persistent weaknesses in Romanian mathematics education, as highlighted in international assessments, such as the 2019 TIMSS, particularly in the areas of data and probability. Its goals are to:

- strengthen teachers' pedagogical content knowledge in data analysis and statistics;
- enhance classroom instruction by supporting the application of real-world data in teaching;
- increase student engagement and performance in solving authentic mathematical problems;
- build teachers' capacity in areas traditionally under-supported, including formative assessment and metacognitive problem-solving strategies.

**Target groups**. The programme primarily targets lower-secondary mathematics teachers in Romania, especially those working with students in grades 5–8. While open to all educators, it particularly seeks to support teachers in under-resourced or high-need contexts, where gaps in instructional quality are most pronounced.

**Activities**. The initiative:

- offers a comprehensive e-learning course covering data literacy pedagogy, formative feedback and student-centred teaching strategies;
- develops and disseminates open-access instructional materials co-designed by practising teachers;
- provides peer-supported learning environments that encourage experimentation and collaborative reflection;
- supports classroom implementation to promote sustained pedagogical change.

**Results/impacts**. Since its launch, approximately 180 teachers have completed the CPD course, with many reporting greater confidence and competence in teaching data-related mathematics topics. The programme has made classroom-ready resources widely available online, contributing to more accessible instructional tools across the country. Based on planned scaling-up efforts, Aspire Teachers aims to reach 500 educators and over 56 000 students. Early evaluation data suggest there is strong potential for impact: over 70 % of participating teachers are expected to demonstrate measurable improvements in teaching practice, and students are projected to score 30 % higher in applied mathematics problems than those taught by non-participating teachers. Increased classroom engagement and use of real-life problem contexts have also been reported ([198]). The Aspire Teachers – Data Math Lab initiative stands out for its targeted response to an identified national learning deficit. Its integration of research-based teaching strategies into a scalable CPD model is particularly relevant to STEM

([197]) https://www.aspireacademy.ro/.

([198]) Romanian-American Foundation, 'Aspire Teachers – Data math lab', Romanian-American Foundation website, https://rafonline.org/en/program/data-science/.

education. The combination of content-specific pedagogy, inclusive access to high-quality resources and a clear plan for impact measurement makes it a replicable model for countries facing similar challenges in mathematics education reform.

These types of initiatives bring the added benefit of directly connecting teachers with cutting-edge technologies, interdisciplinary projects and student engagement strategies, often bridging the divide between formal and non-formal learning environments.

While demonstrating that CPD embedded within non-formal STEM education ecosystems can play a strategic role in transforming classroom practices, some of these examples also indicate another trend emerging from cross-country research: **a growing focus in CPD on the digital competences of teachers, including specialised training in robotics, AI, programming and computational thinking**. These emerging schemes reflect the increasing urgency for education systems to prepare learners for a technology-driven world, beginning with the digital readiness of educators themselves.

These CPD initiatives often differ from traditional training in both format and purpose. Typically offered in **modular, flexible or blended formats**, they target specific digital teaching competences, ranging from programming to designing digitally enriched learning environments. They tend to be shorter in duration, sometimes non-accredited or delivered as part of larger digital education reforms, and frequently involve strong partnerships between public institutions, universities and non-formal education providers. Many of these initiatives integrate hands-on tools and resources (e.g. robotics kits, microcontrollers, online platforms) and promote peer collaboration, school-wide digital innovation and alignment with national digital strategies. Taken together, these examples reflect a shift towards CPD schemes that not only build teachers' foundational digital skills but also empower them to implement and lead digital transformation in STEM education. These schemes support specialisation in emerging technologies, promote collaboration across schools and sectors and often link professional learning with system-level digital strategies.

- In Denmark, the ultra:bit initiative ([199]) exemplifies this targeted, tech-focused CPD model. Launched by DR (the national broadcaster) in partnership with education institutions, ultra:bit aims to build teachers' confidence and capacity in coding instruction by integrating the BBC micro:bit into classroom practice. By 2018, the initiative had reached almost all Danish primary schools, with over 4 000 teachers trained by the Centre for Teaching Materials. Teachers reported significant increases in student motivation and ease with coding: 96 % saw greater interest, and 95 % found students grasped coding more readily than expected ([200]).

([199]) https://drultrabit.dk/om-ultrabit.

([200]) Micro:bit Educational Foundation, 'Denmark – DR Danish Broadcasting Corporation (2018)', Micro:bit website, https://microbit.org/impact/research/#denmark.

- Finland's DigiErko programme ([201]) takes a more advanced and formalised approach. Launched in 2017, this 60-ECTS specialisation course for in-service educators is delivered by the University of Turku, the University of Helsinki and the University of Eastern Finland. It targets experienced teachers from early-childhood education to higher education and focuses on transforming teaching practice and institutional development through digital pedagogy. The programme combines research-based training in ICT use, learning environment design and leadership in digital transformation, creating a national network of digitally competent educators who lead innovation within their schools.
- Also in Finland, the Innokas network ([202]), coordinated by the University of Helsinki, promotes digital innovation and 21st-century skills through a combination of student-facing events and teacher training. Its flagship activity, an annual robotics and programming tournament, is supported by CPD workshops that help teachers integrate robotics and programming into daily instruction. By fostering a culture of experimentation and creativity, the Innokas network helps bridge formal and non-formal learning and advance digital fluency across the school system.
- In Slovakia, the IT academy – Education for the 21st Century ([203]) is a national project that seeks to transform IT and STEM teaching at scale. Since 2017, it has involved over 2 100 teachers across 500 educational institutions, focusing on curricular innovation and ICT integration. The programme includes training teachers to become digital coordinators within their schools, ensuring that CPD leads to sustained institutional change. Specialised training in digital skills has also targeted VET teachers, reinforcing the link between school education and labour market demands ([204]).
- Portugal's Digital Skills Training for Teachers initiative ([205]) represents one of the most extensive national efforts in this area. Launched in 2020, the programme reached over 109 000 educators through more than 7 500 training sessions by 2023. It aims to enhance the digital pedagogical capacity of teachers working at all levels of education, with particular attention given to STEM-related teaching. The programme also fosters communities of practice to facilitate peer learning, innovation and collective problem-solving, contributing to long-term improvements in teaching quality and teacher retention.

([201]) https://digierko.fi.

([202]) https://www.innokas.fi.

([203]) https://itakademia.sk.

([204]) Cedefop, *Slovakia: Initiatives boosting digital transformation*, 2022.

([205]) https://digital.dge.mec.pt/capacitacao-digital-dos-docentes.

**Box 28. Good practice example: Teaching the Future (*Predau Viitor*) – Romania**

**Approach.** Teaching the Future (*Predau Viitor*) ([206]) is a national professional development programme launched in Romania by Asociația Techsoup ([207]) with the support of the Romanian-American Foundation. The programme was created in response to systemic gaps in teacher preparedness following the 2017 curricular reform, which introduced mandatory informatics classes for grades 5–8. Its central aim is to upskill Romania's teaching workforce in digital and mathematical thinking, providing high-quality, practice-oriented training that equips teachers to deliver engaging and inclusive computer science education.

**Objectives.** The programme seeks to strengthen Romania's capacity to teach computer science and digital literacy by improving teachers' pedagogical and technical skills. It aims to support national digital transformation goals, increase the reach and quality of digital skills instruction in schools and ensure equitable access to professional development, particularly in underserved areas, such as rural schools.

**Target groups.** The primary beneficiaries are computer science and ICT teachers, and teachers from related disciplines (e.g. mathematics, physics) who are tasked with teaching informatics. The programme targets both lower- and upper-secondary educators, with a special focus on teachers in rural and small-town schools, who may lack formal training in digital subjects.

**Activities.** Between 2019 and 2022, Teaching the Future delivered 12 structured professional development experiences, including courses in Scratch and Python, combining technical content with innovative teaching strategies. These were supported by an emerging platform for massive open online courses, designed to enhance access without proportional increases in training staff. Teachers benefited from a flexible online learning environment, peer community engagement, and a focus on real-world applications and inclusive classroom practices. The programme also promotes pedagogical innovation, including methods for teaching AI and facilitating product-based learning experiences.

Results/impacts. In just three years, the programme reached 15 % of Romania's computer science teaching workforce and indirectly impacted more than 20 000 students. Teachers consistently described the experience as structured, motivating and directly relevant to their classroom needs. In rural areas, the programme was often the only accessible form of upskilling, helping to address urgent capacity gaps. In 2025, Teaching the Future aimed to reach at least 60 % of computer sciences / ICT teachers in Romania, with 4 200 completing at least one course and 40 % adopting improved, inclusive teaching practices. Beyond numbers, and according to expert interviews, the programme has begun to shift national discourse around informatics education, moving beyond coding to a more holistic and forward-thinking approach that includes AI literacy and real-world problem-solving.

## Support services and networks for STEM teachers

It is evident that, beyond formal training, the vitality of STEM teaching heavily depends on the availability of ongoing support, collaboration opportunities and access to up-to-date knowledge. Cross-analysis of Member States shows that support services for STEM teachers have evolved to include dynamic communities that embed CPD **into peer networks and communities of practice, where STEM educators can share their knowledge and good practices**. These teacher support schemes play an important role in fostering innovation, professional resilience and pedagogical renewal, helping teachers navigate technological, curricular and societal change.

([206]) https://predauviitor.ro/.

([207]) https://www.asociatiatechsoup.ro/.

From this evolution, a new ecosystem of support that complements traditional in-service training has emerged. It combines formal and informal learning and is often led by professional associations, research institutions or networks of schools. These ecosystems help transform teacher development from isolated events into sustained processes of professional growth, deeply embedded in the daily life of teaching.

- In Latvia, this approach is exemplified by the Latvian Physics Teachers' Association, which has become a pivotal actor in the country's STEM education landscape. By partnering with the National Centre for Education and academic institutions, the Latvian Physics Teachers' Association has developed, refined and made publicly available a robust set of instructional resources, from lesson plans to laboratory guides. Its collaboration with international initiatives, like the European Organization for Nuclear Research (CERN) physics teachers programme, adds a global dimension to local CPD efforts. Crucially, the association fosters peer exchange and mentoring, supporting physics teachers through regular events and discussion forums ([208]).
- National events also help galvanise teaching communities. For instance, Latvia's STEM Teacher Conference ([209]), which convenes around 500 educators annually, not only disseminates best practices but also strengthens professional identity. There is also an Excellence Award, recognising outstanding educators in core STEM subjects. Such initiatives help elevate teaching excellence and encourage professional engagement.
- In the Flemish Region of Belgium, integrated STEM learning networks represent a sophisticated model of peer-led support. Launched in 2019, the iSTEM *Inkleuren* ([210]) initiative, supported by all university associations and based on the iSTEM didactic approach, combines teacher training, coaching and resource development. In 2023 alone, it directly trained over 2 600 in-service teachers and indirectly reached more than 17 000 through digital tools. What sets this initiative apart is its full integration with pre-service education, enabling continuity between early career development and lifelong learning. Coaches active in teacher training programmes

([208]) University of Latvia, Department of Physics Education, *Set of methodological materials for the secondary school course Physics I: 245 lesson plans with presentations, laboratory activities and commentary*, Riga, August 2023, [online], available at: https://www.physedu.lu.lv/en/research/projects/set-of-methodological-materials-for-the-secondary-school-course-physics-i/.

([209]) University of Latvia, Interdisciplinary Centre for Educational Innovation (SIIC), *DZMIT STEM Teacher Conferences – "Science, Mathematics, Engineering and Technology in School: Effective and Creative"*, annual August conference section at LU International Scientific Conference, Riga, 27 August 2024 (and earlier editions).

([210]) iSTEM Inkleuren (consortium of Flemish universities and university colleges, coordinated by KU Leuven and led by Prof. Wim Dehaene https://www.istem.be/.

bridge the gap between initial education and ongoing support ([211]). Complementing this, the STEM *voor de basis* network addresses (pre-)primary education. With participation from five teacher training institutions, it aligns STEM instruction between primary and secondary education, while providing intensive coaching trajectories and shorter workshops.

- The FuDo – *Fuerschen Dobaussen* – project in Luxembourg presents a unique model where outdoor inquiry-based learning is embedded into teacher development. Designed to revitalise STEM learning in primary schools, FuDo links teaching with outdoor environments, mapping local natural and historical sites and offering tailored learning activities. Alongside its digital platform, FuDo has built a teachers network to support collaborative design, resource sharing and joint reflection, which is especially valuable in rural or under-resourced settings. It exemplifies how context-responsive networks can address structural challenges in science education, including the lack of specialised training in natural sciences among primary teachers.
- In Sweden, *Matematiklyftet*, a national CPD initiative for mathematics teachers, is built on peer learning and lesson study. It has successfully improved pedagogical practice and boosted teacher confidence. Despite declining participation due to workload, administrative barriers and funding limitations, the programme remains a model of how collaborative professional development can be systematised ([212]).
- In Czechia ([213]), the *Elixír do škol* programme illustrates the strength of decentralised support models. Supported by the Česká spořitelna Foundation, it operates 62 educational centres, including specialised hubs for subjects like chemistry and digital technologies. These centres provide training, peer mentoring and access to resources, reaching 7 000 teachers and 1 000 schools. The programme builds a strong community culture where teachers drive innovation together. It exemplifies how community-rooted networks, when well resourced, can scale up nationally and influence over 400 000 students, while embedding active learning and digital skills into everyday teaching.
- In Germany, the SINUS programme was launched in response to the 1994–1996 TIMSS study to improve the quality of mathematics and

([211]) iSTEM Inkleuren and STEM voor de basis, *Jaarverslag 2023 – Deel 1 – Inhoudelijk luik*, Leuven and Brussels, https://www.istem.be/wp-content/uploads/2024/02/iSTEM-Jaarrapport-2023-Inhoudelijk-Luik-zonder-bijlage.pdf.

([212]) The Swedish National Agency for Education, *Utvärdering av Lärarlyftet – Delrapoort 1 – Utveckling över tid – Report 2020:6 [Evaluation of Lärarlyftet – Interim report 1 – Development over time – Report 2020:6],* Stockholm, 2020, https://www.skolverket.se/getFile?file=7379.

([213]) Elixír do škol, founded in 2013 and based in Prague, has been an autonomous non-profit since 2018; see https://www.elixirdoskol.cz/.

science teaching at the lower-secondary level ([214]). Initiated by the Federal-State Commission for Educational Planning and Research Promotion, it featured 11 modules aimed at fostering meaningful learning, thematic understanding and student motivation. The programme promoted evidence-based innovative teaching, collaborative learning among teachers, inquiry-based methods and real-world applications. It followed a network model, wherein schools worked in professional learning communities to share practices and improve instruction. Continuous professional development (CPD) for teachers was a core element. Due to its success, the programme was extended several times. Since 2017, it has been run by individual federal states ([215]), with corresponding programmes for primary schools still ongoing. The programme led to improvements in instructional quality, teacher professionalisation and school-level cooperation. According to the evaluation evidence, it fostered a more innovative school climate and produced extensive teaching resources. The 2011 TIMSS results showed that primary students involved in the programme outperformed their peers in mathematics, and teachers reported professional growth closely linked to the programme ([216]).

As STEM education evolves to meet the demands of a digitally connected and rapidly changing world, the support systems available to teachers must likewise adapt. Increasingly, **modern support services are migrating towards hybrid and digital-first models, designed not only to transmit knowledge but to embed continuing professional growth into the daily fabric of teaching**. These services are no longer limited to in-person training events or printed materials; instead, they rely on scalable, responsive and often self-directed **digital infrastructure and platforms that support teachers** before, during and after classroom implementation. At their most effective, these platforms serve multiple roles: they act as resource repositories, learning environments and professional communities. They provide curated teaching materials, interactive training modules, assessment tools and structured learning pathways. Importantly, many also feature asynchronous collaboration tools, allowing

([214]) Hertrampf, M. (ed.), *Abschlussbericht: Steigerung der Effizienz des mathematisch-naturwissenschaftlichen Unterrichts*, Leibniz Institute for Science and Mathematics Education, Kiel/Bayreuth, 2008, http://www.sinus-transfer.de/fileadmin/MaterialienBT/abschlussbericht.pdf.

([215]) Qualitäts- und UnterstützungsAgentur – Landesinstitut für Schule, ‘SINUS.NRW: Motivation durch kognitive Aktivierung – Impulse zur Weiterentwicklung des Mathematik- und Naturwissenschaftsunterrichts in Nordrhein-Westfalen’, QUA-LIS.NRW website, 2024, https://www.schulentwicklung.nrw.de/sinus/front_content.php?idcat=1956&lang=9; Qualitäts- und UnterstützungsAgentur – Landesinstitut für Schule, ‘SINUS Bayern – ein Fortbildungsprogramm zur Weiterentwicklung des mathematik-naturwissenschaftlichen Unterrichts’, Bildungsserver Innovations Portal website, last updated 2024, https://www.bildungsserver.de/innovationsportal/innovationsprojekt.html?innovationsprojekte_id=690.

([216]) Dalehefte, I. M., Wendt, H., Köller, O., Wagner, H., Pietsch, M. et al., ‘Taking stock after nine years of SINUS at elementary schools in Germany: An evaluation of mathematics-related data within the framework of TIMSS 2011’, *Zeitschrift für Padagogik*, Vol. 60, No 2, 2014, pp. 245–263.

teachers to connect, reflect and problem-solve together, irrespective of geography or time constraints. However, the success of such platforms hinges on several enabling conditions, including relevance to classroom needs, ease of use, integration with national curricula and, crucially, teacher agency and professional culture.

- Hungary's National School Education Portal, operational since 2014, represents an ambitious attempt to centralise digital resources for STEM and other subjects. Developed with Microsoft Hungary and launched with significant public investment, the portal offers tailored tools and content for personalised learning. However, uptake has been limited, with fewer than 20 % of teachers actively using the platform – a reminder that technology alone is insufficient without sustained teacher engagement, training and awareness ([217]).
- In contrast, Lithuania's Teachers *L*ead Tech platform (*Vedliai*) ([218]), which launched in 2019, illustrates the success of a blended, user-centric model. Originally designed for primary school teachers, the platform combines lesson plans, classroom scenarios and creative coding projects with face-to-face and virtual training. By 2024, over 5 000 teachers and 42 000 students had engaged with the platform, supported by tutorials, communities of practice and national partnerships. Its strong alignment with curriculum needs and focus on teacher digital literacy have made it a cornerstone of informatics education in Lithuania.
- Spain's CodeINTEF ([219]), launched in 2018, further exemplifies how state-led platforms can empower teachers in emerging areas, such as AI, robotics and computational thinking. The initiative offers certified online training, digital badges and open-access resources aligned with Spain's digital competence framework. More than a static platform, Code.INTEF functions as a professional exchange space, driving digital integration and project-based learning across classrooms. Code.INTEF serves as a national hub for both CPD delivery and professional exchange, helping teachers implement digital pedagogies aligned with evolving curricular goals.

The examples provided above show that effective support for STEM teachers across Member States is grounded in strategic, well-integrated initiatives that address both workforce shortages and the evolving demands of STEM education. Several key **success factors** emerge for effective interventions targeting STEM teacher attraction, retention and professional development.

([217]) National Public Education (Hungary), 'Choose a textbook!', National Public Education Portal website, https://www.nkp.hu/tankonyvek.

([218]) https://www.vedliai.lt/.

([219]) https://code.intef.es/.

- **Alignment of incentives with structural needs.** Successful schemes do not just fill vacancies – they align incentives with long-term workforce planning. Lithuania's I C*hoose to Teach!* illustrates how combining financial support with mentoring and professional development can not only attract talent but also retain it beyond the initial commitment. Similarly, Croatia's use of geographically targeted scholarships linked to teaching obligations shows that conditional financial aid can address both recruitment and territorial disparities.
- **Integration of content expertise with pedagogical capacity.** High-impact ITE models, like Hungary's Z Study programme, demonstrate that interdisciplinary and sustainability-linked training produces teachers equipped for modern STEM education. Success lies in designing curricula that balance scientific depth with innovative, inquiry-based pedagogy, enabling future teachers to move beyond rote instruction. These models break down disciplinary silos and promote flexible, context-sensitive teaching.
- **Modular, research-informed CPD as a lever of systemic change.** Germany's STEM-ProNeD and Finland's LUMATIKKA reveal the importance of scalable, modular professional development that is deeply embedded in academic and curricular ecosystems.
- **Embedding CPD within peer-led, practice-based communities.** Belgium's iSTEM *Inkleuren* and Czechia's *Elixír do škol* show that sustainable teacher development relies on embedding learning in communities of practice. What makes these models successful is not just the training content, but the support structures – peer coaching, regional hubs and mentorship – that ensure that new methods are tested, reflected upon and iteratively improved.

#### 5.1.3.5. Instruments targeted at learning support and equity

This section analyses the schemes that explicitly aim at promoting equity and inclusiveness in STEM education. While these schemes differ in their specific objectives – ranging from increasing female participation in STEM careers to enhancing digital literacy among under-represented groups – they often share several key characteristics of support instruments that were already observed throughout this report. These include being deeply embedded in local educational ecosystems, adopting a whole-school or community-based approach, forming strategic partnerships with universities and private companies, and providing non-formal or informal learning experiences that complement formal education. These features allow such initiatives to be both accessible and contextually relevant, thereby enhancing their effectiveness and scalability.

### Instruments promoting STEM education among girls and women

Based on national-level mapping of Member States, the **most widespread types of learning support schemes addressing inequities in STEM education are those targeted specifically at girls and women**. These initiatives aim to address the persistent gender gap in STEM enrolment and careers and counteract cultural stereotypes that discourage female participation in scientific and technical fields. The under-representation of women in STEM careers remains a systemic issue in Europe. Despite policy progress and increased awareness, girls and young women continue to face lower expectations, limited encouragement and a scarcity of visible role models in technical disciplines. In this context, non-formal and informal learning programmes have emerged as powerful tools to dismantle these barriers and promote gender equity.

Typically, these programmes are designed as extracurricular voluntary initiatives that engage participants through project-based learning, hands-on experimentation, mentoring and career exploration. The emphasis on girls and women is often embedded in broader frameworks of digital inclusion, environmental sustainability or innovation, thus normalising female participation within the wider STEM narrative rather than isolating it. Many schemes are supported by public–private partnerships and feature close collaboration between educational institutions, government bodies, NGOs and industry stakeholders.

- A prominent example is the Austrian MINT Girls Challenge ([220]), launched in 2021 by a coalition of public and industrial actors. This nationwide competition invites girls aged 4–19 to submit STEM-related projects addressing real-world issues aligned with the UN sustainable development goals. In 2023/2024, over 900 girls collectively submitted 153 projects, marking significant growth in participation. The success of this initiative lies in its broad outreach, the flexible formats (ranging from videos to prototypes), and the high visibility given to winners through ceremonies and partnerships with leading tech companies.
- In Estonia, the Unicorn Squad ([221]) has gained national visibility as a grassroots initiative promoting STEM learning for girls through girls-only robotics and tech clubs. Founded in 2018 in response to gender exclusion in extracurricular STEM activities, the initiative has now reached nearly 4 000 girls. With dedicated clubs in every county and a growing number of summer camps, the Unicorn Squad is lauded for its scalable, low-cost model and its appeal to both children and parents. Since 2023, it has received state and EU co-funding, enabling further expansion despite current limitations linked to shortages of qualified instructors.

([220]) https://www.mintgirlschallenge.at/.

([221]) https://unicornsquad.ee/.

- The Czech organisation Czechitas ([222]) exemplifies a holistic approach to reducing digital gender divides by offering workshops, mentorship and career transition pathways for women and youth. Since 2014, the organisation has trained over 76 000 people through more than 1 900 courses. With a growing base of industry partners and educational institutions, Czechitas not only equips participants with in-demand digital skills but also strengthens their confidence to enter and thrive in tech careers.
- In France, the long-standing association *Elles Bougent* mobilises more than 3 000 female engineers and technicians to engage directly with school-aged girls. Through national events like *Elles bougent pour l'orientation*, the initiative reached nearly 29 000 girls in 2023, offering exposure to engineering careers through site visits, mentorship and interactive sessions with professionals. The initiative's success is rooted in its scale, sustained partnerships and use of relatable role models ([223]).
- Italy's STEM: Female Plural initiative, promoted as part of the national STEM month, encourages primary and secondary students to reflect on women's contribution to science and explore inclusive learning through creative projects. With themes like developing STEM-focused games or critical essays on gender bias in science, this initiative blends creativity with critical inquiry and integrates inclusiveness into mainstream education efforts.
- Also in Italy, the annual STEMintheCity initiative ([224]), launched by the municipality of Milan in 2017 with support from the UN and private sector partners, exemplifies how inclusive STEM promotion can be integrated into broader urban educational agendas. Held every April, STEMintheCity offers workshops, mentoring, coding classes and inspirational talks across all education levels, with special emphasis on the synergy between science and the arts (STEAM). In 2019 alone, the initiative engaged over 56 000 participants online and more than 14 000 in person, showing the potential of large-scale, city-led mobilisation around equity in STEM.
- In Slovenia, Girls_Do_Code ([225]) offers free, school-based programming courses to girls aged 10–14. Since 2019, more than 400 girls have participated, developing games, apps and web tools. Feedback shows that 93 % of participants gained an increased interest in tech, underlining the impact of early exposure to ICT in non-formal settings.

([222]) https://www.czechitas.cz/.

([223]) Elles bougent - Transmettre la passion, susciter des vocations.

([224]) https://steamiamoci.it/best_practice/stem-in-the-city/.

([225]) https://digitalschool.si/girls-do-code/.

- In Poland, Aramco's partnership with the Perspektywy Educational Foundation ([226]) showcases how large-scale public–private collaboration can drive gender inclusion. Through Girls as Engineers! and the Perspektywy Women in Tech Summit, the initiative targets girls and women at both the secondary and higher education levels. Engaging over 200 000 participants annually, the programmes provide networking, career guidance and role model engagement, highlighting the value of visibility and professional community in fostering lasting interest in STEM.
- In Germany, the #empowerGirl initiative ([227]), launched in 2023, provides an online platform offering equal internship opportunities in STEM for female and non-binary students aged 15 and above. Developed through a partnership between the *MINTvernetzt* initiative and the Alliance of Women in STEM Careers, and supported by the Federal Ministry of Education and Research, the platform exceeded its initial goal within six months, facilitating over 2 500 internships with more than 200 companies ([228]). By bridging the gap between young people and STEM employers, the initiative contributes to making the STEM sector more accessible and attractive to under-represented groups, while also supporting workforce needs.

**Box 29. Good practice example: Progetto NERD? (*Non È Roba per Donne?*) – Italy**

**Approach.** Progetto NERD? (*Non È Roba per Donne?*) ([229]) (isn't it stuff for women?) is a gender-focused STEM initiative launched by the Department of Informatics at Sapienza University of Rome in collaboration with IBM. It adopts a collaborative, academic–industry approach aimed at making technology education more appealing and accessible to young women. Delivered nationally across Italy, the programme introduces female secondary school students to computer science and AI through hands-on, creative learning experiences. The initiative reframes technology as a tool for social impact and problem-solving, rather than a purely technical domain, and is implemented through online and in-person activities led by university experts and industry professionals.

**Objectives.** The primary objective of Progetto NERD? is to inspire female students in upper-secondary school to consider careers in computer science and AI, helping to counter persistent gender stereotypes in STEM. The programme seeks to demonstrate that technology is an interdisciplinary, creative and socially relevant field. It also aims to raise awareness of digital career opportunities and develop participants' practical ICT skills, ultimately contributing to greater gender equity in STEM-related university enrolment and professional pathways.

**Target groups.** Progetto NERD? targets female students aged 15 to 18, primarily those in their third to fifth years of upper-secondary education. It has engaged learners from more than 2 000 high schools across Italy, including in regions with historically low STEM participation, such as southern Italy.

**Activities.** Participants take part in a structured learning programme that includes:

([226]) Aramco Europe and Perspektywy Educational Foundation, 'Aramco supports STEM education in Poland – Partnership launching Girls as Engineers! and Women in Tech Summit to empower young women in STEM', Aramco website, 14 June 2023, Aramco supports STEM education in Poland | Aramco Poland.

([227]) https://empowergirl.de/.

([228]) MINTvernetzt, 'Erstes Ziel übertroffen! – Bereits mehr als 2 000 Praktikumsplätze bei #empowerGirl', MINTvernetzt website, 4 April 2024,. Erstes Ziel übertroffen! - MINTvernetzt.

([229]) https://it.newsroom.ibm.com/nerd2024.

- workshops and online training sessions, where they learn to design and build chatbots using IBM's Watson assistant and other AI tools;
- plenary lectures and hands-on laboratories delivered by university professors and IBM professionals;
- mentorship opportunities with female role models from the tech industry and academia;
- project-based learning centred on real-world issues aligned with the 2030 UN sustainable development goals;
- a final awards ceremony recognising outstanding student projects, with top participants invited to further training and development activities hosted by IBM and other partners.

The programme's focus on real-world problems and technology for good helps connect computer science to broader societal concerns, reinforcing its relevance and appeal to girls.

**Results/impacts.** Since its inception, Progetto NERD? has involved over 50 000 students nationwide. It has contributed to a notable increase in female enrolment in STEM university programmes, with some participating institutions reporting growth of between 15 % and 35 %, particularly in southern Italy ([230]). The initiative has helped reshape perceptions of ICT among young women, highlighting the creative and meaningful dimensions of digital technology. By equipping girls with early exposure to AI and digital skills, Progetto NERD? plays a strategic role in addressing gender imbalances in the tech sector and fostering inclusive participation in the digital economy.

Successful equity-driven STEM initiatives targeting women and girls typically share a **combination of pedagogical, structural and strategic features** and success factors.

Notably, the most impactful programmes – such as Progetto NERD? in Italy or the *Elles Bougent* initiative in France – **combine sustained mentorship and direct interaction with female role models with real-world socially meaningful learning tasks**. These approaches not only increase technical competence but also help participants visualise themselves in STEM careers. Early exposure to hands-on STEM experiences in accessible non-formal formats is also a critical factor, as seen in initiatives like Girls_Do_Code and the Unicorn Squad, which reach girls at key stages in their educational trajectories. Furthermore, initiatives that **leverage strong multi-sector partnerships** – such as Czechitas, STEMintheCity or the Perspektywy Women in Tech Platform – gain credibility, resource depth and scalability. Importantly, the above examples and interviews with stakeholders indicate that success is dependent not on the delivery format alone but rather on how well the programmes align with participants' lived experiences, provide supportive peer networks and visibly challenge gender stereotypes in STEM.

### Instruments targeting students from lower socioeconomic backgrounds and/or rural areas, those with disabilities and those belonging to other vulnerable groups

Building on the analysis of gender-focused initiatives, our study also identified **schemes targeting other under-represented groups in STEM – such as**

([230]) BitMAT, 'Progetto NERD? 50 000 studentesse italiane si cimentano con l'AI di IBM', BitMat website, 28 May 2024, https://www.bitmat.it/news/progetto-nerd-50-000-studentesse-italiane-si-cimentano-con-lai-di-ibm/.

**students from low socioeconomic backgrounds, rural areas or those with disabilities**. Country-level mapping shows that these initiatives appear **less frequently across countries than those focused on girls and women**. Despite the lower prevalence of such initiatives, they play a crucial role in advancing educational equity and demonstrate how inclusive STEM design features can be tailored to a broader range of learners.

Like their gender-focused counterparts, these schemes are often embedded within local learning ecosystems, involve robust public–private or community partnerships and take the form of non-formal or informal learning experiences. What differentiates them is primarily their objective and target group, rather than the structure or modality of the educational intervention.

- One of the strongest examples is Romania's Code Kids – Coding for Kids in Libraries ([231]), implemented by the Romanian-American Foundation in collaboration with the Progress Foundation. Operating primarily in rural areas, the programme brings coding and digital literacy directly into public libraries and community schools (for more details, see Box 30 below).
- In Greece, STEMpowering Youth ([232]) by SciCo (a Greek non-profit science communication organisation) equips local teachers to run STEM workshops in remote and underserved communities. Students aged 12–17 engage in hands-on projects, such as Arduino-based inventions, mobile app development and astronomy simulations. A culminating project challenges students to apply STEM to solve local problems. The programme also supplies equipment and offers incentives like educational trips, while the Generation Next phase (see Section 5.1.3.6 below) expands digital access.
- Ireland's STEM Passport for Inclusion ([233]) focuses on students from schools that are part of the country's delivering equality of opportunity in schools (DEIS) programme (i.e. schools in disadvantaged areas). STEM Passport for Inclusion offers skill-building workshops, mentoring and a recognised credential: the STEM passport. It helps students gain exposure to STEM careers and boosts their confidence to pursue them. Evaluations show that the programme nearly eliminated a 30-percentage-point confidence gap between girls from DEIS and non-DEIS schools. Over 5 000 students have participated, and the government plans a national scale-up.

([231]) Romanian-American Foundation, 'Code kids – Coding for kids in libraries', RAF Online website, https://rafonline.org/en/program/code-kids-coding-for-kids-in-libraries/.

([232]) SciCo, 'STEMpowering Youth – Extracurricular STEM-skills education for teenagers in rural Greece through project-based learning and community innovation', SciCo website, https://scico.gr/en/activities/stempowering-youth/.

([233]) Maynooth University, 'STEM passport for inclusion – All-Ireland STEM qualification and mentoring initiative for girls in DEIS schools from disadvantaged communities', Maynooth University website, https://www.maynoothuniversity.ie/all-institute/all-projects/stem-passport-inclusion.

- Germany's *Mkid – Mathe kann ich doch!* ([234]) targets sixth-graders with unrealised mathematics potential, helping them build confidence and hone their problem-solving skills through workshops, teacher mentorship and field excursions. The programme includes a school grant worth EUR 5 000 over two years to support implementation. Evaluations show improved attitudes and performance in mathematics, particularly for students who previously lacked confidence.
- In Spain, the NGO Friquifund ([235]) engages under-represented youth through science workshops, mentoring and science fairs. It works with schools and municipalities to improve STEM access and awareness in marginalised communities, including rural and migrant populations.
- Sweden's *spetsutbildningar* ([236]) (specialist education programmes) stand out for targeting high-achieving students, who can also be considered an under-represented group in terms of access to enriched learning environments. These competitive programmes in mathematics, science and technology allow students to study advanced topics in smaller classes with intensive support. Students report high satisfaction, particularly with early exposure to university-level STEM. However, evaluations also note the risk of stress and the need for better curriculum continuity between educational levels ([237]).

**Box 30. Good practice example: Code Kids – Coding for Kids in Libraries – Romania**

**Approach.** Code Kids – Coding for Kids in Libraries ([238]) is a flagship programme of the Romanian-American Foundation, implemented in partnership with the Progress Foundation and the National Association of Librarians. It operates free coding clubs for children aged 10–15, primarily in rural and small-town public libraries across Romania. The initiative leverages underutilised public infrastructure – libraries and local schools – as community learning spaces, especially in areas with limited access to formal digital education. Facilitated by trained volunteers and librarians, Code Kids clubs not only teach children how to code but also develop their teamwork, critical thinking and problem-solving skills. The programme exemplifies an inclusive, community-driven approach to rural STEM education.

**Objectives.** The primary objective of Code Kids is to close the digital education gap for children living in remote and rural communities, where opportunities for learning computer science are scarce or non-existent. The programme aims to provide early exposure to digital technologies, foster digital literacy and build confidence in using technology creatively and purposefully. It

([234]) Vector Stiftung, 'Mkid – Mathe kann ich doch!', Vector Stiftung website, https://vector-stiftung.de/mkid/.

([235]) https://friquifund.org/.

([236]) Interviews with national-level stakeholders.

([237]) Swedish National Agency for Education, *Evaluation of Experimental Activities with Advanced Training*, Stockholm, 2019.

([238]) Romanian-American Foundation, 'Code kids – Coding for kids in libraries', RAF Online website, https://rafonline.org/en/program/code-kids-coding-for-kids-in-libraries/.

also seeks to promote gender inclusion and equitable access to STEM education, laying the groundwork for future engagement in technical studies and careers.

**Target groups.** Code Kids targets children aged 10–15 in rural and small-town communities throughout Romania. By reaching underserved areas and populations, the programme specifically addresses regional disparities in access to digital education. It also engages local educators, librarians and community volunteers, creating a multigenerational learning ecosystem that supports sustained involvement.

**Activities.** Code Kids offers a two-year structured learning programme hosted in local libraries and schools.

- In the first year, participants are introduced to foundational digital skills and basic programming using user-friendly platforms, such as Code.org.
- In the second year, learners advance to more complex topics, such as basic robotics and the development of digital projects that address real-world issues – for example, automated irrigation systems or energy-saving devices for schools.
- The programme includes regular coding sessions, collaborative group work, public project showcases and mentorship. Facilitators include trained librarians and volunteers, supported by curriculum materials specifically designed to be accessible even to those without a strong technical background.

**Results/impacts.** Since its launch in 2017, Code Kids has reached over 3 000 children, with more than 220 libraries hosting clubs and over 200 volunteers supporting implementation. It is widely recognised by national and international stakeholders as a best-practice model for rural STEM education and is considered scalable in both Romania and other European contexts. According to interview evidence, the programme has successfully brought coding education to remote areas, resulting in early digital skills development, increased confidence and enhanced educational aspirations among participants. Notably, several students who joined in the early years have since attended technical high school and university programmes in STEM fields, with some returning as volunteers, creating a sustainable multiplier effect within their communities. Interviewees consistently cited the accessibility of the curriculum and the use of local facilitators as key success factors in ensuring the programme's wide reach and long-term impact.

Despite varied formats and target populations, **several features underpin the success of inclusive STEM initiatives addressing broader equity concerns**.

- First, **localisation of the learning offer** – through rural libraries, community schools or public institutions – ensures accessibility and relevance.
- Second, partnerships with NGOs, universities and local authorities enable resource sharing and operational sustainability. Programmes such as Code Kids and STEMpowering Youth also emphasise gradual skills building, whereby learners move from basic to more complex STEM tasks, reinforcing confidence and ownership.

These initiatives underscore the principle that equitable access to STEM is not simply about offering more content but about reshaping delivery to meet learners where they are – both geographically and educationally. When designed with community input and delivered through inclusive pedagogy, such schemes have the potential to transform educational trajectories and advance systemic change.

### 5.1.3.6. Instruments for non-formal/informal STEM learning

In the context of EU education and lifelong learning policy, it is essential to distinguish between non-formal and informal STEM education, as each provides unique and complementary pathways for learning outside traditional school settings.

**Non-formal STEM education** means structured, purpose-driven learning activities that take place outside the formal education system but are intentionally designed with educational objectives in mind. Examples include after-school coding clubs, science camps and structured science centre workshops, often led by educators or STEM professionals. These initiatives are characterised by clear learning goals and guided instruction, enhancing learners' STEM knowledge and skills. In contrast, **informal STEM learning** arises through everyday experiences and is driven by curiosity rather than a structured curriculum. Activities such as exploring interactive science exhibits, participating in citizen science projects, watching educational videos online or experimenting at home fall into this category. These experiences are typically spontaneous, self-directed and without formal learning objectives or assessments ([239]).

Despite differing in structure, both modes are critical to the STEM education ecosystem. Non-formal learning supports the acquisition of specific competences and can offer pathways for recognition, while informal learning ignites interest, nurtures curiosity and promotes lifelong engagement with STEM subjects.

#### Non-formal STEM education instruments

Cross-country analysis shows that non-formal STEM education in Europe takes a variety of forms, including **after-school workshops, community-based programmes, science clubs, coding camps, robotics leagues, mobile laboratories and national or international competitions**. These schemes are driven by a wide range of actors, including NGOs, universities, local authorities and corporate partners. Mapping carried out as a part of this study reveals that virtually each Member State has multiple examples of this type of scheme, complementing the formal education offer.

One of the most successful types of non-formal STEM education support schemes is **interactive, project-based hands-on learning**. These programmes focus on immersive and experiential learning beyond the conventional boundaries of the classroom. Central to their methodology is the principle of learning by doing, whereby students engage directly with scientific concepts through real-world challenges, collaborative problem-solving and iterative

([239]) Council of Europe, European Youth Foundation, 'Definitions', Council of Europe website; European Commission: European Education and Culture Executive Agency, *Validation of non-formal and informal learning in higher education in Europe – Eurydice report*, Publications Office of the European Union, Luxembourg, 2024, https://data.europa.eu/doi/10.2797/296107.

experimentation. Participants are encouraged to hypothesise, test, reflect and refine their ideas through structured yet flexible formats that foreground creativity, resilience and interdisciplinary thinking.

A defining feature and the key success factor of these schemes is their **grounding in inquiry-based learning and the scientific method**. Instead of passive knowledge transmission, students explore open-ended questions, design their own investigations, experiment and interpret their findings, fostering deeper cognitive engagement. Team projects are often at the heart of these initiatives, requiring students to collaborate, divide tasks and develop prototypes, all while honing their communication, leadership and critical thinking skills. This collaborative element not only enhances motivation but simulates real-world scientific and engineering environments, preparing students for future careers.

Programmes in this category are often conceived and delivered through partnerships between schools, universities, research institutes, industry actors and public authorities. These multistakeholder collaborations ensure the scientific integrity of content, access to specialist resources and alignment with regional or national STEM strategies. In many cases, initiatives are embedded within broader territorial education plans, contributing to their scalability and sustainability. Successful models often leverage co-funding from local governments, corporate sponsors and EU projects to support infrastructure, educator training and outreach.

The success of interactive project-based hands-on learning schemes lies in their **ability to engage students** who might not otherwise see themselves as the scientific type. By making STEM tangible, contextualised and relevant to learners' lives and personal interests, these initiatives foster both immediate enthusiasm and long-term interest. Importantly, they often reach students from under-represented groups, helping to democratise access to high-quality STEM learning.

Mapping across the Member States reveals multiple examples of these schemes.

- Austria's Cultural Collisions initiative ([240]), spearheaded by Vienna University of Technology, takes an interdisciplinary approach to non-formal STEM learning by merging science and art. Aimed at 12- to 14-year-olds, the programme addresses complex topics, such as climate change, through collaborative projects between students, artists and scientists. Activities culminate in public exhibitions, fostering both creative expression and scientific understanding. Around 400 students participated during the 2023/2024 academic year.

([240]) https://www.tuwien.at/en/cultural-collisions.

- In Belgium, *STEM Neteland* ([241]) was launched in 2020 through a partnership of five municipalities, the tech company Hidrodoe, the NGO Thomas More and other stakeholders. This project offers after-school STEM workshops to primary school students. Developed through a quadruple helix model involving education, business (e.g. Nike, Johnson & Johnson), government and research actors, the workshops are embedded within local education strategies. Engaging over 70 % of the target group, the initiative exemplifies effective territorial governance and strong community engagement. Plans are under way to expand the scheme into secondary education.
- Sci-high ([242]) in Bulgaria is an extracurricular initiative active in nine schools across five cities. It empowers students to apply scientific methods to real-world issues via science clubs that culminate in public science festivals. This approach develops students' presentation skills, confidence and teamwork. Projects have received national recognition, demonstrating the impact of student-led inquiry and community engagement.
- The junior Science Talent programme ([243]) in Denmark, aimed at high-achieving primary and lower-secondary students, combines talent camps, experimental workshops and critical thinking exercises to nurture scientific curiosity and perseverance. Its structured support for gifted students helps maintain their engagement with STEM disciplines during their formative years. Furthermore, Denmark's LIFE Foundation ([244]), launched in 2020, has created a countrywide infrastructure for non-formal STEM learning by integrating classroom-aligned content with inquiry-based learning methods. LIFE's unique value lies in its mobile laboratories and regional LIFE labs, which bring hands-on STEM activities, often aligned with the UN sustainable development goals, to schools across Denmark free of charge. Students conduct experiments related to real-life environmental and societal issues using cutting-edge scientific equipment, while teachers are supported by a digital platform (MY:LIFE) offering supplementary content.
- The Curious Minds programme in Ireland ([245]) is a nationwide government-funded scheme that introduces primary pupils to scientific thinking through hands-on, inquiry-based activities. It supports teachers with professional

([241]) Region ETE, 'STEM Neteland', Regioneteland website, https://regioneteland.be/strategie-en-organisatie/stem/.

([242]) https://sci-high.org/.

([243]) Science Talenter, 'Science Talent Junior i skoleåret 2025/26', Science Talenter website, https://sciencetalenter.dk/aktivitet/science-talent-junior.

([244]) Novo Nordisk Foundation, 'Novo Nordisk Foundation establishes LIFE as an independent foundation', Novo Nordisk Foundation website, 2 December 2020, https://novonordiskfonden.dk/en/news/novo-nordisk-fonden-etablerer-life-som-selvstaendig-fond.

([245]) https://www.sfi.ie/engagement/curious-minds/.

development and integrates STEM across subjects to stimulate creative problem-solving. Its scale and teacher-centred design contribute to its broad systemic impact.

Country-level mapping also shows that across Europe, **non-formal STEM education initiatives focused on coding, robotics and AI have become increasingly prominent**, in both scope and strategic importance. These programmes have emerged as strategic responses to a confluence of challenges: the growing mismatch between technological change and rigid national curricula, and persistent skill gaps in digital sectors. What distinguishes these initiatives is not only their content – centred around programming languages, robotics systems and digital logic – but also their pedagogical approach: deeply practical, project based and learner driven.

Rather than sitting through abstract lectures, students build robots, write code, simulate AI systems and solve real-world problems through iterative design and collaboration. This **experiential, hands-on learning model** is a central success factor in all the most effective schemes. It replaces rote instruction with exploration and play, allowing young learners to experiment with failure, discover new interests and develop a deeper sense of ownership over their educational journey. Particularly in robotics and coding competitions, this sense of ownership is enhanced by a bottom-up dynamic, a recurring theme across interviews and impact reports. These initiatives often emerge from grassroots efforts, local networks or enthusiastic mentors and are discovered by students, not imposed upon them. This voluntary, curiosity-driven entry point boosts intrinsic motivation; young people feel that they are choosing to learn, not being required to.

Another powerful success factor is the use of **team-based formats**. Unlike traditional academic exercises, which often isolate learners, non-formal STEM programmes, especially robotics competitions, build in collaboration as a core component. Working in teams to design and iterate solutions, working towards shared goals, creates a supportive learning culture wherein students teach each other, problem-solve together and take pride in joint achievements. This structure not only fosters technical learning but also cultivates vital transversal skills, such as communication, leadership, perseverance and creative thinking. The social aspect of team-based STEM learning is one of its most compelling draws, making programmes more inclusive and emotionally engaging.

Many of these initiatives are not isolated experiments but are **embedded within local and national ecosystems**. The most impactful examples are co-designed with municipalities, universities, tech firms and NGOs, ensuring both relevance and sustainability. They often leverage underutilised infrastructure, such as public libraries, makerspaces and youth centres, transforming them into innovation hubs. A consistent focus on inclusivity – reaching girls, rural students or learners from disadvantaged backgrounds – also distinguishes these programmes. Through mobile laboratories, teacher training, free platforms and community engagement, they are closing long-standing equity gaps in STEM education while

building a digitally literate generation. In essence, these initiatives are not merely about learning technology; they are about reimagining how and why young people learn. Cross-country mapping reveals multiple successful examples, illustrating the growing trend of leveraging non-formal education to promote robotics, AI and digital skills among school-age students in Europe.

- In Croatia, the Institute for Youth Development and Innovativity (IRIM) and its Croatian makers movement ([246]), established in 2014, has built the largest non-governmental STEM education network in the EU, reaching over 350 000 children. IRIM's multifaceted approach includes distributing tens of thousands of micro:bits to schools and libraries, organising a national robotics league involving over 12 000 students annually and deploying mobile 'STEM Cars that deliver coding workshops to remote and underserved communities. All initiatives are underscored by a philosophy of democratising STEM education through practical engagement; students learn by building, coding and competing in collaborative challenges. More than 4 500 trained teachers are central to the model's scalability, and resources such as the Izradi! online platform ensure content accessibility. IRIM's success stems from grassroots momentum, diverse funding sources and a pedagogical commitment to hands-on, inclusive and empowering learning.
- In recent years, Romania saw the emergence of a number of initiatives promoting robotics among school students. One, Romania's NEXTLAB.TECH ([247]), launched in 2018 and is the result of a collaboration between the Ministry of Education and Banca Comercială Română. This national non-formal education programme focuses on robotics and digital technologies for students aged 8–16. Its core feature is a robotics competition where teams of learners design and program robots to complete specific tasks, supported by robotics kits and guided by an extensive set of online learning resources. The initiative combines remote digital instruction with hands-on project work, allowing students to build technical skills through direct experimentation and teamwork. Since its inception, over 40 000 students have participated nationwide; in 2023 alone, 500 received robotics kits as prizes, demonstrating the initiative's extensive reach and its use of practical incentives to stimulate interest in technology and learning. NEXTLAB.TECH's success stems from its scalable format, integration with national education objectives and its experiential, bottom-up model, where students discover robotics as an engaging, team-based learning path that fosters both creativity and technical fluency.

([246]) https://croatianmakers.hr/en/home/.

([247]) https://robo.nextlab.tech/.

- Another notable initiative in Romania, the FIRST Tech Challenge ([248]), launched in 2016, has evolved into a national robotics initiative involving over 13 000 students annually and over 200 high schools ([249]). What makes this initiative remarkable is not just its large scale but its **bottom-up, team-oriented model**; students voluntarily form teams, guided by mentors and teachers, and spend months designing, building and coding competition-ready robots. With resources provided by sponsors and a flexible competition structure, the initiative taps into a deep well of student motivation. The collaborative nature of robotics work, along with its real-world application and public recognition (including world championship wins), cultivates both technical and transversal skills. According to multiple stakeholders, this freedom to discover, choose and compete in teams is a key reason why so many students persist and grow through the programme.
- The Luxembourg Tech School ([250]) began as a small pilot in 2016 and has since expanded to eight secondary schools, offering extracurricular courses in fields like game development, big data, space tech and fintech to students aged 12–19. Designed around levels – go (the introductory level), level 1 and level up (advanced) – the programme blends technical instruction with personal mentorship and real-life project development. Each student works through a progression of challenges, often creating prototypes or digital tools that solve real problems. The experiential learning model is central: LTS treats students as creators, not consumers, and gives them the tools and support to innovate independently. Partnerships with the Coordination Service for Educational and Technological Research and Innovation (SCRIPT) and Digital Luxembourg ensure institutional backing, and the programme continues to grow due to its relevance, adaptability and learner-centred philosophy.
- In Lithuania, RoboLabas ([251]), launched in 2019 as part of Panevėžys's Industry 4.0 strategy, serves as both an educational hub and a regional innovation platform. Focused on children aged 6–12, RoboLabas offers project-based learning in robotics, engineering and mechatronics, while older students explore smart technologies and the creative industries. Activities are explicitly tied to local labour market needs and are delivered in partnership with schools, municipal authorities and industry stakeholders. The initiative's strength lies in its integration of regional development, inclusive pedagogy and early STEM exposure. Students build machines, conduct real-world experiments and apply what they learn

([248]) https://natieprineducatie.ro/.

([249]) https://www.brd.ro/en/about-brd/corporate-responsibility/education.

([250]) https://innovative-initiatives.public.lu/initiatives/luxembourg-tech-school-lts.

([251]) Panevėžys Robotics Center RoboLabas, 'About us', RoboLabas website, https://robo-labas.lt/about-us/.

in practical projects. Between 2022 and 2023, participation nearly doubled, and the initiative was awarded a prize as Non-Formal STEM Provider of the Year ([252]), highlighting its success in linking education to innovation.

- In France, the Yes We Code! initiative, developed by the CGénial Foundation ([253]), supports students aged 10–17 in creating digital projects using programmable kits. With a reach of 48 000 learners and 1 400 teachers, the initiative embeds team-based coding activities into the school environment, particularly in underserved areas. Students learn Python, block programming and micro:bit coding through group challenges that culminate in tangible outputs. Evaluations show a measurable boost in student confidence and digital-skill levels, particularly among girls and under-represented learners. Its approachable kit-based format combined with its emphasis on teamwork and discovery makes it a scalable and socially inclusive model of experiential digital learning.

**Box 31. Good practice example: CoderDojo Ireland – Ireland**

**Approach.** CoderDojo Ireland ([254]) is part of the global CoderDojo movement and follows a volunteer-led community-based model. It provides free non-formal learning opportunities for young people aged 7–17 through local coding clubs known as Dojos. These clubs are typically hosted in accessible public spaces, such as schools, libraries and community centres. The approach emphasises hands-on creative learning and peer-to-peer mentoring, where young people learn programming, game development, web design and other digital skills in a supportive, non-competitive environment. Inclusivity is a core principle, ensuring that young people from all backgrounds can participate regardless of their previous experience or access to technology.

**Objectives.** The primary aim of CoderDojo Ireland is to foster interest and confidence in digital technologies among young people. By providing early exposure to coding and related skills, the initiative seeks to nurture creativity, problem-solving abilities, collaboration and an entrepreneurial mindset. It also aims to democratise access to technology education and reduce barriers to entry into STEM fields.

**Target groups.** CoderDojo Ireland targets children and teenagers aged 7–17. The programme is open to all young people across Ireland, with a strong emphasis on reaching those who may not have access to formal or extracurricular STEM learning opportunities.

**Activities.** The core activity is the weekly coding session held in local Dojos. These sessions are facilitated by volunteers, often professionals or students with a background in technology. Participants engage in practical projects, such as building websites, designing games, creating animations or programming microcontrollers. Sessions are informal and interest driven, with participants encouraged to work on what excites them most. Additional activities include mentoring opportunities, public showcases of student work, participation in national or global coding challenges, and community events that promote technology learning and inclusion.

([252]) https://www.mokytojuapdovanojimai.lt/?p=1620.

([253]) CGénial Foundation (France), *Évaluation d'Impact Social de la Fondation CGénial*, https://www.cgenial.org/uploads/media/pdf/b3be27375015493c889bc74c83b40ff33df69a29-cgenial-rapportmesureimpactsocial-2022-23-vf.pdf.

([254]) Code Club, 'CoderDojo is part of the Code Club community', Code Club website, https://codeclub.org/en/coderdojo-community.

**Results/impacts.** Since its inception in 2011, CoderDojo Ireland has grown to over 160 active dojos nationwide ([255]), engaging thousands of young people each year. The programme has had a notable impact on participants' digital confidence and STEM aspirations. A global survey found that more than 80 % of participants reported improved coding skills, and nearly 70 % felt more confident about their future career prospects in technology. Beyond skills development, CoderDojo has helped foster a culture of innovation and collaboration among Irish youth, with many alumni going on to pursue higher education and careers in software development, engineering and other technology-related fields. The programme continues to be a leading example of scalable, inclusive digital education ([256]).

Examples of non-formal education support schemes focusing on robotics, coding and related areas are also provided by Bulgaria ([257]), Latvia ([258]), Poland ([259]) and Slovenia ([260]). Furthermore, as some of the examples are more targeted at specific groups of student, some of them will be discussed in the next sections, which focus on learning support and equity.

**STEM competitions and Olympiads** also represent one of the longest-standing and most prestigious forms of non-formal education in Europe. Rooted in a tradition dating back to the mid 20th century, these academic competitions have played a pivotal role in nurturing talent, deepening subject-matter expertise and strengthening pathways to higher education and STEM careers. Unlike broader STEM outreach or maker programmes, Olympiads typically focus on high-achieving students with strong disciplinary interests in mathematics, physics, computer science or biology. While selective and academically rigorous, their non-formal nature lies in the voluntary, extracurricular framework through which students engage with them, often guided by dedicated teachers, mentors or former participants.

Across many Member States, Olympiads/competitions have grown into national institutions. They operate outside the formal curriculum yet are deeply intertwined with the education system, often endorsed or supported by ministries of

([255]) Raspberry Pi Foundation, *Clubs Annual Survey – 2024 report*, https://static.raspberrypi.org/files/clubs/Raspberry_Pi_Foundation_Clubs_Annual_Survey_2024.pdf.

([256]) Raspberry Pi Foundation, *Clubs Annual Survey – 2024 report*, https://static.raspberrypi.org/files/clubs/Raspberry_Pi_Foundation_Clubs_Annual_Survey_2024.pdf.

([257]) https://robotika.bg/.

([258]) Datorium offers coding, digital skills and AI courses for students aged 14–19 and teacher-applied EdTech solutions; see https://datorium.eu/lv/datorium-ar-inovativiem-tehnologiju-risinajumiem-veicina-jauniesu-digitalo-iemanu-un-programmesanas-prasmes-visa-latvija/. Roboskola is a STEAM education centre offering robotics, AI, science and summer camps for children aged 6–12; see https://roboskola.lv/. StartIT is a national digital education platform providing free computing and programming learning for schoolchildren; see https://www.startit.lv/.

([259]) Polish Ministry of Education and GovTech Centre, *Liga Robotów – National robotics league turning STEAM learning into robot competitions*, available at: https://www.gov.pl/web/ligarobotow.

([260]) Robotics Slovenia (offers VEX Robotics, VEX IQ and VEXcode VR-based educational robotics programmes; see https://robotics-slovenia.com/.

education, universities and scientific societies. These competitions unfold in several stages – at the school, regional, national and international levels – with the top performers frequently going on to represent their countries at global events like the international mathematical Olympiad or the international physics Olympiad.

Olympiads/competitions are characterised by several defining features: their focus on deep, conceptual understanding; emphasis on problem-solving over rote knowledge; a tiered competitive structure; and a strong mentorship model. Participants can work individually but benefit from informal communities of peers and mentors. In recent years, some Olympiads have diversified their formats to include team-based problem-solving and interdisciplinary challenges, reflecting evolving pedagogical trends and workforce needs.

Country-level data collected through desk research and interviews point to several **key success factors** that contribute to the enduring impact of Olympiads in STEM.

- **Long-term mentorship and community.** Olympiads often foster tight-knit intellectual communities where alumni return as mentors and role models.
- **Teacher involvement.** Teachers play a vital role, volunteering their time to identify and train students, often outside their regular teaching duties.
- **Progressive difficulty and recognition.** The staged competition structure motivates students through a clear progression path and peer recognition.
- **Freedom to explore.** Many Olympiads allow students to pursue advanced content outside their school curriculum, increasing the students' intrinsic motivation.
- **Prestige and academic mobility.** High performance often facilitates university admissions and scholarships, particularly in competitive disciplines.

Moreover, interviews with educators and organisers highlight that **bottom-up engagement** is crucial; students often discover Olympiads as an alternative learning pathway, not imposed but embraced. This grassroots discovery fosters stronger intrinsic motivation. Additionally, Olympiads that incorporate collaborative problem-solving or team-based rounds tend to be more engaging, especially for students who thrive in social learning contexts. Examples of such schemes can be found in nearly every Member State.

- In Czechia, the physics Olympiad (*Fyzikální Olympiáda*) ([261]) has been a cornerstone of scientific talent development since 1959. Supported by the

([261]) http://fyzikalniolympiada.cz/.

Ministry of Education and scientific societies, the Olympiad challenges secondary school students through complex theoretical problems and experiments. Organised at the school, district, regional and national levels, it draws on a strong network of volunteer teachers who mentor participants. The programme's alumni often pursue degrees in physics or engineering, many entering elite international universities. Its success rests on its mentorship model and long-standing academic prestige.

- Slovakia's mathematical Olympiad (*Matematická olympiáda*) ([262]), founded in 1950, offers a similarly rigorous structure. With categories tailored to various age groups, it fosters mathematical reasoning and theoretical depth. Slovak participants have consistently performed well at the international mathematical Olympiad, underscoring the strength of their national training. The Olympiad's inclusive approach, with stages open to students from across the country, ensures wide access while maintaining high standards ([263]).

- The Irish mathematical Olympiad ([264]), established in 1988, serves as the national platform for secondary students to explore advanced mathematics. It is both a competition and a training programme, culminating in selection for international Olympiads. The initiative has supported thousands of students over the decades and helped raise the profile of mathematics within the Irish education system.

- Germany's *Jugend forscht* (Youth Research) competition ([265]), established in 1965, blends the Olympiad model with open-ended research. Students aged 15–21, along with juniors aged 9–14, submit original STEM research projects that are evaluated at the regional and national levels. The programme has reached over 300 000 students to date and is renowned for its strong mentorship culture and alignment with scientific practice. Evaluation of the *Jugend forscht* competition confirms that the competition is highly effective in encouraging young people's STEM potential, particularly those who repeatedly participate. It helps students develop scientific and personal skills, fosters interest in STEM careers and supports the talent pipeline ([266]).

([262]) http://skmo.sk/.

([263]) National Institute for Education (Slovakia), 'Matematická olympiáda', National Institute for education website.

([264]) https://www.irmo.ie/.

([265]) Stiftung Jugend forscht e. V., 'Jugend forscht (and Schüler experimentieren) – Annual national STEM research competition for young learners', Jugend forscht website, https://www.jugend-forscht.de/teilnahme/wichtige-infos/teilnahmebedingungen.html.

([266]) Federal Ministry of Research, Technology and Space (Germany), *Evaluationsbericht Jugend forscht 2024*, Evaluation des Wettbewerbs Jugend forscht.

- In France, the CGénial competition ([267]), supported by the CGénial Foundation and the Ministry of Education, engages students in team-based science projects judged by experts and industry professionals. While not a traditional Olympiad, it mirrors many of the same features: progressive challenge, mentorship and recognition. Its interdisciplinary focus and industry involvement highlight its alignment with contemporary STEM needs. According to evaluation reports, the competition significantly improves teamwork, scientific reasoning and interest in STEM careers.
- Cyprus hosts two national competitions, Research by Students and Students in Research, which guide learners through hypothesis development, data analysis and scientific presentation. While more open-ended in nature, these competitions instil research skills that mirror those fostered by Olympiads. The emphasis on real-world challenges, including sustainability and technology, ensures relevance to modern educational goals ([268]).

**A growing segment of non-formal STEM education in Europe is shaped and supported by private sector partnerships, often involving large corporations, industry foundations or business-led networks.** These initiatives aim to bridge the persistent skill gap in science and technology sectors by directly aligning educational experiences with current and future labour market needs. Unlike many school-based or top-down policy interventions, these models often combine practical relevance, rapid adaptability and strong motivational potential for learners.

A defining feature of these initiatives is their ability to **link the non-formal educational offer with economic transformation in real time**. Unlike traditional schooling, which may lag behind current industry practices, these programmes are built around current technologies, platforms and business challenges. Students are not only learning about STEM-related industry areas in theory but also building, testing and presenting real-world applications under the guidance of professionals. This direct exposure to industry standards gives students clearer insights into future career pathways and improves their motivation and confidence. Many programmes go further by involving students in competitions, project showcases and public recognition events that celebrate achievement and creativity.

Another major advantage lies in the **infrastructural and pedagogical support provided to teachers and schools**. These schemes often supply ready-to-use

([267]) CGénial Foundation, *Évaluation d'Impact Social de la Fondation CGénial 2022/2023*, https://www.cgenial.org/uploads/media/pdf/b3be27375015493c889bc74c83b40ff33df69a29-cgenial-rapportmesureimpactsocial-2022-23-vf.pdf.

([268]) Nicolaou, N., *CHOICE – increasing young people's motivation to choose STEM careers through an innovative cross-disciplinary STE(A)M approach to education – National reports on local and regional initiatives, best practices, students' attitudes and teachers' approaches to STE(A)M education in Cyprus*, European Centre of Studies and Initiatives, https://cesie.org/media/CHOICE-Report-Cyprus-EN.pdf.

lesson plans, digital platforms, mobile laboratories or hands-on kits that reduce barriers to adopting STEM knowledge in practical settings. At the same time, they typically include comprehensive professional development opportunities, giving educators the tools and confidence to integrate cutting-edge content into their classrooms. Importantly, industry-led initiatives frequently promote a spirit of innovation and experimentation, encouraging students to explore new technologies without fear of failure and develop transversal skills, like collaboration, critical thinking and design.

Analysis across Member States shows that the most successful examples also reflect a nuanced understanding of equity, inclusion and regional development. While some early models primarily benefited students already on a STEM trajectory, many newer initiatives now include outreach to under-represented groups, support for rural schools and scaffolding for teachers in disadvantaged settings. A growing number also incorporate targeted scholarships, ambassador programmes and parental engagement strategies to create a more inclusive STEM pipeline. These programmes thus play a dual role: they help industry secure future talent and they broaden access to high-quality future-relevant learning opportunities for diverse youth populations.

- In Croatia, **STEMwave** ([269]) is a private sector-led initiative that brings together high-tech companies, most notably Stemi ([270]), A1 and Infobip, to reshape how STEM subjects are taught and experienced in Croatian schools. The programme is designed as a holistic ecosystem for non-formal digital learning, offering modular courses for students aged 10–18 on AI, robotics, game development and future careers. Through its digital platform, Stemi LAB ([271]), schools receive access to all necessary software, lesson materials and pedagogical support. Teachers benefit from professional development, coaching through a dedicated chat and email service, and participation in an active network of over 500 ‘hero teachers’ who champion STEM innovation in their schools. One of STEMwave’s most distinctive features is its emphasis on project-based learning and public celebration: each academic cycle culminates in Innovation Day, a national showcase where over 650 students and teachers gather to present projects, engage with technology experts and compete for prizes. The programme also integrates industry-led learning experiences, such as the Greatest of All Tech (GOAT) talks, where students hear directly from Croatian tech leaders. In 2023, the programme involved 281 schools, over 580 teachers and more than 3 800 students, with strong uptake across all regions of Croatia. Its success lies in its

([269]) Stemi provide industry-based STEAM learning for middle and high schools via a cloud-based platform available at https://stemi.education/.

([270]) https://stemi.education/.

([271]) https://stemi.education/solutions/stemi-lab/.

hands-on modular approach, the sustained mentorship of teachers and the strong motivational impact of recognition and industry engagement.

- In Greece, the **Generation Next** ([272]) programme, launched by the Vodafone Foundation in 2017, offers one of the most comprehensive models of private sector-driven STEM education in Europe. Developed in collaboration with the Hellenic Open University and supported by the Daissy research group ([273]) and the NGO SciCo ([274]), the programme combines open-access digital learning with in-person workshops, teacher training and an annual national STEM competition. The platform provides students and teachers with a robust digital curriculum incorporating robotics, programming and environmental science, all designed using inquiry-, project- and problem-based learning methodologies. Importantly, Generation Next targets not only urban centres but also remote and underserved areas through its travelling laboratory workshops. Teachers receive online training and access to a university-accredited course on STEAM pedagogy, helping to build long-term capacity within the education system. Since its inception, Generation Next has reached over 112 000 beneficiaries and supported the development of 721 student-led projects addressing real-world community challenges. Recognised by winning the 2019 Mariano Gago Ecsite Sustainable Success Award, the programme exemplifies how scalable, inclusive and academically rigorous private-led STEM education can be when rooted in systemic partnerships and pedagogical innovation ([275]).
- In Lithuania, the **#EnergySmartSTART** ([276]) programme was initiated in 2022 by Ignitis Group, a state-controlled energy company, as part of a long-term strategy to address critical workforce shortages in the energy sector. The initiative is multifaceted, combining in-school energy literacy sessions, excursions to energy facilities, teacher training and scholarship funding. During the 2022/2023 school year alone, over 300 school lessons were delivered by Ignitis employees, reaching more than 8 000 students, with an additional 1 800 individuals participating in site visits to power plants and renewable energy projects. The programme aims to familiarise students with careers in the sector, such as renewable energy engineer or hydrogen technology expert, and provides targeted information about relevant university and VET pathways. Complementing this outreach, Ignitis has committed over EUR 450 000 to fund STEM scholarships for

([272]) https://www.vodafonegenerationnext.gr/.

([273]) Daissy research group, ‘Daissy – National STEAM education and social computing research unit addressing inclusive digital learning, MOOCs, IoT and educational innovation’, Daissy website, http://daissy.eap.gr/en/.

([274]) https://scico.gr/.

([275]) SciCo – Science Communication (Greece), ‘Generation next’, SciCo website, https://scico.gr/en/activities/generation-next/.

([276]) https://energysmartstart.lt/en/.

university students, with plans to extend support to students pursuing degrees abroad. A parallel teacher training component includes ready-made lessons, videos and content on sustainable energy use. Through its scale, relevance and integration of industry expertise, #EnergySmartSTART has become a model for how sectoral employers can invest in the long-term sustainability of both STEM education and the workforce ([277]).

- In the Netherlands, **Kids4Twente** ([278]) is a regionally rooted initiative that brings together primary schools and local businesses to embed STEM into everyday learning. While still largely focused on primary education, it stands out for its integration of curriculum support, professional teacher development and business engagement. Schools receive guidance on incorporating STEM into lesson plans while participating in co-designed projects with local firms. For example, at one school, students collaborated with the company Mindhash to design an automated irrigation system, directly linking classroom learning to problem-solving in real environments. The programme is further supported by a regional deal that has enabled its expansion and sustainability. Key to its success is its investment in teachers: Kids4Twente offers annual professional development programmes; training for STEM coordinators; and events, like Network Cafés and Knowledge Labs, to foster continuous learning and innovation.
- In Bulgaria, **Dream Space** ([279]), launched in 2022 by Microsoft Bulgaria in collaboration with Telelink Business Services, offers immersive research-based STEAM learning experiences to students and teachers across the country. The programme includes age-specific student workshops on real-world challenges using digital tools, from basic STEAM principles in primary school to advanced technology integration in secondary education. Teachers are trained in effective STEAM pedagogy and given access to ongoing support materials, while a complementary online platform, Dream Space TV, delivers educational content to support creativity, computational thinking and digital literacy. Within its first month of operation, the programme engaged over 500 students, reflecting high demand. Dream Space's strength lies in its accessibility, its close alignment with future job skills and its ability to reach learners through both physical and digital formats.

([277]) https://energysmartstart.lt/en/.

([278]) https://kids4twente.nl/.

([279]) CEE multi-country news center, 'Dream space opened in Bulgaria – A free STEAM learning hub available for all teachers and students', Microsoft News website, 2022, https://news.microsoft.com/en-cee/2022/10/31/dream-space-opened-in-bulgaria-a-free-steam-learning-hub-available-for-all-teachers-and-students/.

- In Poland, the ***Universiada* STEM Education Competition** ([280]), backed by global materials company PPG, focuses on inspiring interest in chemistry and applied sciences among students aged 10–14. Student teams, mentored by teachers, are challenged to develop projects with real-world applications, such as the development of bioplastics to replace petroleum-based plastics. Winning teams receive grants and public recognition, with over PLN 130 000 (EUR 30 300) awarded to date. While long-term impact data are still limited, the competition has become a popular entry point into STEM for younger learners and illustrates how thematic competitions can mobilise creativity, collaboration and early engagement in science.
- In Sweden, ***Teknikspråget*** is a national internship programme, launched in 2012 and managed by the Royal Swedish Academy of Engineering Sciences, that offers four-month paid internships to recent high school graduates to encourage them – especially young women – to pursue STEM studies and careers by providing real-world experience in engineering and technology fields (see Box 32 below for more details).

**Box 32. Good practice example: *Teknikspråget* – Sweden**

**Approach.** *Teknikspråget* ([281]) is a national internship programme in Sweden designed to bridge the gap between secondary education and higher education in STEM. It offers recent high school graduates four-month paid internships in engineering and technical workplaces. The initiative is managed by the Royal Swedish Academy of Engineering Sciences and is supported through government funding. Established in 2012 following Sweden's 2010 national skills strategy, the programme aims to provide practical experience and career orientation at a critical decision-making stage for young adults. *Teknikspråget* engages public and private sector employers, who host interns and expose them to real-world work environments in science, technology and engineering fields.

**Objectives.** The primary goal of *Teknikspråget* is to encourage more young people, especially women, to pursue university studies and careers in engineering and technical fields. The programme addresses skills shortages in Sweden's technology sector by increasing exposure to STEM professions and raising awareness of the career opportunities available. It also aims to provide participants with experiences so that they can make informed decisions about their future education and career paths.

**Target groups.** *Teknikspråget* targets young adults aged 18–20 who have completed upper-secondary education (typically with a science or technical focus) and are considering post-secondary studies.

**Activities.** The programme offers structured four-month full-time paid internships at engineering and technology-based companies and public institutions. Participants apply through a centralised national platform, and successful applicants are matched with participating employers across various industries. Interns receive mentoring, complete workplace-based projects and gain first-hand insight into STEM-related professions. *Teknikspråget* also maintains outreach and promotional efforts to attract applicants and hosts alumni networks and ambassador initiatives to increase visibility.

([280]) PPG Industries, 'PPG awards STEM education prizes to primary school students in Poland', News.PPG website, 2025, https://news.ppg.com/press-releases/press-release-details/2025/PPG-awards-STEM-education-prizes-to-primary-school-students-in-Poland/.

([281]) Government of Sweden, Government decision U2012/5580/GV – assignment to implement *Teknikspråget* [engineering internship scheme], Stockholm, 2012.

**Results/impacts.** Between 2012 and 2020, 19 959 young people applied to *Teknikspranget*, and 4 791 were accepted, indicating a selective process with an acceptance rate of approximately 24 %. Evaluations by the Swedish National Agency for Education and other national bodies show that participants are significantly more likely to pursue STEM studies at university after completing the internship and report highly positive experiences with the programme. Notably, female participants appear to benefit the most, with increased interest and confidence in pursuing engineering degrees ([282]).

The available examples demonstrate the significant impact and **effectiveness of non-formal education and its associated online resources, especially in situations where traditional education is disrupted by unexpected circumstances, such as the COVID-19 pandemic**. In Bulgaria, for instance, the Education without Backpacks association ([283]) has been instrumental in promoting digital inclusion and supporting self-paced learning. As the official partner of the Khan Academy platform in Bulgaria, Education without Backpacks has translated and adapted thousands of STEM-related resources into Bulgarian, greatly expanding access to high-quality digital content. During the pandemic, the use of Khan Academy tripled, underscoring the critical role of accessible, adaptable online platforms.

### Informal STEM education initiatives

It is difficult to identify the impacts of **informal education** compared with non-formal schemes. Unlike structured programmes with clear learning objectives and participation metrics, informal STEM initiatives are often open access, episodic and community oriented. Yet their influence can be profound. **By reaching large audiences, embedding STEM experiences in everyday contexts and fostering public appreciation for science and technology**, these initiatives shape societal attitudes and inspire lifelong learning. Across Europe, a number of long-running, high-profile initiatives illustrate how informal education can successfully promote STEM engagement, particularly when it leverages creativity, community participation and cross-sectoral partnerships.

Informal STEM education thrives on several interlinked advantages. First, **accessibility and visibility** are essential; these programmes often meet people where they are, both physically (in public squares, schools and museums) and socially (through media, art and culture). Second, **informality allows for innovation**; by loosening the constraints of formal curricula, these initiatives can integrate interdisciplinary approaches, artistic formats and playful learning. Third, **partnerships are critical**; collaboration with scientific institutions, cultural organisations and media enables the design of engaging, high-quality content. Finally, sustained engagement is more likely when programmes are embedded

([282]) Swedish National Agency for Education, *Utvärdering av Teknikspranget* [*Evaluation of the Technology Leap*], Stockholm, 2022.

([283]) https://obr.education/en/.

in national or regional ecosystems, allowing them to evolve, grow and adapt to the public's needs over time.

- In Croatia, two flagship initiatives illustrate different models of informal engagement. The Science Picnic ([284]), organised by the Professor Baltazar Association since 2011, is the country's most prominent public science event. With approximately 4 000 annual visitors, it brings together associations, educational institutions and individuals to host lectures, interactive demonstrations and performances focused on robotics, natural sciences and emerging technologies. Meanwhile, Mathematics Night (*Večer matematike*), organised by the Croatian Mathematical Society, offers a decentralised nationwide celebration of mathematics each December ([285]). In 2024, over 100 000 people across 650 institutions participated in workshops, lectures and problem-solving activities. This event not only popularises mathematics but also strengthens community ties and showcases mathematics as an enjoyable everyday experience.
- Ireland offers multiple standout examples of informal STEM education. Science Foundation Ireland's Discover Programme ([286]) funds science festivals, school outreach events and public exhibitions, supporting thousands of jobs and generating wide public engagement. The BT Young Scientist and Technology Exhibition ([287]) is a national showcase of student innovation, attracting over 40 000 visitors annually and creating significant pathways into STEM careers. Its long-term impact is seen in alumni who pursue advanced studies and contribute to national STEM policy and innovation ecosystems.
- In Italy, Maker Faire Rome ([288]) has become a flagship event for grassroots innovation. As Italy's largest gathering dedicated to creativity, science and technology, it offers workshops, exhibits and performances that connect students, teachers, entrepreneurs and families. The fair is known for initiatives like Call for Schools and Call for Makers, which provide free platforms for learners to present their work. Its inclusive, festival-like atmosphere supports a wide range of learning styles and age groups.
- Estonia's TeaMe 3.0 ([289]) programme takes a comprehensive approach to informal STEM promotion, combining public science campaigns,

([284]) Naslovna.

([285]) Soucie, T. and Brückler, F. M., 'Autumn math festivals in Croatia', European Mathematical Society website, 12 January 2025, https://euromathsoc.org/news/autumn-math-festivals-in-croatia-141.

([286]) https://www.sfi.ie/engagement/sfi-discover/.

([287]) https://www.yste.ie

([288]) https://makerfairerome.eu/it/.

([289]) https://etag.ee/rahastamine/programmid/teame-3-0/.

experimental learning, science communication and career awareness efforts. Activities include science shows, online platforms, school seminars and researcher festivals. Based on evaluation evidence, while coverage remains uneven across regions, the programme's long-term funding and multi-pronged strategy have made it a national model and the impacts on science popularisation in the country are substantial ([290]).

- Lithuania's science festival Spacecraft Earth ([291]), held annually since 2004, brings science directly to communities through lectures, experiments and school-based outreach. Attracting 5 000 to 15 000 participants annually and backed by institutions such as the Lithuanian Academy of Sciences and the British Council, the festival offers hands-on activities across disciplines and publishes a companion book series to extend learning beyond the event.
- In Luxembourg, the biannual science festival ([292]), launched in 1995 by the National Museum of Natural History and the National Research Fund, hosts over 50 interactive workshops and attracts about 12 000 visitors over four days. The accompanying platform Science.lu supports year-round engagement through digital content, social media and science journalism. In 2022, the platform recorded nearly 800 000 page views and 1.6 million YouTube views.
- Finally, Malta's Science in the City festival ([293]) represents an innovative fusion of science and the arts. Held annually in Valletta and attracting more than 30 000 visitors, the event integrates performances, installations and interactive science experiences. With a strong focus on inclusivity, it actively involves students with mixed abilities and neurodivergent learners. Regular impact assessments have confirmed its effectiveness in increasing public understanding and science capital.

**Box 33. Good practice example: *Rakett69* – Estonia**

**Approach.** *Rakett69* is a nationally broadcast Estonian science competition television show launched in 2011 by the Estonian Association of Physics. It blends entertainment with education to promote STEM learning and scientific thinking among youth and the general public. The show features secondary school students competing in hands-on science challenges that require creativity, problem-solving and teamwork. Produced in collaboration with the Science Centre AHHAA and the Estonian national broadcaster, *Rakett69* is jointly funded by the state and private sector donors. Over time, it has evolved from a science popularisation project into a strategic tool for shaping societal attitudes towards STEM and academic achievement. In 2024, the initiative was expanded with the launch of *Rakett Junior*, a version of the show tailored to primary students in grades 4–6.

([290]) https://etag.ee/tegevused/uuringud-ja-statistika/uuringud/teadust-ja-tehnoloogiat-populariseerivate-tegevuste-kaardistamine-ja-analuus/.

([291]) https://www.mokslofestivalis.eu/.

([292]) https://www.fnr.lu/science-festival/.

([293]) https://scienceinthecity.org.mt.

**Objectives.** The main objective of *Rakett69* is to popularise science among the general public and inspire young people to pursue STEM education and careers. The programme also seeks to enhance the public image of scientific achievement, reinforcing the message that being knowledgeable and academically ambitious is both socially desirable and rewarding. By using a televised competition format with real-life challenges and monetary prizes, *Rakett69* positions science as exciting, aspirational and relevant.

**Target groups.** *Rakett69* primarily targets secondary school students, typically aged 15–19, with an expanded reach to younger pupils (grades 4–6) through *Rakett Junior*. Beyond these core age groups, the show also aims to reach the general population, raising public awareness and appreciation for science and education. With approximately 10 % of the Estonian population regularly viewing the show, *Rakett69* achieves broad visibility.

**Activities.** Each season of *Rakett69* features a televised competition with 12 student finalists selected from across the country. Contestants face complex scientific and engineering challenges that test their knowledge, creativity and teamwork under pressure. The show is professionally produced and aired nationally, complemented by monetary prizes, ranging from EUR 1 000 in the first season to EUR 15 000 in 2023, which boost participation and prestige. In addition to the broadcast, the initiative includes outreach events, school engagement campaigns and spin-off programmes like *Rakett Junior*. The show format has also been licensed internationally, highlighting its adaptability and transferability.

**Results/impacts.** Since 2011, *Rakett69* has completed 14 consecutive seasons, with three more planned, confirming its longevity and strong public appeal. Participation among students has grown steadily, and the show continues to attract a wide audience, consistently reaching around 10 % of the national population. The initiative has contributed to a positive shift in the perception of science in Estonia, positioning it as engaging and socially valued. Participants often go on to pursue STEM studies and careers, reflecting the show's motivational impact. In 2012, the European Broadcasting Union named *Rakett69* the best educational TV show, and its format has since been replicated in Luxembourg, demonstrating its scalability. The programme's success lies in its unique ability to combine mass media, education and competition to inspire STEM aspirations across diverse audiences ([294]).

**Science centres and museums across Europe have emerged as dynamic hubs for non-formal and informal STEM education**, bridging the gap between scientific research, formal education and public engagement. Unlike traditional schooling environments, science centres and museums offer flexible, hands-on and often immersive learning experiences that ignite curiosity and stimulate inquiry-based learning. These institutions not only serve as platforms for knowledge dissemination but also foster community engagement, inspire career aspirations and promote scientific literacy across all age groups.

One of the defining features of science centres is their role as intermediary spaces – hubs that connect schools, students, researchers, policymakers, industry actors and the general public. They facilitate collaboration between these stakeholders while **providing a physical and intellectual space where science becomes accessible and tangible**. Their versatility allows them to support both structured, curriculum-linked activities for school groups and open-ended exploration for families, tourists or individuals.

Science centres are also vital in supporting lifelong learning and enhancing public understanding of science. Through interactive exhibitions, workshops, science shows and public lectures, they demystify complex scientific concepts and present them in a way that is engaging and relevant to everyday life. Moreover,

([294]) https://rakett69.ee/ajalugu.

they often act as incubators for educational innovation, experimenting with new formats and pedagogies that are later adapted in formal education settings. In addition, many centres run targeted programmes for underserved or under-represented groups, thus playing a critical role in advancing inclusion and equity in STEM education. There are multiple examples across Member States of this type of science centre, whose main objective to act as a central hub, providing non-formal and informal STEM education experiences.

- The ScienceCenter-Netzwerk ([295]) in Austria exemplifies the power of a networked approach to informal STEM learning. Established in 2005, it connects over 160 partners, including museums, research institutes and educational NGOs, to co-create science communication formats rooted in interactivity and collaboration. Its strength lies in the ability to unify multiple actors around a common goal: embedding science and technology into everyday life. The network received the Austrian State Prize for Adult Education in 2024, acknowledging its systemic impact on public engagement and lifelong learning.
- In Finland, Heureka ([296]), the Finnish Science Centre, located in Vantaa, offers a model of excellence in interdisciplinary, multistakeholder science education. Founded in 1989, Heureka is supported by a foundation that includes universities, industry associations, city authorities and national ministries. It attracts around 300 000 visitors annually, offering permanent and temporary exhibitions, a digital planetarium, science theatre and workshops. Its Pop-up Heureka initiative extends outreach into remote areas, while its international collaboration ensures global relevance. The centre has shown adaptability in the face of challenges, notably expanding its digital content to maintain engagement during the COVID-19 pandemic.
- The Curiosity Centre Futurimo ([297]) in Latvia, launched in cooperation with the Riga city council in 2023, provides an excellent example of targeted investment in youth STEM engagement. Designed to stimulate curiosity and hands-on experimentation among children and adolescents, the centre delivers practical demonstrations in subjects such as chemistry and physics. Futurimo's contribution is measurable; visitor numbers and student interest in STEM fields are tracked through clear indicators, such as the percentage of young people aiming to study STEM at Riga Technical University. These data demonstrate a growing and sustained interest in science and technology careers in Latvia.
- In Luxembourg, science engagement is anchored in institutions like the Luxembourg Science Centre ([298]), which welcomes over 70 000 visitors

([295]) https://www.science-center-net.at/about-the-network/.

([296]) https://www.heureka.fi/en.

([297]) https://futurimo.lv/.

([298]) Luxembourg Science Centre, 'About us', Luxembourg Science Centre website, https://www.science-center.lu/en/about-us.

annually. The centre offers teachers and educators access to experimental tools and demonstrations that complement classroom learning, promoting active and experiential pedagogy. Alongside the Science Centre, the Scienteens Lab, run by the University of Luxembourg, runs advanced workshops targeted at high school students in disciplines ranging from renewable energy to AI. Evaluations show that over 60 % of participants found the experience influential in career planning. With multilingual instruction and continuous pedagogical adaptation, the Scienteens Lab addresses equity and curriculum gaps in STEM education.

- In Poland, the Copernicus Science Centre ([299]) has grown into one of Europe's most visited science centres since its founding in 2010. With over a million visitors annually, it houses hundreds of hands-on exhibits and hosts events like science picnics and transformation festivals. Its strong educational mandate is underpinned by its 2015 status as a scientific unit, enabling it to directly contribute to educational reform and research. The centre recently launched the Copernican Revolution Laboratory, a research and development strand dedicated to advancing science education methodologies and tools.
- Portugal's Ciência Viva – the country's national agency for scientific culture – coordinates a network of science centres and clubs across the country. By 2023, it had engaged over 720 000 students and partnered with more than 4 000 organisations. Ciência Viva offers internships, camps and community science events, with a strong emphasis on reaching girls, minorities and economically disadvantaged youth. Its decentralised partnership-driven structure exemplifies how informal STEM education can achieve national scale and inclusivity ([300]).
- In Slovenia, the Center Noordung ([301]) focuses on space science and education. Through interactive exhibitions, student workshops and collaboration with the European Space Education Resource Office, the centre makes abstract scientific themes accessible to young audiences. By developing didactic tools and accredited training for teachers, Center Noordung enhances synergy between non-formal and formal education while inspiring future careers in aerospace and STEM more broadly.
- Greece's STEM Education organisation ([302]) represents another model of activity rooted in civil society. As a non-profit organisation, it delivers

([299]) https://www.kopernik.org.pl/

([300]) Ciência Viva, *Plano de Atividades 2024*, https://webstorage.cienciaviva.pt/public/pt.cienciaviva.www/sobre/planos/Plano%20de%20Atividades_2024.pdf.

([301]) https://www.center-noordung.si/en/.

([302]) https://stem.edu.gr/en/.

resources, infrastructure and teacher support to schools while coordinating robotics competitions and STEM clubs. By integrating industry partnerships and responding to formal education system needs, STEM Education operates as both a facilitator and an innovator in the national STEM ecosystem.

- Spain's National Research Council ([303]) (Spain's largest public research institution) also contributes to informal science education through its flagship outreach initiative, *todas hacemos ciencia*. This programme aims to promote gender equality in STEM by connecting female researchers with schools, offering workshops and mentorship opportunities that foster inclusiveness and provide role models for STEM careers.

The examples above show that successful informal STEM education initiatives share **several key enabling factors** that make them impactful, scalable and socially embedded. First, cross-sectoral partnerships consistently underpin high-quality delivery. Initiatives such as Maker Faire Rome or Ireland's BT Young Scientist and Technology Exhibition thrive because they mobilise broad alliances – industry, education, media and civil society – resulting in rich, interdisciplinary content and strong outreach capacity. Second, structural anchoring within ecosystems ensures continuity and reach. Programmes embedded in national frameworks (TeaMe 3.0, Ciência Viva, ScienceCenter-Netzwerk) benefit from policy alignment, stable funding and systemic integration, enabling them to evolve beyond episodic events into long-term drivers of STEM literacy and inclusion. Third, accessibility through flexible, low-barrier formats is essential. Science festivals, open laboratories and mobile exhibitions meet learners in diverse settings – schools, streets, screens – broadening participation. Success depends not only on physical access but also on cognitive and emotional engagement, particularly when programmes target under-represented groups (e.g. Malta's inclusive Science in the City, Latvia's Futurimo).

### Mentorship / role model programmes, career counselling, advice and other support for STEM careers

While much attention is given to formal and non-formal STEM learning environments, there is growing recognition that successful engagement in STEM fields depends not only on educational provision but also on targeted support systems – mentorship, career guidance and financial assistance. These mechanisms play a vital role in **bridging transitions between educational levels**, increasing retention of those on STEM pathways and improving participation among under-represented groups. As it was indicated in Section 5.1.2.2, as students advance from primary to secondary and higher education, they often encounter decision points marked by uncertainty, structural constraints stemming from education systems, unequal access to information,

([303]) https://www.csic.es/en/csic.

financial constraints and other difficulties. Effective support programmes can ease these transitions, provide motivational role models and address structural inequities that might otherwise hinder students' progress.

One of the most impactful approaches is providing access to **role models and mentorship**.

- In France, the Blaise Pascal Foundation ([304]) implements several initiatives that connect students, especially girls, with professionals in mathematics and computer science. The *1 scientifique – 1 classe: chiche!* programme ([305]) sends researchers into classrooms to share their career paths and introduce students to the social relevance of digital science. Similarly, the *Journées Filles, maths et informatique* initiative combines workshops and dialogue with female professionals to encourage more girls to pursue STEM disciplines. Since 2021, the foundation has also offered summer schools focused on subjects such as mathematics and astronomy, immersing students in high-level scientific inquiry and boosting their academic confidence.
- Croatia's *ŠUZA* – from School to Science and the Academic Community ([306]) programme is another noteworthy example. Its mission is to motivate students to pursue STEM fields, provide them with the necessary knowledge to enrol in academic programmes in these areas and educate teachers in STEM throughout all educational levels. Organised by the Faculty of Electrical Engineering and Computing at the University of Zagreb, it brings scientists and engineers into schools to run interactive workshops and lectures for both students and teachers. *ŠUZA* not only increases young people's exposure to modern technologies and scientific fields but also equips teachers with new strategies to communicate complex topics in engaging ways. This dual focus on student motivation and teacher development contributes to its long-standing success.
- Similarly, the Researchers at School ([307]) programme in **Luxembourg**, launched in 2010 by the Luxembourg National Research Fund, creates opportunities for secondary students to meet researchers from the public and private sectors. These sessions help students understand the realities of a research career: what it entails, how one can be attained and why such work matters. While systematic impact assessments are lacking,

([304]) https://www.fondation-blaise-pascal.org/.

([305]) https://www.fondation-blaise-pascal.org/nos-actions/les-projets-de-la-fondation/projet-1-scientifique-1-classe-chiche/.

([306]) https://www.fer.unizg.hr/suza/en.

([307]) Luxembourg National Research Fund, 'Sharing insights to inspire the next generation', Luxembourg National Research Fund website, 2 April 2019, https://www.fnr.lu/research-with-impact-fnr-highlight/sharing-insights-to-inspire-the-next-generation/.

anecdotal evidence and testimonials from participants indicate a meaningful influence on career choices.

At the systemic level, **alliances with private partners and national programmes** have proven effective in embedding STEM career orientation into educational ecosystems. In Denmark, the Engineer the Future alliance ([308]), a coalition of more than 50 stakeholders from industry and education, has been instrumental in promoting STEM careers. Through influencer campaigns, curriculum collaboration and outreach events, the alliance works to shift public perception and make engineering careers more visible and attractive, especially to younger students considering higher education pathways.

Estonia offers two strong public–private partnership models: the IT Academy ([309]) (launched in 2012) and the Engineering Academy ([310]) (launched in 2023). These initiatives align secondary, vocational and higher education curricula with the needs of the labour market. They include outreach to schools, teacher training, curriculum support, student competitions and mentoring by professionals. Such structured collaboration and long-term commitment are critical to maintaining continuity across education levels (see Box 34).

**Box 34. Good practice example: IT Academy – Estonia**

**Approach.** The IT Academy is a long-term public–private partnership launched in Estonia in 2012 to address the national shortage of skilled ICT professionals. Originally focused on higher education, the programme has since expanded to include secondary and vocational education as of 2023. It is coordinated through collaboration between the Estonian government, universities, vocational education institutions and the Association of IT Companies. The IT Academy takes a system-wide approach by targeting curriculum development, improving teaching quality and fostering early engagement in ICT. The initiative supports the creation of a coherent ICT learning pathway from secondary school through to university, while also responding to workforce needs in Estonia's digital economy. The programme is backed by substantial long-term funding, with a budget of EUR 22.1 million allocated for 2023–2029.

**Objectives.** The primary goals of the IT Academy are to strengthen ICT curricula, raise teaching competences and reduce dropout rates in higher education, particularly in ICT-related fields. It also aims to improve the alignment of secondary, vocational and higher education programmes, making transitions smoother and helping young people make informed decisions about digital careers. By exposing students to computer science fundamentals early on, the initiative works to enhance digital literacy, raise awareness of ICT professions, and increase the number and quality of graduates entering the tech sector.

**Target groups.** The programme initially focused on higher education students but now includes secondary school pupils, vocational-education learners and teachers at all levels. Its reach spans universities, three pilot vocational institutions, and selected secondary schools involved in ICT pathway development and outreach activities. The initiative also targets university- and school-level educators through its teacher training and development programmes.

**Activities.** IT Academy activities are implemented through partnerships that include universities and vocational schools. Key components include:

([308]) https://engineerthefuture.dk/.

([309]) https://www.educationestonia.org/it-academy/.

([310]) https://harno.ee/inseneriakadeemia#inseneriakadeemia-ul.

- curriculum development in digital competences and ICT across secondary, vocational, and higher education;
- teacher training and professional development, with digital tools and teaching materials often shared across institutions;
- outreach and preparatory programmes in secondary schools, delivered in partnership with universities and industry, to introduce students to computer science and digital technologies before university enrolment;
- digital career awareness campaigns, including school visits, student competitions and media outreach, to raise visibility of STEM career paths;
- support for vocational institutions, three of which have fully integrated IT Academy activities into their programmes;
- development of scalable teaching materials and projects that can be adapted for use across educational levels.

**Results/impacts.** The IT Academy has had a visible, positive impact on Estonia's ICT education pipeline. One key indicator is the slowing decline in students pursuing STEM education – from a 15 % drop in 2013 to just 4 % in 2022 – suggesting a stabilisation of interest ([311]). Moreover, schools participating in IT Academy programmes report higher average graduation grades, indicating improvements in student performance and academic preparation. The initiative has also led to stronger alignment between school- and university-level ICT curricula, reinforcing a coherent digital education ecosystem. Through its flexible and partnership-driven model, IT Academy has demonstrated strong scalability potential without compromising effectiveness ([312]). It is increasingly seen as a replicable model for other countries aiming to strengthen their national digital talent pipelines through sustained collaboration between education and industry.

In Belgium's French-speaking community, the STEMentiel ([313]) platform provides a combined educational and career exploration experience. Focused on sustainable development, space and digital technology, the platform allows students and teachers to engage with curated scientific content. In addition, the platform facilitates school visits from STEM professionals. A distinctive feature of STEMentiel is indeed its engagement with professionals from STEM-related fields, who can be invited into classrooms to share insights about their careers. This direct interaction bridges theoretical content with real-world careers, enhancing both motivation and relevance.

**Targeted guidance and career orientation** are equally important. Hungary's Career Orientation programme ([314]) aimed to familiarise students with STEM professions through workshops and hands-on activities. While the initiative successfully increased STEM awareness in many schools, evaluations highlighted structural shortcomings – especially in reaching disadvantaged students and innovating beyond traditional formats. Its lessons emphasise the

([311]) https://harno.ee/it-akadeemia-programm.

([312]) https://harno.ee/it-akadeemia-programm.

([313]) https://www.stementiel.be/.

([314]) Hungarian Ministry of Human Capacities, *EFOP-3.2.5-17 Career Orientation Program Guidelines*, Budapest, 2020.

need to design guidance programmes that are both inclusive and context sensitive ([315]).

Malta's Unconventional Science Careers initiative reflects a promising approach to broadening students' understanding of STEM pathways. Targeting year-8 students, the programme organises immersive visits to university faculties, where students explore less-visible careers in fields like robotics, coding and virtual reality. These early interventions help students see STEM as diverse and attainable, especially when they include opportunities for direct interaction with researchers and course guidance.

Similarly, Malta's Teen Science Café and Tiny Teen Science Café programmes, coordinated by the Science Centre within the Ministry for Education, provide valuable platforms for students to meet STEM professionals. These initiatives promote career awareness by enabling children and young people to interact informally with scientists and engineers in accessible formats, encouraging interest in STEM from a young age and addressing gender gaps through targeted outreach, such as the women in STEM strand.

The importance of **financial support** should not be underestimated. In Croatia, the national Ministry of Science and Education introduced fully automated state scholarships ([316]) for students in STEM fields in 2018. The scholarships aim to promote enrolment in priority fields and support talented students throughout their studies, particularly those from disadvantaged backgrounds. Approximately 3 400 scholarships are awarded each academic year. Each scholarship provides EUR 160 per month for nine months (October to June), and the process is entirely automated – students do not need to apply individually. Eligibility is determined using official academic data from the national enrolment and evaluation systems and socioeconomic indicators (e.g. eligibility for social assistance or the student's place of residence). Students are notified through their university email accounts. The programme covers full-time undergraduate and integrated bachelor–master students in recognised STEM programmes and is open to Croatian nationals, EU citizens with registered residence and individuals with approved international or temporary protection status.

These examples indicate several **key enabling factors of successful schemes** focused on support for STEM career orientation and mentorship.

- **Early engagement and continuity across education levels.** Successful programmes begin career guidance in lower-secondary or even primary

([315]) Kopint-Tárki Institute for Economic Research, *Evaluation report on measures promoting access to higher education: Lessons from the EFOP programmes*, Kopint-Tárki Institute for Economic Research, Budapest, 2023, https://kopint-tarki.hu/wp-content/uploads/2023/03/Felsooktatasi-Ertekelo-Jelentes.pdf.

([316]) Republic of Croatia Ministry of Science, Education and Youth, 'State scholarships for students in STEM subjects', Republic of Croatia Ministry of Science, Education and Youth website, https://mzom.gov.hr/highlights/education/state-scholarships/state-scholarships-for-students-in-stem-subjects/4055.

school, ensuring continuity as students progress. This is particularly relevant considering previous findings that, in many systems, curricular and teaching approaches often change abruptly between primary and lower-secondary – when siloed natural science subjects are usually introduced – and again between lower- and upper-secondary levels. These discontinuities might create learning gaps and hinder the development of coherent STEM competences.

- **Mentorship by relatable role models.** Opportunities to meet professionals, especially those from under-represented groups, help students visualise a future in STEM. Students respond positively to practical, hands-on learning experiences and examples that show the relevance of STEM skills to real-world problems.
- **Whole-school/ecosystem approaches.** Programmes that align secondary and higher education with labour market needs and include teacher training tend to have greater long-term impact, as evidenced by the Estonian IT Academy programme.
- **Sustained funding and institutional commitment.** Long-term, adequately resourced programmes such as Estonia's IT Academy or Denmark's Engineer the Future offer stable support to students and schools.
- **Equity in access.** Programmes targeting students from disadvantaged backgrounds or those under-represented in STEM, through financial support or tailored interventions, are critical for broadening participation.

#### 5.1.3.7. Data availability and research on promoting STEM education in schools

Country-level mapping of instruments promoting STEM education in schools also reveals persistent and systemic weaknesses in the availability and quality of data.

- At the system level, countries often **rely heavily on international large-scale assessments, such as PISA and TIMSS**, to gauge performance in mathematics and science. While these tools provide useful benchmarking, they offer limited scope for monitoring the specific impact of national policies or reforms and do not provide granular real-time insights into what works in local contexts.
- At the level of individual instruments or programmes, the **lack of robust monitoring and evaluation remains a major challenge**. Most initiatives only track output indicators, such as the number of participants, teachers trained or resources distributed. In cases where evaluations do take place, they are typically confined to immediate feedback – such as participant satisfaction or perceived knowledge gain – without assessing long-term impact on student outcomes, career trajectories or systemic change.

- Longitudinal studies, which are especially critical in STEM education given the long-term nature of skill acquisition and career formation, are rare. The main reasons for this include the complexity, cost and technical capacity required – factors particularly challenging for NGOs and local education providers, which often lead STEM initiatives.

Despite these challenges, several countries offer good-practice examples of data generation, research and monitoring that can serve as inspiration for more evidence-based policymaking.

- In Croatia, the JOBSTEM project (full title – STEM career aspirations during primary schooling: a cohort-sequential longitudinal study of relations between achievement, self-competence beliefs and career interests) stands out as a rare example of a well-structured longitudinal research effort. Conducted by Croatian and international researchers over four years, JOBSTEM ([317]) examined STEM interest and career aspirations among younger primary school students across 16 schools. Using an experimental longitudinal-sequential design, the project tracked three cohorts from grades 4–6, employing a combination of quantitative and qualitative methods. In addition to extensive data collection (surveys of over 2 100 students and in-depth assessments of 1 053 students), the project implemented targeted interventions including hands-on workshops, robotics activities and educational visits. The findings offered deep insights into the factors influencing STEM interest among both high- and low-achieving students. Crucially, it highlighted the importance of early engagement, the value of informal learning and the need for differentiated approaches to reach students with varying levels of self-confidence and from different socioeconomic backgrounds.
- In Denmark, Research on Children and Young People's Interest in Science (the SCOPE project) ([318]) represents one of the most ambitious monitoring undertakings in Europe. Launched in 2020, it is designed as a 10-year longitudinal study of students' evolving relationship with science. By focusing on the concept of 'science capital', the project explores how different socioeconomic and cultural factors influence a child's ability to engage with science meaningfully over time. Though still in its early phases, SCOPE aims to inform systemic interventions and guide curriculum development by offering longitudinal insight into the enablers of and barriers to science participation.
- The Longitudinal Study of Basic Education Outcomes (which started in 2018 and is ongoing) is conducted by the Finnish Education Evaluation Centre ([319]). Launched in the autumn of 2018 with a cohort of first-graders,

([317]) http://www.jobstem.eu/project/.

([318]) SCOPE - Research on children and young people's interest in science - Novo Nordisk Fonden

([319]) https://www.karvi.fi/en/evaluations/pre-primary-and-basic-education/learning-outcomes-evaluations/longitudinal-assessment-learning-outcomes-basic-education-first-and-third-grade.

this study tracks students' learning outcomes at key transition points – third grade (2020), sixth grade (2023), with follow-ups planned at the end of and of ninth grade – and in upper-secondary and higher education. It assesses competences in mathematics; mother tongue/literature (Finnish/Swedish); and transversal skills, aligned with Finland's national curriculum. About 10 000 students were tested in the first phase to establish a baseline, followed by a second assessment in 2020 to measure early progress ([320]). The study is expected to yield important insights into how students' skills develop over time and where learning gains or gaps emerge.

- In Germany, the National Educational Panel Study ([321]) – a long-term cohort study of educational trajectories – is conducted by the Leibniz Institute and funded by the Federal Ministry of Education and Research. It started in 2009 and is the largest longitudinal education study in Germany, tracking more than 70 000 individuals and 50 000 of their parents/teachers over time. Several cohorts cover primary and secondary education – for example, one cohort was first surveyed in grade 5 and another in grade 9 – allowing analysis of STEM skills development during school years. The study collects detailed data on students' competences in mathematics and science, educational choices and progression into higher education or careers. It uses periodic assessments and interviews to understand how competences evolve and what factors (e.g. family background, school context or gender) influence educational outcomes in STEM fields.
- In Belgium's Flemish Region, as part of its STEM Action Plan, a STEM Monitor has been set up ([322]) – a data tracking system of indicators (enrolments, graduations and transitions in STEM fields) to annually measure progress towards the plan's targets. The monitor tracks students' inflow into STEM-oriented study tracks in secondary education, their outflow into STEM higher education and eventual entry into STEM occupations, together with gender breakdowns at each stage. This combination of policy interventions and continuous research/monitoring allows for longitudinal insights into the Action Planeffects.
- Another example from Denmark is the LabSTEM project ([323]), which emphasises teacher-led experimentation with integrated STEM activities. The initiative resulted in detailed practical guides and booklets for various

([320]) https://www.karvi.fi/en/longitudinal-assessment-learning-outcomes-basic-education-first-phase.

([321]) https://www.lifbi.de/en-us/Start/Research/Large-Scale-Projects/NEPS-National-Educational-Panel-Study/NEPS-chronicles.

([322]) https://www.vlaanderen.be/publicaties/stem-monitor.

([323]) https://www.sdu.dk/en/forskning/labstem.

educational levels – from daycare to technical school – and provides an evidence-informed basis for integrating mathematics-focused STEM learning in formal curricula. While not longitudinal in nature, the project is noteworthy for its collaborative approach, engaging educators at different educational levels in co-designing and testing innovative activities.

- Slovenia provides multiple examples of system-wide efforts to combine curriculum innovation with data generation. The *naravoslovje, matematika, pismenost, opolnomočenje, technologija, interaktivnost* (NA-MA POTI) project (2017–2022) ([324]), coordinated by the National Education Institute, was aimed at developing pedagogical strategies for enhancing scientific, mathematical and financial literacy from kindergarten through to secondary school. It involved 98 institutions and collaborated with 7 faculties to produce over 7 000 learning resources and 10 methodological guides. These materials were piloted and evaluated across institutions, and the outcomes were used to inform teaching practice. Complementing this, the *Inovativna Pedagogika* 1:1 project ([325]) aimed to reduce the digital divide by developing ICT-supported learning environments. The project included extensive piloting in 75 schools and demonstrated improvements in digital inclusion and teaching practice. Its successor, *Innovative Pedagogy* 5.0 ([326]), continues this work by focusing on computational thinking and informatics integration, reaching 480 classrooms across the country. These projects include embedded monitoring and evaluation components that assess both implementation and student learning outcomes.

- Also in Slovenia, the B-RIN project (full title: development of core computer content and knowledge in computer science and informatics in kindergartens and primary schools) (2023–2026) ([327]) represents a forward-looking effort to pilot and evaluate informatics and computing education in early childhood and primary education. Co-funded by the EU's Recovery and Resilience Plan, B-RIN features experimental design and output evaluation tools, offering another model for combining educational innovation with structured research.

These examples demonstrate that, while robust monitoring and evaluation remain the exception rather than the rule, they are achievable. When well designed, they provide critical insights into what works in STEM education, for whom and under what conditions.

([324]) https://www.zrss.si/projekti/projekt-na-ma-poti/.

([325]) https://www.zrss.si/projekti/inovativna-pedagogika-11-2/.

([326]) https://inovativna-sola.si/.

([327]) https://www.cedefop.europa.eu/en/news/slovenia-recently-implemented-action-plan-andi-transform-digital-education; https://nobrainogain.eu/b-rin/.

The most impactful initiatives share several **success factors**. First, they involve **sustained partnerships between researchers, education institutions and government bodies**, ensuring scientific rigour and policy relevance. Second, they are embedded within the national or regional education systems, allowing findings to directly inform practice. Third, they adopt mixed-method approaches that combine qualitative insights with longitudinal quantitative tracking of student outcomes. Finally, they provide open-access resources and guidance to scale up learning and inform peer initiatives. These features not only strengthen the evidence base but also foster a culture of continuous improvement in STEM education policy and practice.

### 5.1.4. Key lessons learned from non-EU countries

As part of the study's broader objective to identify examples of international good practice and policy learning opportunities, six non-EU countries – Australia, Canada, Japan, Peru, Singapore and Switzerland – were selected for in-depth review. The selection was based on a combination of factors, including international recognition for innovation or excellence in STEM education (e.g. strong PISA or TIMSS performance), structural similarities or complementarities with EU education systems (e.g. decentralisation, dual VET models) and geographical and socioeconomic diversity to ensure a breadth of transferable insights. Each country offers examples of effective responses to challenges commonly faced across Member States, ranging from teacher shortages and curriculum rigidity to limited interdisciplinary learning, insufficient collaboration with external actors and inequities in access and participation.

The sections below synthesise selected good practices that are particularly relevant to the European context. Rather than providing comprehensive country profiles, they highlight specific approaches and institutional arrangements that align with the key challenges and policy areas identified in Sections 5.1.2 to 5.1.3 of this report.

#### 5.1.4.1. Switzerland – integrated vocational pathways and strong cross-sectoral partnerships

Switzerland demonstrates how coherent governance and systematic stakeholder collaboration can strengthen the alignment between STEM education and labour market needs. The country's dual VET system integrates academic instruction with structured workplace learning across a wide range of STEM-related sectors. The active involvement of industry bodies (e.g. Swissmem), cantonal authorities and national institutions (e.g. the State Secretariat for Education, Research and Innovation and the Swiss Federal Institute for Vocational Education and Training) ensures that curricula remain relevant and adaptive.

In particular, Switzerland offers good practice examples of:

- cross-sectoral coordination through a well-structured federal–cantonal governance model that allows regional flexibility while ensuring coherence in STEM policy;
- industry–school collaboration, with companies providing apprenticeships, co-designing curricula and contributing to STEM outreach and career guidance;
- flexible pathways, enabling transitions between vocational and academic tracks, thereby broadening participation and reducing stratification.

These features provide useful insights for Member States seeking to improve the attractiveness of VET, enhance work-based learning in STEM and institutionalise partnerships between schools and the private sector.

#### 5.1.4.2. Japan – specialised STEM schools and research-linked learning

Japan offers a long-standing example of national-level coordination to promote excellence in STEM education through specialised institutions. The Super Science High School programme, supported by the Japan Science and Technology Agency, fosters inquiry-based and project-oriented STEM learning in upper-secondary schools. Schools receive additional funding and access to university and industry partners, allowing them to develop advanced curricula, conduct research projects and participate in science fairs and international exchanges.

A key feature of Japan's approach is the emphasis on **cross-disciplinary inquiry**, whereby students work on complex open-ended problems that integrate knowledge and skills from across STEM subjects, often extending into the social sciences and humanities. These projects promote systems thinking, collaboration and scientific communication, aligning with core STEM competence frameworks and the integrated learning models increasingly promoted in Europe.

Key elements of good practice include:

- institutional specialisation through dedicated school models that promote deep engagement in STEM fields;
- partnership-based innovation, linking schools with higher education and research organisations to promote cutting-edge hands-on learning;
- strategic governance, with coordination across education and science ministries to ensure sustainability and national reach.

Japan's example illustrates how structural support and targeted investment can facilitate excellence and expand opportunities for gifted students in STEM, while also offering models for mainstream schools seeking to strengthen science inquiry and real-world applications.

### 5.1.4.3. Singapore – whole-system reform and integrated pedagogy

Singapore exemplifies long-term system-wide reform in STEM education, underpinned by coherent governance, a future-oriented curriculum and sustained investment in teachers' professional development. Its approach is notable for aligning curriculum, pedagogy, assessment and teacher development within a broader strategy of national economic and social transformation, making it highly relevant for European systems aiming to strengthen systemic coherence and policy alignment.

A cornerstone of Singapore's model is the Applied Learning Programme (ALP), introduced across all secondary schools to foster interdisciplinary real-world learning in areas such as robotics, environmental science, biotechnology and design. The ALP encourages schools to develop their own STEM specialisms, often in collaboration with industry and higher education institutions, while following national guidelines. This supports both curricular innovation and local adaptability.

The ALP is complemented by the Learning for Life Programme (see Box 35), which focuses on values-based education and often intersects with STEM through sustainability, health or digital citizenship themes. Together, these initiatives exemplify how STEM can be embedded in whole-school approaches that are both inclusive and mission driven.

Further good practices include the following.

- **Integrated curriculum and assessment reform.** STEM competences are embedded across subject areas, and assessment frameworks include performance-based and project-based evaluations designed to assess inquiry, collaboration and applied problem-solving skills. These are aligned with the national 21st Century Competence Framework.
- **Robust teacher education and professional learning ecosystem.** All teachers are trained at the National Institute of Education, with access to structured career pathways, continuous professional development and specialisation in STEM pedagogy. Teaching is a high-status profession supported by rigorous selection and career development structures.
- **Data-driven planning and innovation.** Singapore leverages digital platforms and learning analytics to personalise instruction and monitor student progress. Tools such as the Student Learning Space provide digital content aligned with the curriculum and facilitate blended learning across schools.
- **Policy coherence across sectors.** STEM education reforms are tightly coordinated with national economic planning, research and innovation policy and workforce development strategies, notably through

collaboration among the Ministry of Education, SkillsFuture Singapore, and the Economic Development Board.

Singapore's approach is particularly relevant for Member States aiming to:

- strengthen cross-ministerial alignment of education and innovation policy;
- build school capacity for local curriculum innovation within national frameworks;
- promote inclusive excellence through differentiated pathways and school-level STEM specialisation;
- ensure system-wide support for teacher recruitment, training and retention in STEM fields.

**Box 35. Good practice example: Applied Learning Programme – Singapore**

Singapore's Applied Learning Programme (ALP) ([328]) was introduced by the Ministry of Education in 2014 to strengthen the connection between academic learning and real-world application, beginning with a focus on STEM. Designed as a non-examinable, school-owned initiative, ALP encourages schools to develop context-specific programmes that promote creativity, inquiry and problem-solving through hands-on, experiential learning. By 2023, ALPs were implemented in all primary and secondary schools, expanding beyond STEM to include five other domains, including languages, the humanities and entrepreneurship ([329]). Despite this broadening, STEM remains the most popular focus, with 41 % of schools offering STEM-related ALPs as of 2022.

A key design feature is that ALPs are insulated from exam-driven pressures, with dedicated curriculum time and pedagogical freedom, setting them apart from typical enrichment activities. STEM ALPs are particularly noted for their practical, engaging projects, such as prototyping smart devices or designing energy-efficient solutions, which stimulate students' curiosity and build foundational skills for future STEM study or careers.

To support schools, the Ministry of Education collaborates with STEM Inc., a dedicated unit within Science Centre Singapore. STEM Inc. provides structured implementation support through three key components: (1) pairing each school with a Ministry of Education officer and STEM Inc. curriculum specialist to co-develop lesson packages; (2) assigning a full-time STEM educator to each school for up to three years to co-teach, mentor staff and help embed the ALP into school culture; and (3) mobilising industry professionals through the STEM Industrial Partnership programme, offering real-world mentorship and exposure ([330]).

([328]) Ministry of Education (Singapore*),* Applied Learning Programme (ALP) – School-specific opportunities', Ministry of Education website, accessed 4 December 2024, Applied Learning Programme (ALP) | MOE.

([329]) Tan, A.-L. and Teo, T. W., 'Status and trends of STEM education in Singapore', in: Lee, Y.-F. and Lee, L.-S. (eds), *Status and trends of STEM education in highly competitive countries: Country reports and international comparison*, National Taiwan Normal University and K–12 Education Administration (Taiwan) and Technological and Vocational Education Research Center, Taipei, 2022.

([330]) Teo, T. W. and Choy, B. H., 'STEM education in Singapore', in: Tan, K. H., Kim, C. and Wee, C. L. (eds), *Singapore Math and Science Education Innovation: Beyond PISA*, Springer, Singapore, 2021, pp. 43–59.

#### 5.1.4.4. Australia – targeted inclusion strategies and digital innovation

Australia provides a diverse set of good practices that address many of the challenges identified in this study, particularly in relation to equitable participation, early STEM engagement and digital learning integration. Its federal system allows states and territories to trial differentiated approaches, resulting in a dynamic ecosystem of programmes supported by national coordination and resource platforms.

One significant initiative is the Early Learning STEM Australia (ELSA) programme, which targets ECEC to build foundational STEM thinking and curiosity in children aged four to six years old. Developed by the University of Canberra and funded by the Australian Government Department of Education, ELSA provides a research-informed digital toolkit that introduces young learners to key STEM concepts, such as patterns, spatial reasoning, measurement and data, through play-based activities. The toolkit supports both digital and hands-on learning and is designed to build educator confidence and capacity through accompanying professional development modules.

The ELSA initiative illustrates effective practice in:

- early STEM engagement through age-appropriate, inquiry-based learning experiences that support cognitive and socioemotional development;
- digital tool integration in the early years, with platforms that are developmentally aligned and pedagogically sound;
- equity of access, with resources tailored to diverse settings, including remote and disadvantaged communities.

In the formal education system, Australia also promotes equity in later phases of STEM learning through initiatives such as the Girls in STEM Toolkit and the indigenous STEM Education Project, which provide targeted learning pathways, mentorship and culturally relevant curriculum content. These efforts aim to address long-standing participation gaps and broaden access to STEM careers.

Other key good practices include:

- localised, flexible curricula, which allow states and schools to adapt content and pedagogy to local industry needs, cultural contexts and learner profiles;
- national digital resource hubs, such as the STEM Learning Hub and Digital Technologies Hub, which provide curated teaching resources and facilitate teacher networking across jurisdictions;
- whole-system digital integration, including national digital assessment trials and teacher capacity building in computational thinking and data literacy.

Australia's experience is particularly relevant for European education systems seeking to:

- embed STEM education from early years onwards, including in ECEC policy frameworks;
- expand the use of high-quality digital tools to support differentiated and inclusive learning;
- design equity-oriented interventions that engage under-represented learners across gender, geography and ethnicity.

By investing in scalable research-based programmes and ensuring national coordination of digital and pedagogical infrastructure, Australia demonstrates how inclusive STEM education can be embedded across the learning continuum, from early childhood to upper-secondary education.

#### 5.1.4.5. Canada – community engagement and experiential learning

Canada's federal structure and high degree of provincial autonomy have created an environment that allows innovation in STEM education at the regional and local levels. Provinces and territories are responsible for education policy, which has enabled diverse and context-specific approaches to curriculum design, equity strategies and cross-sectoral collaboration.

One example is Ontario's specialist High Skills Major programme, which allows upper-secondary students to pursue focused learning tracks in key economic sectors, including STEM fields, such as information technology, health and wellness, environmental studies and engineering. Students following this programme take credits tailored to the sector, engage in workplace learning, earn industry-recognised certifications and explore post-secondary-education pathways through dual enrolment and career guidance. The programme exemplifies how STEM can be embedded into flexible career-oriented learning pathways that respond to regional labour market needs while maintaining academic rigour.

In British Columbia and other provinces, interdisciplinary, project-based and place-based learning has become a prominent feature of STEM curriculum reform. Schools integrate STEM with sustainability, indigenous knowledge systems and global citizenship education, aligning well with EU priorities around the green and digital transitions.

Canada also offers relevant good practices in:

- community and industry engagement, with strong links between schools, employers, higher education and indigenous communities to co-design learning experiences and ensure local relevance;

- equity-oriented curriculum development, including initiatives to engage under-represented groups, such as girls, ethic minority students, and First Nations, Métis and Inuit learners;
- teacher support and professional learning, delivered through provincial resource hubs, networks and professional associations with a focus on inquiry, digital skills and inclusive pedagogy;
- digital innovation, as several provinces have introduced digital portfolios and performance-based assessments to track student progress in problem-solving, collaboration and design, which are supported by online platforms for resource sharing and peer collaboration among educators.

Canada's decentralised yet collaborative approach offers valuable insights for Member States seeking to:

- empower schools and regional authorities to co-create STEM learning opportunities that reflect local identities, priorities and labour markets;
- develop inclusive and responsive curriculum frameworks that embed STEM across disciplines and cultures;
- foster partnerships between formal and informal learning sectors, including through community-based programmes and non-traditional learning spaces.

By demonstrating how equity, innovation and career readiness can be advanced simultaneously within diverse systems, Canada serves as a model for flexible and inclusive STEM policy implementation at multiple levels.

#### 5.1.4.6. Peru – expanding STEM participation through low-cost innovation and community outreach

Peru illustrates how emerging economies can foster innovative and inclusive approaches to STEM education despite significant resource constraints. In recent years, the country has taken deliberate steps to broaden STEM engagement, particularly in underserved and rural areas, by leveraging non-formal learning, international partnerships and targeted teacher support (see Box 36).

One of the most notable initiatives is Science Clubs Peru (*Clubes de Ciencia Perú*), a non-profit programme implemented in partnership with universities and the Ministry of Education. It offers free short-term STEM workshops led by scientists and graduate students for secondary-level learners across the country. The clubs emphasise hands-on, inquiry-based learning and provide students, particularly those from marginalised backgrounds, with exposure to real-world science and technology applications. This initiative reflects the growing role of non-formal, informal and extracurricular learning in widening participation and sparking interest in STEM fields.

In parallel, the annual National Science and Technology Week (*Semana Nacional de la Ciencia y Tecnología*), coordinated by the National Council for Science, Technology and Technological Innovation, provides a national platform for public engagement in STEM. Activities include mobile science fairs, interactive exhibitions and outreach to schools and families, bringing science education into communities with limited access to formal infrastructure.

Peru also offers examples of promising practices in:

- teacher training and pedagogical innovation – particularly in science education – through collaborations between the Ministry of Education, universities and international donors, with initiatives including cascade training models, active learning toolkits and regional training hubs targeting under-resourced areas.
- curriculum development integrating sustainability, with recent reforms embedding environmental science, climate change and natural resource management into upper primary and secondary curricula;
- public–private and international partnerships, which have supported the roll-out of low-cost digital tools and mobile laboratories in rural schools, contributing to more equitable access.

Despite systemic challenges, such as infrastructure disparities, teacher shortage and limited evaluation capacity, Peru demonstrates how targeted, scalable interventions can generate momentum for STEM education reform. These approaches are especially relevant for parts of Europe facing similar constraints, such as remote regions, areas with high socioeconomic disadvantage or countries rebuilding education systems post-crisis.

**Box 36. Good practice example: National Programme for Educational Infrastructure – Peru**

The National Programme for Educational Infrastructure was established in 2014 in Peru and is dedicated to enhancing the physical infrastructure of educational institutions, with a particular focus on rural and underserved regions. While the programme's primary objective is to improve school facilities overall, it also emphasises the advancement of STEM education. This is achieved through the construction and refurbishment of science laboratories, the provision of modern technological equipment and the creation of dynamic learning environments conducive to practical and interactive STEM learning experiences.

The programme has initiated numerous projects across the country, contributing to a reduction in the infrastructure gap and fostering an improved learning environment for students. Specific outputs also include the construction and refurbishment of hundreds of schools. By integrating these resources, the programme aims to bridge educational disparities, foster an interest in STEM subjects among students and equip them with essential skills for the modern world. The programme's initiatives have led to notable improvements in the quality of education, particularly in areas that previously lacked adequate facilities, thereby contributing to the overall development of Peru's educational landscape.

## 5.2. Role of the EU in STEM education

The EU simultaneously promotes STEM education in schools at the strategic level, providing direction and targets for EU and Member State action, and at the programme level, which translates into concrete projects funded by the various programmes available under direct, shared or indirect management of the European Commission. While Section 4.3 outlines the broader EU policy context and key strategic initiatives relevant to STEM education in schools, this section examines the EU's contribution through specific instruments and programmes.

This includes the Erasmus+ programme and other programmes, such as the Digital Europe programme, Horizon Europe and its predecessors. The European Structural and Investment Funds, particularly the European Social Fund+ (ESF+) and European Regional Development Fund (ERDF), foster regional implementation of reforms and investment. Yet other programmes encourage reforms at the national level of Member States, notably those funded by the Recovery and Resilience Facility (RRF), InvestEU, and the Technical Support Instrument (TSI) and its predecessor, the Structural Reform Support Programme (SRSP).

EU instruments operate at different levels and provide complementary levers to support reforms and investments in school-level STEM education. For example, funding programmes like Erasmus+ and Horizon Europe often support cross-border cooperation and innovation in teaching practices. In contrast, structural instruments such as the ESIF or the TSI are designed to support larger-scale reforms and investments at the national or regional level. These structural instruments can help scale up successful innovations or implement systemic reforms – provided that STEM education is prioritised in national or regional strategies.

A common challenge associated with all these instruments, however, is the lack of consistent and systemic data on how STEM education is being implemented and reformed across Member States – especially at the school or local project level. While data from projects funded through, for example, Erasmus+ or Horizon Europe are systematically collected and available at the EU level, comparable insights from national programmes or regionally funded initiatives are often fragmented or missing. This imbalance limits the EU's ability to draw a comprehensive picture of the impact of those instruments on STEM education developments across Europe.

The remainder of this section summarises the findings related to EU programmes. We start by presenting the contributions of Erasmus+, followed a section dedicated to other EU instruments (EU Framework Programmes, ESIF, TSI and Digital Europe).

### 5.2.1. Analysis of Erasmus+ contributions to STEM education

Erasmus+ is the EU's key funding programme for all levels of education. The budget available for Erasmus+ in the 2021–2027 programming period is approximately EUR 26 billion ([331]). In order to approximate the overall number of STEM-related projects and the financial support made available to them, the current study performed a keyword search on all Erasmus+ good practices available on the Erasmus+ Project Results Platform ([332]). This high-level overview has been further complemented by a more detailed analysis of 127 Erasmus+ projects.

An in-depth analysis of Erasmus+ project data reveals substantial support for STEM education in schools, particularly through mobility and cooperation initiatives. Between 2014 and 2020, **over 4 100 good practice projects** relevant to STEM education in schools were supported by Erasmus+, representing a total EU grant of approximately EUR 593 million. In the current (2021–2027) programming period, 179 good practice projects have been identified so far, with a total budget of EUR 14.6 million – figures that are expected to grow as the programme progresses ([333]). Most STEM-relevant projects are implemented under key action 1 ('Learning mobility of individuals') and key action 2 ('Cooperation among organisations and institutions'), reflecting the programme's strength in promoting cross-border teacher development, school partnerships and innovation in teaching practices (see Tables 2 and 3). This suggests that, while Erasmus+ plays a vital role in enabling local- and school-level STEM initiatives, its potential to support broader policy innovation in STEM education is not fully realised.

**Table 2. Erasmus+ STEM good practice projects during the 2014–2020 programming period**

| Key action | Number of projects | Sum of EU grants awarded (EUR) | Average value of EU grant awarded (EUR) |
|---|---|---|---|
| **KA1 – learning mobility of individuals** | 2 438 | 288 733 476.60 | 118 430.47 |
| **KA2 – cooperation for innovation and the exchange of good practices** | 1 661 | 304 621 507.02 | 183 396.45 |

([331]) https://erasmus-plus.ec.europa.eu/programme-guide/part-a/priorities-of-the-erasmus-programme/budget.

([332]) The project records were made available by the European Commission. The only ones included were finished projects marked as 'good practice', that is, with a final evaluation score of at least 80 out of 100.

([333]) Since the analysis only focused on good practice projects, the total number of projects addressing STEM education can be assumed to be even higher.

| | | | |
|---|---|---|---|
| **KA3 – support for policy reform** | 11 | 487 074.55 | 44 279.50 |
| **Total** | **4 110** | **593 842 058.17** | **346 106.42** |

*Note:* KA, key action.
*Source:* Technopolis Group based on the Erasmus+ Project Results Platform.

**Table 3. Erasmus+ STEM good practice projects during the 2021–2027 programming period**

| Key action | Number of projects | Sum of EU grants awarded (EUR) | Average value of EU grant awarded (EUR) |
|---|---|---|---|
| **KA1 – learning mobility of individuals** | 112 | 3 660 672.28 | 32 684.57 |
| **KA2 – cooperation among organisations and institutions** | 67 | 10 981 052.20 | 163 896.30 |
| **Total** | **179** | **14 641 724.48** | **196 580.87** |

*Note:* KA, key action.
*Source:* Technopolis Group based on the Erasmus+ Project Results Platform.

Looking at the geographical distribution of STEM-related Erasmus+ projects over both programming periods (Table 4), the countries strongly represented in the sample include larger Member States such as Spain, with the highest number of projects (541), followed by Germany (330), Poland (303), France (262) and Italy (234). Medium-sized to smaller Member States are also featured with a large number of projects, including Czechia (209), followed by Slovakia (200), Belgium (162), Croatia (131) and Romania (124). Most remaining Member States were host to roughly 30 to 100 projects. The lower end is composed of Luxembourg, which coordinated 13 of the identified Erasmus+ good practice projects. Of non-EU countries, the United Kingdom, with data spanning 2014–2020, had 205 projects. Türkiye has also been a key programme country, with 88 projects.

**Table 4. Geographical distribution of Erasmus+ good practice projects**

| Coordinator country | KA1 | KA2 | KA3 | Total |
|---|---|---|---|---|
| **Belgium** | 101 | 61 | | **162** |
| **Bulgaria** | 14 | 21 | | **35** |
| **Czechia** | 158 | 51 | | **209** |
| **Denmark** | 19 | 11 | | **30** |
| **Germany** | 143 | 187 | | **330** |
| **Estonia** | 20 | 21 | | **41** |
| **Ireland** | 93 | 14 | 1 | **108** |
| **Greece** | 37 | 55 | 1 | **93** |

| Coordinator country | KA1 | KA2 | KA3 | Total |
|---|---|---|---|---|
| **Spain** | 387 | 154 | | **541** |
| **France** | 134 | 128 | | **262** |
| **Croatia** | 95 | 36 | | **131** |
| **Italy** | 125 | 109 | | **234** |
| **Cyprus** | 63 | 33 | 1 | **97** |
| **Latvia** | 47 | 32 | | **79** |
| **Lithuania** | 21 | 79 | | **100** |
| **Luxembourg** | 9 | 4 | | **13** |
| **Hungary** | 185 | 29 | | **214** |
| **Malta** | 23 | 11 | | **34** |
| **Netherlands** | 48 | 48 | | **96** |
| **Austria** | 45 | 62 | 1 | **108** |
| **Poland** | 119 | 184 | | **303** |
| **Portugal** | 79 | 25 | | **104** |
| **Romania** | 80 | 43 | 1 | **124** |
| **Slovenia** | 67 | 21 | 1 | **89** |
| **Slovakia** | 118 | 82 | | **200** |
| **Finland** | 33 | 27 | | **60** |
| **Sweden** | 61 | 40 | 1 | **102** |
| **Iceland** | 28 | 8 | 2 | 38 |
| **Liechtenstein** | 8 | 11 | | 19 |
| **North Macedonia** | 8 | 3 | | 11 |
| **Norway** | 13 | 11 | | 24 |
| **Serbia** | 2 | 3 | | 5 |
| **Türkiye** | 56 | 30 | 2 | 88 |
| **United Kingdom ([334])** | 111 | 94 | | 205 |
| **Total** | **2 550** | **1 728** | **11** | **4 289** |

*Note:* KA; key action.
*Source:* Technopolis Group based on the E+ Results Platform.

To examine the actual objectives and policy aspects covered in Erasmus+ projects, 231 project descriptions and entries on the Erasmus+ Project Results Platform were manually checked and verified. Attention was paid to include a balance of geographical coverage, project types, key policy aspects, levels and types of education. Following the coding of impact, innovation and scalability dimensions, 127 projects were selected and retained as part of the good practice

([334]) The United Kingdom was a Member State and a programme country until 2020. The data cover projects for 2014 until 2020 only.

inventory ([335]). The purpose of this exercise was to further investigate the contribution and focus of Erasmus+ projects, possible gaps, challenges and lessons learned. These could, for example, concern the practical implementation of the project, the effectiveness of the intervention in supporting STEM learners, teachers or school, and more. For 15 projects, more in-depth case studies were produced.

As shown in Table 5 below, the vast majority of Erasmus+ good practice projects analysed address core instructional dimensions: **STEM curriculum, pedagogy and assessment** (covered in 114 out of 127 projects) and **non-formal/informal learning, learning support and equity** (95 projects). These findings reflect the programme's core strengths in fostering practice-based innovation and collaboration at the school level.

**STEM teacher development and support** also feature prominently, with 68 projects dedicated to this area. This dimension is particularly emphasised in newer actions, such as the Teacher Academies launched during 2021–2027, all of which focus on enhancing teacher capacity alongside curriculum and inclusion-oriented practices.

In contrast, **governance and infrastructure-related aspects** of STEM education are less consistently addressed, with only 45 projects (approximately 35 %) covering this area. This points to a gap in how structural and institutional enablers of STEM reform – such as school leadership, resourcing strategies or systemic coordination – are supported through Erasmus+ initiatives.

The most notable gap concerns **research and evaluation related to STEM education** in schools. Only two projects from both programming periods in total explicitly address this dimension, indicating limited attention to generating evidence of how STEM teaching practices translate into improved student learning, engagement or equity. While Erasmus+ effectively supports local-level pedagogical and organisational innovation, there is insufficient focus on building a systematic understanding of what works in STEM education in different contexts. This gap points to a broader policy need – greater investment in research, data collection and performance monitoring – to inform continuous improvement and guide national and EU-level strategy.

Notably, actions under key action 3 ('Support to policy development and cooperation') remain limited in number and underutilised in STEM. Although these projects typically receive higher average grants (e.g. over EUR 1 million for policy experimentations), their potential to anchor practice in broader policy learning, system-level change or strategic knowledge has not yet been fully leveraged.

([335]) Several Erasmus+ Teacher Academies active in STEM education were added into the set of screened projects in order to include projects supported under this new instrument. The original dataset only included finalised projects, which do not include the currently ongoing Teacher Academies.

These patterns suggest that Erasmus+ functions as a catalyst for bottom-up innovation and capacity building. By reaching a large number of participating organisations, Erasmus+ creates impetus for change at the local level. Nonetheless, due to the smaller scale of many Erasmus+ projects, it is difficult to ascertain the impact they have on systemic policy development and research-based transformation at the national level. To maximise impact, stronger coordination with Horizon Europe and other EU-level programmes is needed – particularly in terms of knowledge transfer, cross-programme learning and fostering links between practice and policy. Strengthening these connections would allow Erasmus+ to not only support practice innovation in schools but also contribute meaningfully to the evidence base and strategic policy dialogue on STEM education at the European level.

**Table 5. Policy aspects addressed in Erasmus+ good practice projects focusing on STEM education in schools**

| Programming period | 2014–2020 | | | | 2021–2027 | | | |
|---|---|---|---|---|---|---|---|---|
| Policy aspect | Total | KA1 – learning mobility of individuals | KA2 – cooperation for innovation and the exchange of good practices | KA3 – support for policy reform | Total | KA1 – learning mobility of individuals | KA2 – cooperation among organisations and institutions | Total |
| **STEM education governance and infrastructure** | **43** | 8 | 28 | 7 | **2** | 0 | 2 | **45** |
| **STEM teacher development and support** | **52** | 15 | 32 | 5 | **16** | 1 | 15 | **68** |
| **STEM education curriculum, pedagogy and assessment** | **97** | 18 | 72 | 7 | **17** | 1 | 16 | **114** |
| **STEM non-formal/informal learning, learning support and equity** | **81** | 19 | 54 | 8 | **14** | 0 | 14 | **95** |
| **Research on promotion of STEM education in schools** | **2** | 0 | 0 | 2 | **0** | 0 | 0 | **2** |
| **Total number of projects** | **110** | **21** | **78** | **11** | **17** | **1** | **16** | **127** |

*Source:* Technopolis Group based on the E+ Results Platform.

## Impacts of Erasmus+ projects focusing on STEM education in schools

From the inventory, 15 Erasmus+ case studies focusing on STEM education in schools were selected, and they provide rich evidence of the programme's diverse impacts ([336]). Spanning pre-primary, primary, lower-secondary and, in some cases, upper-secondary education, the case studies reveal how Erasmus+ has evolved from supporting pilot initiatives to acting as a tool that tackles many of the EU priorities in STEM education. The programme contributes directly to STEM teacher professionalisation, curriculum innovation and, importantly, improved student engagement with science and technology. It also shows the effects on evidence-informed policymaking. These impacts are often visible at the local level but more difficult to capture and ascertain at, for instance, the national level.

**Production and dissemination of teaching resources for innovative STEM teaching and learning.** One of the key direct results of the analysed projects was that Erasmus+ enabled the development and broad dissemination of high-quality, innovative, openly licensed STEM teaching resources. These included innovative lesson plans, digital platforms, scenario banks and teacher guides, aligned with national curricula and designed for long-term use and replication. Usually, these tools accompanied the **development and mainstreaming of innovative STEM pedagogies**, contributing to the shift from traditional didactic instruction to learner-centred, inquiry-based and interdisciplinary teaching practices. These approaches typically integrate real-world problem-solving and digital tools, fostering critical thinking and student engagement.

- The DIGITALIS (digital scenarios for STEM teaching and learning() project developed five interactive, digitally supported teaching scenarios, each integrating technologies such as virtual reality, online simulations and digital games to teach topics including climate change and ocean energy. Designed for integration into pre-service teacher education, the scenarios offered learners immersive, hands-on experiences aligned with contemporary scientific and environmental issues.
- The DIGICAMP (virtual immersive environment for STEM disciplines) project developed PIM's World, a gamified virtual learning environment covering mathematics, informatics and physics. This platform enabled students to navigate abstract concepts through interactive, exploratory experiences.
- Similarly, the Space Schools programme, part of the Future Space project, produced 22 interdisciplinary teaching scenarios aligned with national curricula. Each scenario included structured lesson plans, assessment tools and real-life applications of space science, promoting cross-curricular integration of STEM.

([336]) See Appendix C for an Erasmus+ report that includes the 15 good practice case studies.

- Another strong example is the InAMath (interdisciplinary approach to mathematical education) project, which created 55 teaching scenarios combining mathematics with subjects such as literature and the arts and topics like sustainability. These pedagogical models embody the Erasmus+ strategy to support integrative, future-focused STEM teaching.
- The Green STEAM Incubator (green STEAM incubator for youth-led sustainability and entrepreneurship) produced hands-on materials linking sustainability and agrotechnology to practical classroom activities. These resources allowed students to develop innovation and problem-solving skills while addressing environmental challenges.

**Professionalisation and capacity building of STEM teachers.** One of the most commonly reported impacts across all projects was the professionalisation of STEM teachers through the development of competences in digital pedagogy, research-informed practice, interdisciplinary teaching and inclusive education. Professional development for STEM teachers was a central theme in multiple projects analysed. Impacts often included increased confidence and competence in applying innovative tools and pedagogical methods.

- In the DIGITALIS project, participating pre-service teachers reported significantly increased confidence and competence in using digital tools for STEM teaching.
- The RiTE (research-based inclusive teaching education) project demonstrated measurable improvements in trainee teachers' ability to integrate research into lesson planning.
- In the project called the Child is a Researcher and a Practitioner, teachers cited increased openness to adopting new methodologies and described the project as a catalyst for long-term change in their pedagogical mindset.
- The STE(A)M IT (science, technology, engineering, arts and mathematics integrated teaching) project designed a comprehensive capacity-building programme and conducted interdisciplinary workshops for STEM and non-STEM teachers. These initiatives helped shift practice from fragmented instruction towards integrated, problem-based approaches that prioritise real-world application.

Several projects supported **system-level innovation, including through the creation of STEM-specific curricula or competence frameworks for educators**. These frameworks, for example, defined core STEM teacher competences, such as competences related to inquiry-based learning, interdisciplinary instruction, inclusive teaching and leadership.

- The SpicE (inclusive STEAM education for students with disabilities) Teacher Academy project developed a detailed STEAM competence framework for teachers to be adopted in multiple countries' training programmes.

- DIGICAMP also addressed new learning contexts by producing a practical guide for teachers about planning and delivering distance STEM education. Teachers reported improved ability to manage virtual environments and enhance student engagement online – skills that proved essential during the COVID-19 pandemic.

**Student motivation and STEM career awareness.** Several projects successfully increased students' awareness of and interest in STEM careers, often by contextualising learning in real-world scenarios and showcasing diverse professional pathways, for example through testimonies from STEM professionals.

- In STE(A)M IT, the Career Advisors Network connected schools with families and industry actors, catalysing meaningful conversations about STEM futures. Teachers observed a rise in student motivation and interest, with some learners pursuing advanced projects and entering competitions. The STEAME project similarly documented a shift in student attitudes, particularly in science and engineering. Learners began to view STEM as a field of creative problem-solving with broad societal relevance.
- The Future Space project developed the Space Career Paths initiative, which included video interviews, podcast episodes, a directory of space-related degree programmes and an internship catalogue. These resources introduced students to a broad spectrum of career opportunities and made STEM careers more visible and attainable.

**Student learning outcomes and competence development.** Beyond attitudes, several projects reported direct improvements in student learning outcomes in STEM-related subjects. Often, this was the result of innovative, inquiry-based teaching and learning approaches and tools that were produced during the projects and adapted in classrooms of beneficiary schools.

- Pre- and post-intervention assessments conducted during Future Space revealed increased student knowledge of astronomy and space science; better understanding of climate risks; and enhanced transversal skills, such as creativity, collaboration and information literacy. Mission planning and space research tasks were consistently identified by students as the most engaging and educational.
- The IN2STEAM (inclusive integrative STE(A)M learning in pre-primary and primary education) project found measurable attitudinal improvements among girls aged 8–11. Pre/post questionnaires showed greater confidence and interest in STEM subjects – gains that were linked to structured activities co-facilitated by 22 female STEM professionals serving as role models. These results underline the potential of Erasmus+ in influencing both learning and learner identity in relation to STEM.

**Advancing inclusive and gender-sensitive STEM education.** Promoting inclusive and gender-responsive STEM teaching was a central aim of multiple

projects. Erasmus+ facilitated the design of methods and tools that improved accessibility and equity in science and technology learning. Typically, this was achieved by designing innovative and inclusive teaching and learning approaches and materials that are sensitive to the needs of different groups of STEM learners.

- SENSIMINT (language-sensitive science education for multilingual classrooms) enhanced teacher awareness of the role of language in learning. Teachers reported changing their communication strategies and using more accessible, inclusive language. This led to better student participation, particularly among multilingual learners, and more confident use of scientific vocabulary.
- IN2STEAM developed a gender-sensitive STEAM curriculum and teacher training tools, with clear gains in pupil motivation and interest. These inclusive strategies aligned closely with the EU's objectives on gender equality, social inclusion and closing achievement gaps in STEM.

**Policy contributions and monitoring tools.** Erasmus+ projects also contributed to system-level policy development by generating evidence, tools and recommendations to support STEM strategy design. In some cases, this took the shape of direct policy recommendations targeting schools, STEM policymakers and other stakeholders; in other cases, this entailed monitoring data or targeted guidance for policymakers on implementing specific practices.

- The EUSTEAM (European STEM strategy and monitoring) project developed the European STEM monitor, offering a harmonised, indicator-based overview of STEM participation and outcomes across Member States. The monitor enables strategic planning by aggregating data on gender balance, enrolment trends and graduate flows in STEM disciplines.
- DIGITALIS issued policy recommendations for integrating technology-enhanced STEM teaching into teacher preparation programmes, addressing digital readiness and resource gaps.
- Similarly, RiTE produced accessible guidance for educators and policymakers regarding implementing research-based practice in education systems. These outputs provide practical instruments to support evidence-informed policy reforms across Europe.

**Institutional uptake and pedagogical transformation.** Some projects reported lasting institutional change. Schools incorporated project tools and curricula into daily practice, and teachers continued using innovative STEM teaching approaches and resources well beyond the project's end.

- For example, in DIGICAMP, participating schools integrated virtual learning tools into their digital education strategies.

- In Future Space, 100 % of surveyed teachers planned to continue using project materials, with 88 % committing to embed them into regular instruction.

These findings confirm that Erasmus+ can generate sustainable pedagogical change when resources are aligned with curricular needs and teachers' capacities.

**Networks and communities of practice.** The creation of professional networks and transnational communities of practice was another key outcome. These structures ensure long-term collaboration, knowledge sharing and continued capacity development among key stakeholders, such as schools and educators.

- The SpicE project established a community of practice for inclusive STEAM education and launched the Inclusive STEAM Alliance to sustain and scale up results.
- Projects such as 3C4Life (career guidance and communities for lifelong STEM teachers) combined teacher training with career development and community-building platforms, reinforcing the professional identity and long-term engagement of STEM educators.

While the case studies reviewed in this analysis provide evidence of localised and context-specific impacts derived from individual projects, they collectively point to a broader evolution in the role of Erasmus+ in STEM education. Thus, Erasmus+ is progressively positioning itself as both an incubator of pedagogical innovation and a catalyst for long-term strategic developments in school-level STEM education across Europe. Despite the nature of the programme, which funds a large number of grassroots innovation, more targeted policy-oriented projects increasingly also seek to nurture system-level changes in support of effective STEM education. Projects have moved beyond classroom experimentation to produce open-access competence frameworks for STEM educators, curricular models and policy recommendations designed for transferability and institutional uptake. These developments suggest that Erasmus+ is not only enhancing teaching and learning at the school level but also laying the groundwork for more systemic learning effects involving key stakeholders in STEM education, including educators, schools, policymakers and providers of non-formal STEM education. However, it must be noted that impacts beyond the project level, illustrated by the case studies, are difficult to evaluate due to a lack of systematic monitoring data from the Erasmus+ programme. To further grow the programme's impact, specific attention should therefore be paid to supporting evidence-based approaches that support effective STEM education.

### 5.2.2. Contributions of other EU programmes to promoting STEM education in schools

#### 5.2.2.1. Horizon Europe and Horizon 2020

Over the past decade, Horizon 2020 and Horizon Europe have become vital instruments in advancing STEM education in Europe. While Erasmus+ has primarily focused on mobility, training and school partnerships, the EU framework programmes offer a complementary research and innovation dimension. They support diverse actions, ranging from experimental pedagogy to systemic reform and science engagement, often through large-scale or multistakeholder projects.

An in-depth review of more than 50 projects across both frameworks reveals that Horizon-funded STEM initiatives span a broad array of themes and operate at multiple levels of the education ecosystem. These projects can be grouped according to eight broad thematic areas ('groupings'), each covering several specific STEM education aspects, spanning informal learning, systemic reform, teacher capacity, inclusion and curriculum innovation (see Table 6). These aspects are not mutually exclusive; many projects address multiple dimensions simultaneously, underscoring the integrated nature of EU research and innovation efforts. These thematic areas reveal the strategic breadth of Horizon Europe's interventions and also reflect consistent alignment with broader EU policy frameworks, including the European Education Area, the European Research Area, the Digital Education Action Plan and the EU Skills Agenda.

The results of this exercise and the project examples are reported in Table 6, grouped indicatively into several archetypical clusters.

**Table 6. STEM education aspects addressed in Horizon Europe projects**

| Grouping | Examples | STEM education aspects |
|---|---|---|
| **European Researchers' Night projects** | - All projects funded under the European Researchers' Night action | - Informal education activities (visits to science centres and museums; online platforms and STEM education resources; public engagement events, workshops, science festivals, public lectures and science nights) |
| **STEM related to industrial ecosystems and societal challenges** | - BioBeo (innovative education for the bioeconomy)<br>- CLEVERFOOD (connected labs for empowering versatile engagement in | - Informal education activities (visits to science centres and museums; online platforms and STEM education resources; public engagement events, workshops, science festivals, public lectures and science nights) |

| Grouping | Examples | STEM education aspects |
|---|---|---|
| | radical food system transformation)<br>- LOESS (literacy boost through an operational educational ecosystem of societal actors on soil health)<br>- ProBleu(promoting ocean and water literacy in school communities)<br>- OTTER (outdoor science education for a sustainable future)<br>- Our space our future<br>- EUSPACE-AWE (EU space awareness) | - Local community engagement projects/initiatives (whole-school approach)<br>- Innovative teaching and learning methods, practices or materials (e.g. integration of technology and digital tools in curriculum development) |
| **STE(A)M policy and roadmaps** | - SENSE (the new European roadmap to STEAM education)<br>- Road-STEAMer (developing a STEAM roadmap for science education in Horizon Europe)<br>- SEER (the STE(A)M education European roadmap)<br>- ICSE science factory<br>- STEAMbrace (European coordination network and activities to embrace a sustainable and inclusive STEAM educational system: the blend of artistic | - Interdisciplinary/integrated STEM teaching (e.g. STE(A)M, integrating STEM with the arts, social sciences and humanities)<br>- School governance and funding<br>- STEM curriculum content and structure |

| Grouping | Examples | STEM education aspects |
|---|---|---|
| | and creative approaches in STEM education, research & innovation)<br>- SySTEM 2020: connecting science learning outside the classroom | |
| **Gender- and inclusion-related projects** | - STREAM IT (streaming girls and women into STEAM education, innovation and research)<br>- AGRIGEP (assessment and implementation of agriculture and life science universities' first gender equality plans in widening countries)<br>- Shemakes.eu, (opportunity ecosystems bridging the gender gap)<br>- EQUALS-EU (Europe's regional partnership for gender equality in the digital age)<br>- INCLUDE (physics departments' culture, structure and gender inequality)<br>- WE4STEM (women entrepreneurs for STEM) | - Learning support targeted at girls/boys<br>- Non-formal education activities (after-school STEM clubs and programmes, science camps and summer programmes; STEM volunteer and outreach programmes; makerspaces and fab labs)<br>- Partnerships with industry and other local stakeholders, such as NGOs, science museums and centres, public authorities, cultural institutions, universities and research institutions and parents (e.g. support for student industry internships, collaboration between schools and non-formal learning providers) |
| **Open schooling approach to STEM education** | - SEAS (science education for action and engagement towards sustainability)<br>- PULCHRA (science in the city: building | - Local community engagement projects/initiatives (whole-school approach)<br>- Partnerships with industry and other local stakeholders, such as NGOs, science museums and centres, public authorities, |

| Grouping | Examples | STEM education aspects |
|---|---|---|
| | participatory urban learning community hubs through research and activation)<br>- CONNECT (inclusive open schooling through engaging and future-oriented science)<br>- Make it open<br>- SALL (Schools as Living Labs)<br>- MOST (meaningful open schooling connects schools to communities)<br>- PAFSE (partnerships for science education)<br>- MULTIPLIERS (multiplayers' partnerships to ensure meaningful engagement with science and research)<br>- FEDORA (future-oriented science education to enhance responsibility and engagement in the society of acceleration and uncertainty)<br>- COSMOS (creating organisational structures for meaningful science education through open schooling for all) | cultural institutions, universities and research institutions and parents (e.g. support for student industry internships, collaboration between schools and non-formal learning providers) |
| **Science education and science** | - SciCar (addressing attractiveness of science career awareness) | - Non-formal education activities (after-school STEM clubs and programmes, science camps and summer programmes; |

| Grouping | Examples | STEM education aspects |
|---|---|---|
| **awareness projects** | - SEAS (science education for action and engagement towards sustainability)<br>- CREATIONS (developing an engaging science classroom)<br>- STEM4youth (promotion of STEM education by key scientific challenges and their impact on our life and career perspectives)<br>- C4S (communities for sciences – towards promoting an inclusive approach in science education) | STEM volunteer and outreach programmes; makerspaces and fab labs)<br>- Informal education activities (visits to science centres and museums; online platforms and STEM education resources; public engagement events, workshops, science festivals, public lectures and science nights) |
| **Research projects on the assessment and evaluation of education policies** | - UNEQUAL ED (unequal education: the role of educational constraints in shaping inequalities)<br>- CLEAR (constructing learning outcomes in Europe: a multi-level analysis of (under)achievement in the life course)<br>- SCIREARLY (policies and practices based on scientific research for reducing underachievement and early school leaving in Europe)<br>- EFFEct (enhancing efficiency and | - Studies, evaluations, impact assessments, data collection and monitoring covering all policy aspects<br>- STEM assessment approaches and practices<br>- School governance and funding<br>- Learning support targeted at ethnic minorities, students from low-income families, people with disabilities and other vulnerable groups in STEM education<br>- Learning support targeted at girls/boys |

| Grouping | Examples | STEM education aspects |
|---|---|---|
| | effectiveness in education)<br>- MapIE (mapping of longitudinal data of inequalities in education)<br>- MTSS-K (early identification and remediation of literacy, numeracy, and social-emotional difficulties in kindergarten: an examination of the efficacy of a multi-tiered system of support)<br>- PERFORM (participatory engagement with scientific and technological research through performance)<br>- SellSTEM (spatial thinking in STEM learning: training a new generation of researchers to increase enrolment and gender balance in STEM learning by addressing deficits in spatial ability among children in Europe) | |
| **Specific STEM subjects** | - LI-PrimaryTeachers (contributions to the in-service education of primary school teachers from their engagement in mathematics landscapes of investigation)<br>- ProDiME (problem-based learning trajectories in discrete | - Innovative teaching and learning methods, practices or materials (e.g. integration of technology and digital tools into curriculum development)<br>- STEM curriculum content and structure<br>- STEM assessment approaches and practices<br>- Formal (continuing) professional development |

| Grouping | Examples | STEM education aspects |
|---|---|---|
| | mathematics education)<br>- SPATHS (spatial skills and mathematics, towards a causal understanding of mechanisms) | |

*Source:* Technopolis Group based on the Community Research and Development Information Service.

**European Researchers' Night.** The cluster of projects funded under the European Researchers' Night action exemplify Horizon's long-standing role in promoting science awareness and informal STEM education ([337]). These projects provide a gateway to STEM for school-aged audiences through science festivals, fairs, public lectures and interactive exhibitions, often in partnership with museums and science centres. Although not integrated into formal education systems, the European Researchers' Night projects contribute to the EU goals of raising science literacy and diversifying early pathways into STEM. Their informal, low-barrier format helps democratise access to STEM learning and shift public perceptions of science and scientists.

**STEM in societal and sectoral contexts.** A growing cluster of Horizon projects – such as CLEVERFOOD (connected labs for empowering versatile engagement in radical food system transformation) ([338]), OTTER (outdoor science education for a sustainable future) ([339]) and BioBeo (innovative education for the bioeconomy) ([340]) – demonstrate how STEM education can be positioned within the context of broader societal challenges, including sustainability, environmental transitions and food systems. These initiatives advance whole-school and community-based approaches, often emphasising experiential learning, problem-solving and real-world relevance. By linking STEM education to priority policy areas like the European Green Deal or the circular economy, these projects increase curricular relevance while fostering student agency in responding to contemporary challenges.

**STE(A)M policy and roadmaps.** Horizon Europe plays a crucial role in advancing STEM policy development, particularly through its coordination and support actions. Projects such as Road-STEAMer (developing a STEAM

([337]) See https://marie-sklodowska-curie-actions.ec.europa.eu/actions/msca-citizens for an introduction to the Marie Skłodowska-Curie action (MSCA) and Citizens action, which currently funds European Researchers' Night projects.

([338]) https://cordis.europa.eu/project/id/101086320.

([339]) https://cordis.europa.eu/project/id/101006482.

([340]) https://cordis.europa.eu/project/id/101059900.

roadmap for science education in Horizon Europe) ([341]), SEER (the STE(A)M education European roadmap) ([342]), SENSE (the new European roadmap to STEAM education) ([343]) and ICSE Science Factory ([344]) work directly with national ministries, school leadership bodies and stakeholders to develop roadmaps for curriculum reform, governance, and funding mechanisms. Typical activities are developing roadmaps, large-scale analysis of STEM education approaches and policies, building awareness, action and advocacy in relation to STEM education stakeholders at the EU and other levels. Importantly, many of these initiatives promote STE(A)M integration, embedding the arts, humanities and social sciences into STEM learning to promote interdisciplinary thinking and creativity. This approach is consistent with EU-level policy frameworks such as the Council recommendation on key competences for lifelong learning (2018) ([345]) and the European Skills Agenda ([346]), which emphasise modernising education, promoting inclusivity and embedding innovation in teaching practice.

**Gender and inclusion.** Horizon Europe has significantly expanded its focus on tackling inequality in STEM education and careers, supporting a broad range of projects that address barriers to participation for women, students from disadvantaged socioeconomic backgrounds, migrants and learners with disabilities. This emphasis aligns with the European Research Area policy agendas (for 2022–2024 ([347]) and proposed for 2025–2027 ([348])) and Horizon Europe's Gender Equality Plan requirements, which apply to all public institutions receiving funding. Several high-profile projects exemplify this commitment. SheMakes.eu (opportunity ecosystems bridging the gender gap) ([349]), INCLUDE (physics departments' culture, structure and gender inequality) ([350]), EQUALS-EU (Europe's regional partnership for gender equality in the digital age) ([351]) and STREAM IT (streaming girls and women into STEAM education, innovation and

([341]) https://cordis.europa.eu/project/id/101058405.

([342]) https://cordis.europa.eu/project/id/101058569.

([343]) https://cordis.europa.eu/project/id/101058507.

([344]) https://cordis.europa.eu/project/id/101093387.

([345]) Council Recommendation of 22 November 2018 on key competences for lifelong learning (OJ C 189, 4.6.2018), https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018H0604(01).

([346]) https://employment-social-affairs.ec.europa.eu/policies-and-activities/skills-and-qualifications/european-skills-agenda_en.

([347]) See, for example, action 5 'Promote gender equality and foster inclusiveness' (https://european-research-area.ec.europa.eu/policy-agenda-2022-2024/deepening-truly-functioning-internal-market-knowledge).

([348]) https://research-and-innovation.ec.europa.eu/news/all-research-and-innovation-news/commission-adopts-proposal-next-european-research-area-policy-agenda-2025-2027-2025-02-28_en.

([349]) https://cordis.europa.eu/project/id/101006203.

([350]) https://cordis.europa.eu/project/id/101064061.

([351]) https://cordis.europa.eu/project/id/101006396.

research) ([352]) target structural and cultural barriers limiting access to STEM, particularly for women and under-represented groups. These projects often work at the intersection of education and social policy, contributing to the development of inclusive pedagogies and frameworks that Member States can adopt through their national strategies.

Among the most prominent projects is STEAMbrace (European coordination network and activities to embrace a sustainable and inclusive STEAM education system: the blend of artistic and creative approaches in STEM education, research & innovation) ([353]), funded under the 2023 Horizon Europe work programme, which promotes gender equality and broader inclusion across all levels of STEM education, from primary schooling to tertiary education and career pathways. Its systemic approach reflects the EU's strategic goal to embed equity into institutional practices and curriculum design, supporting the development of inclusive school environments and teacher training modules that challenge stereotypes and foster participation.

In addition, public engagement initiatives under the Marie Skłodowska-Curie action (MSCA) and Citizens action – including European Researchers' Night – play a role in promoting science awareness and breaking down gendered perceptions of STEM from an early age. These initiatives use informal and non-formal settings such as fairs, competitions and museum-based activities to reach school-aged children and help broaden aspirations, particularly among girls.

The promotion of gender equality is also supported through Horizon Europe's alignment with the European Strategy for Universities, linking institutional change with broader societal transformation. By addressing equity through both targeted projects and structural incentives (e.g. making Gender Equality Plans funding prerequisites), Horizon Europe positions diversity not only as a matter of social justice but as a driver of excellence and innovation in education, research and the economy.

**Open schooling for STEM education.** Projects such as SEAS (science education for action and engagement towards sustainability) ([354]), PULCHRA (science in the city: building participatory urban learning community hubs through research and activation) ([355]), Make it Open ([356]) and MULTIPLIERS (multiplayers' partnerships to ensure meaningful engagement with science and research) ([357]) embody Horizon Europe's support for the open schooling model, which encourages collaboration between schools and external stakeholders,

([352]) https://cordis.europa.eu/project/id/101131843.

([353]) https://steambraceproject.eu/.

([354]) https://cordis.europa.eu/project/id/824522.

([355]) https://cordis.europa.eu/project/id/824466.

([356]) https://cordis.europa.eu/project/id/872106.

([357]) https://cordis.europa.eu/project/id/101006255.

including NGOs, science centres, universities and cultural institutions. These initiatives help create real-world learning environments that transcend classroom boundaries and foster collective problem-solving. The emphasis on community engagement and co-creation makes these projects particularly well suited for addressing place-based challenges and supporting school-level innovation, consistent with the whole-school approach.

**Science awareness and non-formal learning.** Separate from European Researchers' Night projects, other Horizon projects focus on structured, non-formal STEM learning. Projects like CREATIONS (developing an engaging science classroom) ([358]), STEM4Youth (promotion of STEM education by key scientific challenges and their impact on our life and career perspectives) ([359]) and SciCar (addressing attractiveness of science career awareness) ([360]) develop science camps, after-school clubs, makerspaces and volunteer-led STEM activities targeting children and young people. These interventions are especially important for students who may lack access to enrichment opportunities, and they often serve as incubators for later interest in STEM studies and careers. Their design frequently integrates digital platforms and learner-centred pedagogies, consistent with the Digital Education Action Plan's vision for digital education.

**Research on policy evaluation and systemic reform.** A distinct strand of Horizon projects support targets, system-level research and evidence building. Projects such as SCIREARLY (policies and practices based on scientific research for reducing underachievement and early school leaving in Europe) ([361]), CLEAR (constructing learning outcomes in Europe: a multi-level analysis of (under)achievement in the life course) ([362]), UNEQUAL ED (unequal education: the role of educational constraints in shaping inequalities ([363])), MapIE (mapping of longitudinal data of inequalities in education) ([364]) and effect (enhancing efficiency and effectiveness in education) ([365]) focus on the evaluation of education policy, funding effectiveness, teacher development and student assessment, often with direct implications for national- and EU-level reform strategies. These projects enhance data availability and policy intelligence, feeding into EU mechanisms like Erasmus+, the Recovery and Resilience Facility (RRF), and the European Semester. Their contributions is especially critical given the EU's role in education, making robust evidence a vital tool for coordination.

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([358]) https://cordis.europa.eu/project/id/665917.

([359]) https://cordis.europa.eu/project/id/710577.

([360]) https://cordis.europa.eu/project/id/952470.

([361]) https://cordis.europa.eu/project/id/101061288.

([362]) https://cordis.europa.eu/project/id/101061155.

([363]) https://cordis.europa.eu/project/id/101044361.

([364]) https://cordis.europa.eu/project/id/101132474.

([365]) https://cordis.europa.eu/project/id/101129146.

**STEM-subject-specific innovation.** Finally, Horizon Europe also supports subject-specific innovation in teaching and learning. Projects such as ProDiME (problem-based learning trajectories in discrete mathematics education) ([366]), SPATHS (spatial skills and mathematics, towards a causal understanding of mechanisms) ([367]) and LI-PrimaryTeachers (contributions to the in-service education of primary school teachers from their engagement in mathematics landscapes of investigation) ([368]) develop new methods and tools for science, mathematics and digital literacy education. They frequently include professional development for teachers, curriculum pilots and classroom experimentation. Although often implemented at a small scale, these projects provide scalable models and insights for pedagogical innovation, feeding directly into Erasmus+ Teacher Academies and other national professional learning systems.

Collectively, these Horizon Europe initiatives demonstrate strategic alignment with the EU's education, innovation and inclusion goals. They offer policy-relevant experimentation opportunities, foster cross-sectoral coalitions and generate scalable models for national reform. Horizon also plays a unique role in supporting areas that are under-addressed by other instruments, such as the link between education and societal challenges, and the integration of research with pedagogical innovation.

However, the fragmentation of project themes and lack of systematic coordination across funding streams – particularly Erasmus+, ESIFs and Horizon – remain persistent challenges. Many Horizon-funded projects generate valuable frameworks, evidence and policy tools, but their uptake in national systems is uneven. Formalised knowledge transfer and upscaling mechanisms, such as EU-level policy laboratories, digital repositories or structured communities of practice, could enhance impact.

Ultimately, Horizon Europe functions as a catalyst, driving the early-stage development of ideas, partnerships and systemic innovations in STEM education. Its success depends on complementary investment, prioritisation and policy commitment at the national and regional levels to ensure that innovation translates into sustainable educational transformation.

#### 5.2.2.2. The Digital Education Action Plan and the roles of the Digital Europe programme and the European Institute of Innovation and Technology

The **Digital Europe Programme** mainly supports the implementation of the Digital Education Action Plan, thus focusing on ICT and (advanced) digital or deep tech skills. While not directly used to support STEM or STEAM approaches,

([366]) https://cordis.europa.eu/project/id/101066847.

([367]) https://cordis.europa.eu/project/id/101150769.

([368]) https://cordis.europa.eu/project/id/101103353.

the calls and projects under the Digital Europe programme seek to address the shortages of students enrolling in STEM and ICT-related disciplines, with a specific emphasis on increasing female participation. The education level for these activities ranges from primary to tertiary.

The **European Institute of Innovation and Technology** (EIT) is working to close the gender gap in STEM by encouraging greater participation of girls and women in related studies and careers. This objective is central to the EIT's 2021–2027 strategy ([369]). Among its targeted initiatives are interdisciplinary higher education programmes, and Girls Go Circular ([370]). Girls Go Circular was launched in 2020 and coordinated by EIT RawMaterials in partnership with other EIT Knowledge and Innovation Communities and the Directorate-General for Education, Youth, Sport and Culture. It equips girls aged 14–19 with digital and entrepreneurial skills. To date, more than 38 000 participants from 24 Member States have completed the programme, and there are plans to extend its reach to all 27 Member States, according to EIT's 2023 annual report ([371]). A flagship event under this initiative is the Women and Girls in STEM Forum, now in its fourth edition. The forum brings together key stakeholders to advance gender equality in STEM and ICT and inspire young women to pursue careers in these fields.

STEM activities are also facilitated under the Single Market programme. This programme supports the **entrepreneurship, science, technology, engineering, arts and mathematics (ESTEAM) festivals** organised as part of the Digital Education Action Plan, and targets girls aged 8–17, teachers and parents ([372]).

#### 5.2.2.3. European Structural and Investment Funds

European Structural and Innovation Funds (ESIFs) play a key role in linking EU-level and national/regional strategic and programme priorities.

([369]) Decision (EU) 2021/820 of the European Parliament and of the Council of 20 May 2021 on the strategic innovation agenda of the European Institute of Innovation and Technology (EIT) 2021–2027: Boosting the innovation talent and capacity of Europe and repealing Decision No 1312/2013/EU (OJ L 189, 28.5.2021, p. 91, ELI: http://data.europa.eu/eli/dec/2021/820/oj).

([370]) https://eit-girlsgocircular.eu/.

([371]) EIT, 'Decision 23/2024 of the Governing Body of the European Institute of Innovation and Technology (EIT) on the assessment and adoption of the 2023 annual activity report of the Authorising Officer of the European Institute of Innovation and Technology', 2024, https://eit.europa.eu/sites/default/files/2024-06/GB%20Decision%2023-2024%20EIT%20CAAR%202023_web.pdf.

([372]) https://eismea.ec.europa.eu/news/empowering-women-and-girls-through-digital-and-entrepreneurial-competences-esteam-fests-and-2022-03-07_en.

Table 7 reports the results of a search using STEM- and education-related keywords applied to ESIF project descriptions in the Kohesio database ([373]). It includes an overview of the total number of ESIF projects identified for each funding programme, and the total and average EU contributions. The European Social Fund / ESF+ and ERDF lead the count, with 32 954 projects overall and 7 848 projects falling under the search criteria. In general, ESIFs may fund more projects than Erasmus+, with 42 707 projects contributing almost EUR 8.5 billion. However, a more robust approach is needed to ascertain the actual contribution, since the total number may include false positives, which can only be eliminated through manual screening.

**Table 7. Number of STEM-related ESIF projects by Member State**

| Member State | Single-Member-State projects | Interreg projects coordinated in Member State | Total projects in Member State |
|---|---|---|---|
| **Belgium** | 22 | 0 | 22 |
| **Bulgaria** | 207 | 5 | 212 |
| **Czechia** | 10 398 | 8 | 10 406 |
| **Denmark** | 9 | 20 | 29 |
| **Germany** | 2 003 | 5 | 2 008 |
| **Estonia** | 71 | 17 | 88 |
| **Ireland** | 0 | 3 | 3 |
| **Greece** | 2 037 | 28 | 2 065 |
| **Spain** | 1 628 | 0 | 1 628 |
| **France** | 1 738 | 34 | 1 772 |
| **Croatia** | 113 | 2 | 115 |
| **Italy** | 8 700 | 33 | 8 733 |
| **Cyprus** | 7 | 0 | 7 |
| **Latvia** | 165 | 1 | 166 |
| **Lithuania** | 771 | 31 | 802 |
| **Luxembourg** | 1 | 0 | 1 |
| **Hungary** | 4 857 | 0 | 4 857 |
| **Malta** | 4 | 0 | 4 |
| **Netherlands** | 68 | 60 | 128 |
| **Austria** | 18 | 103 | 121 |
| **Poland** | 6 414 | 28 | 6 442 |
| **Portugal** | 571 | 8 | 579 |
| **Romania** | 619 | 46 | 665 |

([373]) https://kohesio.ec.europa.eu/en/.

| Member State | Single-Member-State projects | Interreg projects coordinated in Member State | Total projects in Member State |
|---|---|---|---|
| **Slovenia** | 41 | 2 | 43 |
| **Slovakia** | 970 | 3 | 973 |
| **Finland** | 718 | 48 | 766 |
| **Sweden** | 58 | 14 | 72 |
| **Total** | **42 208** | **499** | **42 707** |

*Source:* Technopolis Group based on Kohesio.

#### 5.2.2.4. Leveraging EU instruments for educational reform: Recovery and Resilience Facility, Technical Support Instrument / Structural Reform Support Programme and InvestEU

The Recovery and Resilience Facility (RRF), the Technical Support Instrument (TSI) – which succeeded the Structural Reform Support Programme – and InvestEU are key EU-level funding and support mechanisms aiming to drive reforms and investments across Member States. The RRF, established under the EU's post-COVID recovery plan, provides financial support for reforms and investments aligned with national Recovery and Resilience Plans, including those in education. The TSI offers tailored technical expertise to help design and implement structural reforms, including in education policy and school systems. InvestEU mobilises private and public investment to support policy priorities such as innovation, skills development and social infrastructure, complementing national and EU funds through financial instruments.

National Recovery and Resilience Plans (under the RRF are being used strategically to support education policy reforms, including targeted efforts to strengthen STEM education in schools. Several Member States – such as Bulgaria, Croatia, Italy, Lithuania and Portugal – have mobilised RRF funding to enhance skills development and modernise their education systems. Italy and Portugal, in particular, have introduced specific measures to promote women's participation in STEM, addressing long-standing gender disparities. In parallel, Bulgaria and Lithuania have focused on upgrading school infrastructure, including through the creation of new STEM centres and laboratories to promote innovation and experiential learning (see Table 8).

**Table 8. National RRF plans addressing STEM education**

| Member State | Action title | Key policy aspect |
|---|---|---|
| **Bulgaria** | - Creation of STEM laboratories | - STEM curriculum reforms/regulation<br>- Basic school infrastructure |

| Member State | Action title | Key policy aspect |
|---|---|---|
| | - Enhancement of STEM subjects in schools<br>- Reform of STEM curricula | - Laboratory infrastructure (including computer laboratories, computers, tablets and software)<br>- Others |
| **Croatia** | - Measures to foster skills development, including STEM and ICT<br>- Strengthening STEM | - Others |
| **Italy** | - Investment to enhance women's participation in STEM | - Learning support, equal access and inclusivity in STEM education (policies addressing target groups (e.g. people with lower socioeconomic backgrounds, migrants, people with disabilities), gender aspects, etc.) |
| **Lithuania** | - Measures upgrading STEM centres | - Basic school infrastructure<br>- Laboratory infrastructure (including computer laboratories, computers, tablets and software)<br>- Others |
| **Portugal** | - Equipping schools with modern digital equipment in order to support women's participation in STEM<br>- Implementing scholarship schemes and providing accommodation in order to increase the number of STEM students | - Learning support, equal access and inclusivity in STEM education (policies addressing target groups (e.g. people with lower socioeconomic backgrounds, migrants, people with disabilities), gender aspects, etc.)<br>- Basic school infrastructure<br>- Laboratory infrastructure (including computer laboratories, computers, tablets and software)<br>- Others |

*Source:* Technopolis Group compilation based on RRF thematic analysis.

A similar reform opportunity is available through the **Technical Support Instrument** (TSI), which succeeded the **Structural Reform Support** Programme (SRSP). The TSI provides tailored technical assistance to Member States in designing and implementing reforms that strengthen economic performance and improve institutional, administrative and structural frameworks. However, a review of TSI annual programmes, flagship projects and country factsheets

shows that the instrument is rarely used to directly support STEM-related reforms in education.

Some relevant initiatives do exist. For instance, Belgium implemented TSI projects focused on enhancing ICT capacity in schools, and partnered with the Netherlands regarding digital competences in teacher professional development. In terms of multi-country projects, Bulgaria and Portugal collaborated on governance, monitoring and evaluation in early childhood education and care (ECEC), while Ireland and Finland engaged in projects promoting inclusive and high-quality education. These interventions primarily address horizontal education challenges – such as teacher shortages, inclusion and governance – that may indirectly benefit STEM education, although their STEM-specific impacts are limited and not explicitly defined.

Overall, while instruments like the RRF and TSI offer meaningful potential to align national education reforms with EU-level priorities, this remains largely untapped in the context of STEM education. Enhancing strategic coordination and guidance could help expand the uptake of systemic, STEM-focused reforms. Notably, infrastructure investments supported by the RRF – such as the establishment of STEM laboratories and centres – create visible entry points for change. Yet, without parallel efforts in curriculum reform, teacher training and institutional capacity-building, their transformative potential may not be fully realised. Few countries have taken decisive action to reduce gender disparities in STEM.

Where efforts have been made (e.g. in Italy and Portugal), they demonstrate that meaningful change requires intentional, well-designed policies backed by targeted resources. EU funding instruments such as the RRF, the TSI and, potentially, InvestEU provide multiple levers for educational reform. Member States would benefit from more-coordinated use of these tools to pursue comprehensive and systemic strategies that integrate digital, green and inclusive dimensions, including in STEM education.

#### 5.2.2.5. Other Europe-wide initiatives supporting STEM education in schools

In addition to the specific EU programmes discussed in the previous sections, there is a growing ecosystem of Europe-wide initiatives and networks that support STEM education. These initiatives, primarily organised by STEM stakeholders, are generally independent, although they are often funded by various EU sources. They complement the EU's efforts and interventions in advancing STEM education.

- The **EU STEM Coalition** ([374]) is a pan-European network comprising national STEM platforms and other organisations dedicated to

([374]) https://www.stemcoalition.eu/.

strengthening STEM education across Europe. The coalition offers a stable platform for partners to exchange experiences, share good practices on common challenges and facilitate communication between European stakeholders and their national counterparts. Its activities, supported by programmes like Erasmus+ and other EU funding sources, benefit various groups, including local and regional authorities, higher education institutions and, indirectly, teachers and students. The coalition focuses on a broad range of STEM-related issues in schools, with particular significance at the EU level in terms of data collection, monitoring and policy dissemination. Its role is acknowledged in EU policy, notably in the Digital Education Action Plan, which supports the development of new higher education programmes for engineering and ICT based on the interdisciplinary STEAM approach. This includes leveraging the EU STEM Coalition to help establish national STEM platforms and disseminate results from Erasmus+-funded projects ([375]).

- **European Schoolnet** ([376]) is an NGO that connects ministries of education across Europe and plays a pivotal role in supporting STEM education. As a partner in various European projects, its contributions are recognised under action 7 of the European Skills Agenda, particularly in the dissemination of research results on science education. Through its **Scientix** ([377]) platform, European Schoolnet fosters a strong community of practice for STEM educators, providing resources, sharing good practices, mapping policies and organising projects. Additionally, European Schoolnet manages the **STEM Alliance** ([378]), a network that includes companies and employers interested in STEM education. Through these activities, the organisation contributes significantly to networking and policy-related work, including studies, evaluations, data collection and monitoring.
- The **European Science Education Research Association** (ESERA) ([379]) supports science education research through a network of academics focused on effective teaching and learning strategies, and related policies. ESERA contributes to studies, evaluations and data collection in the field of science education by organising conferences, summer schools and special interest groups that explore specific research topics and methodologies.

([375]) European Commission, 'Women's participation in STEM studies and careers', European Commission website, 20 June 2025, accessed 29 July 2025, https://education.ec.europa.eu/focus-topics/digital-education/action-plan/action-13.

([376]) http://www.eun.org/.

([377]) https://www.scientix.eu/.

([378]) htrps://www.scientix.eu/community/stem-alliance.

([379]) https://www.esera.org/.

- The **Association for Teacher Education in Europe** (ATEE) ([380]) is a network that connects individuals and organisations involved in teacher education. ATEE hosts a research and development community dedicated to science and mathematics education, linking research into teacher education with the training of pre-service and in-service teachers.
- **Science on Stage** ([381]) is a pan-European community of science teachers from 35 countries. It aims to enhance teachers' capacity to deliver science education. The community organises regular festivals, maintains a database of teaching materials and supports teacher training events.
- The **European Space Education Resource Office** ([382]), hosted by the European Space Agency, supports science education in 22 European Space Agency member states. The European Space Education Resource Office provides teacher resources and classroom support, and organises national projects in collaboration with local science education centres. These projects often focus on informal learning, STEM career aspirations and teacher development.
- The **International Centre for STEM Education** ([383]) works to advance STEM education by providing a platform for innovative research and collaboration. It brings together educators, researchers and policymakers to share best practices, develop new educational strategies and support the integration of STEM into national curricula. The centre also focuses on professional development for teachers, helping them stay up to date with changing STEM methodologies and technologies. By fostering cross-border collaboration and promoting global dialogue on STEM education, the centre contributes to the development of sustainable, high-quality STEM learning environments.
- The **European Network of Science Centres and Museums** (Ecsite) ([384]) is a dynamic network of science centres and museums dedicated to enhancing public engagement with STEM. Ecsite brings together science communicators, educators and museum professionals to share knowledge, develop innovative learning programmes and engage the public in science-related activities. The network plays an important role in informal STEM education by supporting science museums in creating hands-on, interactive experiences that inspire curiosity and promote lifelong learning. Through its collaborative projects and events, Ecsite contributes to the wider STEM education ecosystem by encouraging creativity, critical thinking and public interest in scientific exploration.

([380]) https://atee.education.

([381]) https://www.science-on-stage.eu/.

([382]) https://www.esa.int/Education/Teachers_Corner/European_Space_Education_Resource_Office.

([383]) https://icse.eu/.

([384]) https://www.ecsite.eu/.

These initiatives contribute significantly to the STEM education landscape in Europe by providing structure and spaces for the engagement of key stakeholders and by fostering communities of practice. The EU STEM Coalition and Scientix act as essential bridges between EU-level initiatives and national or local actors, sharing expertise and good practices, while gathering feedback for EU and national policy development. Other networks, such as ESERA and ATEE, provide valuable links to the latest research in science education and teacher education, ensuring that educational practices remain informed by current evidence. Additionally, initiatives like Science on Stage directly engage teachers, enhancing their professional development and capacity to deliver high-quality STEM education.

### 5.2.3. Evolving STEM concepts, strategic policy challenges, gaps and ways forward

#### 5.2.3.1. Conceptual evolution of STEM and STEAM in EU policy

As mentioned in Section 4.2.1, STEM is not a consistently defined concept and, in particular with the extension to STEAM, invokes different notions of disciplinary focus, interdisciplinary and integrated approaches, or innovation in learning and teaching methods. Section 5.1.1.1 highlights the different conceptualisations of STEM across Member States.

The conceptualisation of **STEM education in EU policy has evolved over the past decade**, shifting from a traditional emphasis on discrete science and technology disciplines to a more **interdisciplinary, inclusive and societally embedded framework**, increasingly articulated as 'STEAM'. This change reflects the broader policy objective of fostering innovation, equity and relevance in education systems across Member States.

In the early 2010s, STEM was primarily understood through the lens of subject-specific competence development. For example, the **2018 key competence framework** offered clear definitions of individual STEM subjects, while also recognising transversal skills – such as critical thinking, collaboration and creativity – as essential complements ([385]). However, the **2017 Communication on school development** ([386]) marked an early step towards expanding this scope, advocating STEM being 'linked to economic, environmental and social challenges' and even the arts and design, to better connect learning with real-world contexts.

([385]) Pokropek, A., *STEM Competencies, Challenges, and Measurements: A literature review*, Publications Office of the European Union, Luxembourg, 2024, JRC138618.

([386]) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – School development and excellent teaching for a great start in life, COM(2017) 248 final of 30 May 2017.

This interdisciplinary orientation gained further momentum in subsequent strategic documents. The **European Education Area strategic framework** ([387]) explicitly adopted the term '**STEAM**', reflecting an emerging policy consensus around the value of integrating the arts, humanities and social sciences into STEM learning. While the **EU Skills Agenda** (2020) continued to use the term '**STEM**', it did so primarily in relation to increasing the number of graduates and addressing skills shortages, without explicit reference to STEAM or the integration of the arts.

The **Digital Education Action Plan (2021–2027)** supported this transition by referencing both 'integrated STEM' and 'STEAM', particularly in initiatives like the ESTEAM festivals. Here, STEM is linked with digital skills, inclusion and creativity, core themes that drive the expansion of the STEM model into a more comprehensive pedagogical approach. A **Council recommendation of 2023** ([388]) reinforces this by promoting STEAM as a key strategy for aligning digital education with creativity and cross-disciplinary innovation.

A turning point came with the **Erasmus+ Regulation** (Regulation (EU) 2021/817 ([389])), which institutionalised STEAM in legal terms. Article 4(1)f explicitly supports the development of 'knowledge, skills, competences and attitudes [people] need in forward-looking study fields or disciplines such as science, technology, engineering, arts and mathematics (STEAM)'. This marked the beginning of dual terminology in EU programming, with both STEM and STEAM appearing across education initiatives.

The **European Strategy for Universities** builds on this by framing STEAM as a 'multidisciplinary set of approaches to education removing traditional barriers between subjects and disciplines to connect STEM and ICT education with the arts, humanities, and social sciences' ([390]). This acknowledges not only the relevance of arts integration but also the broader shift towards problem-solving, ethical reflection and social responsibility in higher education and research.

The **2021 Erasmus+ Programme Guide** reflects this dual emphasis in practice. It promotes 'interest and excellence' in STEM at the school level, while simultaneously encouraging the STEAM approach through interdisciplinary

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([387]) Council resolution on a strategic framework for European cooperation in education and training towards the European Education Area and beyond (2021–2030) (OJ C 66, 26.2.2021, p. 1).

([388]) Council recommendation of 23 November 2023 on improving the provision of digital skills and education (OJ C 444, 29.11.2023, p. 1), https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:C_202401030.

([389]) Regulation (EU) 2021/817 of the European Parliament and of the Council of 20 May 2021 establishing Erasmus+: the Union programme for education and training, youth and sport and repealing Regulation (EU) No 1288/2013 (OJ L 189, 28.5.2021, p. 1, ELI: http://data.europa.eu/eli/reg/2021/817/oj), recital 15.

([390]) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on a European strategy for universities, COM(2022) 16 final of 18 January 2022, footnote 32, https://eur-lex.europa.eu/legal-content/EN/TXT/?Uri=celex:52022DC0016#footnoteref33.

teaching. At the higher education level, it prioritises 'developing STEM/STEAM in higher education', particularly increasing women's participation in STEM fields. The guide also advocates for the design of fit-for-purpose STEM curricula that follow a STEAM approach, reinforcing the relevance of, and diversity and gender equity in, teaching and learning ([391]).

#### 5.2.3.2. Consolidation in EU strategic plans and policy briefs

The transition has been fully consolidated in the **2025 Erasmus+ Work Programme** ([392]), which not only reiterates STEAM's value but also includes a detailed definition in a dedicated footnote. It describes STEAM as '[t]he use of multidisciplinary pedagogies (teaching of science in political, environmental, socio-economic, and cultural contexts … for making STEM subjects and careers more attractive'. The document highlights the creative potential of connecting STEM education with the arts, humanities and social sciences, especially in motivating girls and women to pursue careers in ICT and engineering and gain advanced digital skills.

A parallel expression of this shift is found in the **Council recommendation of 16 June 2022 on learning for the green transition and sustainable development** ([393]), which employs similar language to advocate for contextual, interdisciplinary and challenge-based learning models in STEM education.

The **Horizon Europe Strategic Plan 2025–2027** ([394]) solidifies this vision from a research and innovation policy perspective. It highlights the integration of the **social sciences and humanities** into STEM domains as fundamental for fostering interdisciplinary collaborations. Importantly, it underscores the need for a human-centric approach, positioning STEM within a broader framework of societal relevance and ethical responsibility.

The 2025 **JRC policy brief *STEM and STEAM education, and Disciplinary Integration*** ([395]) marks a significant step in clarifying and systematising the conceptual development of STEM within EU education policy. It distinguishes between traditional STEM, integrated STEM (which merges science, technology,

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([391]) European Commission, *Erasmus+ Programme Guide*, version 3, 2021, https://erasmus-plus.ec.europa.eu/sites/default/files/2021-09/2021-erasmusplus-programme-guide_v3_en.pdf.

([392]) European Commission, *The 2025 annual work programme for the implementation of Erasmus+: The Union programme for education, training, youth and sport*, Brussels, 2024, p. 18, https://erasmus-plus.ec.europa.eu/sites/default/files/2024-10/awp-erasmus-oct-2025_en.PDF.

([393]) Council recommendation of 16 June 2022 on learning for the green transition and sustainable development (OJ C243 27.6.2022 p.1) EUR-Lex - 32022H0627(01) - EN - EUR-Lex.

([394]) European Commission: Directorate-General for Research and Innovation, *Horizon Europe Strategic Plan 2025–2027*, Publications Office of the European Union, Luxembourg, 2024, p. 40, https://data.europa.eu/doi/10.2777/092911.

([395]) Mazzeo Ortolani, G., *STEM and STEAM Education, and Disciplinary Integration: A guide to informed policy action*, European Commission, Brussels, 2025, JRC141438.

engineering and mathematics into coherent, cross-disciplinary learning) and STEAM or STE(A)M (which explicitly incorporates the arts, social sciences and humanities to foster creativity, inclusivity and relevance to societal challenges). The brief frames disciplinary integration not merely as curriculum design but as a system-wide approach requiring alignment across pedagogy, teacher professional development, infrastructure and assessment. Importantly, it stresses that integrated STEM/STEAM must be tailored to the context, warning against one-size-fits-all solutions and emphasising the need to address persistent equity gaps, particularly in relation to gender and socioeconomic background. In doing so, the brief consolidates the EU's evolving vision of STEM as a driver of innovation, citizenship and sustainable development, grounded in interdisciplinarity and social relevance. This is closely aligned with the objectives of the EU STEM Education Strategic Plan ([396]), which similarly prioritises interdisciplinarity, equity and societal impact in shaping future education policy.

#### 5.2.3.3. Policy gaps and coordination challenges

The EU's evolving policy landscape thus demonstrates a conceptual shift: from STEM as a set of discrete technical subjects to STEAM as an interdisciplinary, inclusive and pedagogically progressive approach. While STEM remains dominant in regulatory and economic contexts (e.g. the EU Skills Agenda), STEAM is now firmly embedded in education, research and curriculum frameworks. This reflects the EU's broader policy goal of linking education to societal needs, innovation ecosystems and inclusive excellence, laying the foundation for future-ready, equitable learning environments across Europe.

At the same time, the analysis of the development of the STEM concept across key EU policy documents shows that, while the inclusion of the arts in STEM – thus forming STEAM – is increasingly recognised, there is still **no coherent or unified definition of competences for the arts, social sciences and humanities component**. Current references remain largely indirect, often embedded within transversal skills such as creativity, critical thinking or collaboration, as outlined in the 2018 key competence framework. In parallel, digital and IT skills are frequently associated with STEM, although primarily within the scope of digital-focused strategies – most notably the Digital Education Action Plan and the 2023 Council recommendations on digital learning – rather than as fully integrated components of a broader STEAM framework.

The evolution and coexistence of the different STEM and STEAM definitions and concepts relates to many of the five clusters identified at the Member State level in Section 5.1.1.1. In particular, the different definitions recall the interdisciplinary and policy-integrated approaches, innovation- and technology-driven framing, and industry-aligned and skills-oriented definitions used within Member States.

([396]) European Commission, *STEM Education Strategic Plan 2025*, Publications Office of the European Union, Luxembourg, 2025.

In contrast, the EU-level definitions resonate less with curriculum-centred and discipline-based definitions, which may be explained by the largely integrative approach taken at the EU level. Yet the European Education Area monitoring framework uses science and mathematics achievements as key indicators, which partially contradicts the broad STEM definitions used in the underlying policy documents.

Another factor possibly leading to the diversity of STEM definitions relates to the many policy areas with high salience at the EU level (e.g. digital and green transitions, AI, industrial transformation, competitiveness), which are crucially dependent on advanced and diverse STEM or STEAM skills. In this context, a certain flexibility in the use of definitions allows for greater adaptability across sectors and policy domains. It enables the education system to adjust to changing skills demands and to experiment with varied approaches, including interdisciplinary and STEAM-based interventions. However, this openness also raises questions about coherence: when definitions diverge too widely, adaptability can conflict with the need for comparability and shared direction.

While flexible definitions allow for tailoring to specific contexts, they also affect key actions such as monitoring and strategic planning for STEM education. Integrated STEM or STEAM approaches are frequently presented as means to raise interest in STEM fields and improve achievement in core subjects. A more consistent definition covering these approaches would support the design of monitoring frameworks, strengthen skills intelligence and enhance policymaking, particularly in the context of the recent STEM Education Strategic Plan.

#### 5.2.3.4. Monitoring and impact evaluation

A significant challenge in assessing EU-level support for STEM education is the **lack of a coherent and systematic monitoring framework across the various funding programmes**. Currently, **there is no centralised mechanism for collecting reliable data** on STEM-related interventions or their implementation, effectiveness or alignment across programmes. This fragmentation hampers efforts to evaluate the coherence and impact of EU investments in STEM education.

Among the major EU programmes, **Erasmus+ is the only one with a dedicated tagging system** for STEM-related projects, enabling easier identification and tracking through its project platform. In contrast, other key instruments, such as **Horizon Europe**, the **European Structural and Investment Funds** (ESIFs)**,** and the **Recovery and Resilience Facility** (RRF)**,** lack such tagging or classification mechanisms. As a result, there is no systematic reporting or aggregation of STEM-related activities across these programmes.

Moreover, monitoring at the **project outcome level** remains limited. While most EU-funded education projects report basic output metrics, such as the number of

participants (students, teachers) or activities delivered, **there is little to no systematic evaluation of the effects on student learning outcomes or achievement levels in STEM**. This gap persists across multiple funding instruments, including Erasmus+, Horizon Europe and ESF+, and was observed in the projects analysed for this report.

Without consistent tracking of both project-level interventions and their educational impact, it remains difficult to assess the overall contribution of EU programmes to promoting STEM education. Monitoring also relates to the **targets of EU policy regarding supporting STEM education**. At the school level, a key target is to reduce the share of low-achieving 15-year-olds in science and mathematics, according to the European Education Area monitoring framework ([397]). There are, so far, no performance targets for younger pupils based on TIMSS or similar data. In addition, the main monitoring indicator focuses on science and mathematics only and does not align with the broader conceptions of STEM – such as integrated STEM or STEAM approaches – reflected in recent EU policy documents. These gaps limit the ability to identify which policies and interventions effectively support STEM education and which hinder the identification of evidence-based good practices at the programme level ([398]).

The monitoring mechanisms proposed under the STEM Education Strategic Plan, including STEM skills intelligence and the future European Skills Intelligence Observatory, supported by the European Semester process, may therefore play a key role in addressing this gap at the EU level ([399]).

The Commission's STEM Education Strategic Plan also acknowledges shortcomings in programme monitoring, noting that one of the most important factors for developing STEM education is increasing the number of well-designed studies on the effectiveness of STEM and STEAM ([400]). Key measures to remedy this problem could include experimental and longitudinal study designs, relying

([397]) Council resolution on a strategic framework for European cooperation in education and training towards the European Education Area and beyond (2021–2030) (OJ C 66, 26.2.2021, p. 1).

([398]) The Erasmus+ analytical report, developed in parallel with this report, details project-level good practices and lessons learned.

([399]) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A STEM Education Strategic Plan: Skills for competitiveness and innovation, COM(2025) 89 final of 5 March 2025, https://education.ec.europa.eu/sites/default/files/2025-03/STEM_Education_Strategic_Plan_COM_2025_89_1_EN_0.pdf.

([400]) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A STEM Education Strategic Plan: Skills for competitiveness and innovation, COM(2025) 89 final of 5 March 2025, https://education.ec.europa.eu/sites/default/files/2025-03/STEM_Education_Strategic_Plan_COM_2025_89_1_EN_0.pdf.

on clearly defined outcomes and measuring tools and thus yielding insights into which interventions are effective ([401]).

#### 5.2.3.5. Policy aspects

The EU programmes supporting STEM education show heterogeneous coverage of policy aspects related to STEM education in schools. Erasmus+ projects largely address STEM curricula and pedagogy, and also formal, non-formal and informal learning. They frequently address the professional development of teachers, but less so systematic reforms of teacher careers. In addition, research on STEM education in schools is largely absent and was covered only in 2 out of 15 Erasmus+ good practice projects analysed through case studies in the present study. Finally, Erasmus+ projects do tackle the topic of to education governance, although again rarely in the form of systematic governance reforms. **Infrastructure investments** fall under programmes such as **ESIFs (ERDF, ESF+) and the RRF**. In the absence of a deeper investigation into the contributions of the ESIF projects on promoting STEM education, further research on these programmes is advisable, especially given the large-scale investments that they entail.

The **EU Framework Programmes** (Horizon 2020, Horizon Europe) support a range of issues, such as non-formal and informal STEM education opportunities through the MSCA and Citizens action and other projects. Coordination and support actions ([402]) are crucial tools addressing policy actions relevant for STEM education in schools, STEM curricula reforms and STEAM policies, and also women's participation in STEM careers. The Road-STEAMer ([403]) project is mapping systemic barriers to and developing a policy roadmap for mainstreaming STEAM education across Europe, with a strong focus on inclusiveness, interdisciplinarity and evidence-informed reforms. It supports the integration of the arts and social sciences into STEM education and proposes practical models for STEAM-based curricula and teacher training. Similarly, the SEER ([404]) project contributes by identifying effective STEAM practices across Member States and developing frameworks for competence-based learning, formative assessment and cross-sectoral partnerships. Through the different specific programmes of Horizon Europe and Horizon 2020, including bottom-up projects under Pillar 1, various aspects are addressed, such as student assessment, competence frameworks, evaluation and policy actions, school leadership, funding and

([401]) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A STEM Education Strategic Plan: Skills for competitiveness and innovation, COM(2025) 89 final of 5 March 2025, https://education.ec.europa.eu/sites/default/files/2025-03/STEM_Education_Strategic_Plan_COM_2025_89_1_EN_0.pdf.

([402]) https://rea.ec.europa.eu/horizon-europe-how-apply_en.

([403]) https://www.road-steamer.eu/.

([404]) https://cordis.europa.eu/project/id/101058569.

governance, and research into individual STEM subjects and their teaching and learning approaches.

EU programmes support various policy aspects of STEM education, yet several **important gaps persist**. Erasmus+ addresses STEM curricula, pedagogy and teacher professional development across formal and informal learning settings but provides limited support for systemic reforms such as career pathways for STEM teachers, governance innovation, research on the effectiveness of interventions and infrastructure investment. Research framework programmes (Horizon 2020, Horizon Europe) cover a wide range of relevant areas – including non-formal learning, curriculum reform, STEAM policy, gender equality and school governance – through coordination and support actions. However, projects are often fragmented across programme pillars ([405]) and calls, making coherence and scale-up challenging. Crucially, key policy areas such as recruitment campaigns, retention measures, career support for STEM teachers and transitions between educational levels remain largely unaddressed across all funding instruments.

#### 5.2.3.6. Programming and coordination

EU programmes provide a range of funding options for various stakeholders and activities related to STEM education in schools. These include funding for individual mobility, school cooperation, research projects, coordination and policy support actions, outreach and communication activities, and school infrastructure. Our analysis shows that all EU funding instruments are being utilised to support STEM education.

There are also innovations in the programming mix, such as the Erasmus+ Teacher Academies, trialling new types of interventions in the field of teacher professional development, with budgets of up to EUR 1.5 million per project (Table 9). At least seven of the Erasmus+ teacher academies funded so far have addressed topics related to STEM education in schools and could warrant further attention after their conclusion in 2025–2026.

**Table 9. Erasmus+ teacher academies addressing STEM**

| Title of the project | Start date | End date | EU grant (EUR) |
|---|---|---|---|
| acaSTEMy – (trans-national STEM teacher education focussing on transversal competence and sustainability education) | 1 June 2023 | 31 May 2026 | 1 480 611.56 |
| EduSTA – (academy for sustainable future educators) | 1 June 2022 | 31 May 2025 | 1 258 525.44 |

([405]) For more details on the Horizon Europe programme structure, see https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en.

| | | | |
|---|---|---|---|
| NBS academy (a European academy for integrating nature-based solutions (NBS) in teacher education) | 1 June 2023 | 31 May 2026 | 1 499 391.00 |
| proSTEM – (ICSE academy – European collaboration and mobility in professional development of pre- and in-service STEM teachers) | 1 June 2022 | 31 May 2025 | 1 495 323.00 |
| SpicE – (special education STEAM academy) | 1 July 2022 | 30 June 2025 | 1 486 729.86 |
| STEAME-academy (STEAME teacher facilitators academy) | 1 June 2023 | 31 May 2026 | 1 162 029.40 |
| TEFF-academy – (teacher education for a future in flux (TEFF)) | 15 June 2023 | 14 June 2026 | 1 499 999.57 |

*Source:* Technopolis Group based on the E+ Results Platform.

The wide scopes of EU-funded projects, combined with the challenge of systematically monitoring and evaluating ongoing interventions, creates coordination difficulties and limits the effective transfer of good practices across initiatives.

It is critical that the lessons learned from these projects are disseminated to relevant policymakers, stakeholders and other beneficiaries of Erasmus+, Horizon Europe, ESIFs, RRF and other programmes, ensuring that the lessons are transferred where applicable. This includes the results of implementing innovative STEAM teaching and learning approaches to enhance achievements in individual STEM subjects and across disciplines. Both Erasmus+ and Horizon Europe support bottom-up innovation and experimentation, generating practical evidence on the effects of different teaching methods and approaches on learners. Policy-oriented projects under Horizon Europe (e.g. Road-STEAMer, SEER, STEAM Europe), together with Erasmus+, provide valuable input, networks and examples of effective practice that contribute to advancing STEM education across Europe.

A key challenge, therefore, lies in **coordinating the portfolio of projects and ensuring that good practices are effectively transferred** across these instruments, Member States and associated countries, alongside ensuring the application of **a systematic approach to monitoring and evaluation**.

The question of which entity should oversee such coordination remains unresolved. Most of the working groups under the European Education Area strategic framework do not explicitly address STEM education, which may limit opportunities for policy learning and the design of new interventions. A stronger institutional anchoring of STEM education may therefore be necessary for future strategies. New bodies created under the Union of Skills strategy and the STEM Education Strategic Plan from March 2025, such as the European Skills High-level Board and the STEM Executive Panel, could play a key role in filling this gap. A central task for these bodies could be to follow up on the Draghi report's

recommendation on becoming more responsive to changing skills needs and gaps identified through skills intelligence, ensuring that curricula are revised accordingly with input from employers and other stakeholders ([406]). Interventions should be informed by the latest available evidence, which requires not only data collection but also the establishment of bodies – such as dedicated expert panels, advisory councils or interinstitutional committees – capable of making decisions about strategic programming, policy targets and other, related matters.

Interviewees from both EU- and national-level organisations also emphasised the need to improve communication about the benefits of various funding programmes for Member States and schools working to improve STEM education. While programmes like Erasmus+ and ESF+ are widely recognised, relevant stakeholders – such as regional and national education policymakers – must be made more aware of the opportunities offered by other programmes, including the RRF, InvestEU, and the TSI, so that they can leverage them for STEM education interventions.

#### 5.2.3.7. Education levels and transitions

The current EU policy and programme mix focuses, in principle, on all levels of education: Erasmus+ projects address all levels from pre-primary to tertiary education. Projects funded under Horizon Europe have the tendency to address secondary to tertiary education, in particular with a focus on careers in STEM and reducing gender gaps.

However, as shown by the Erasmus+ project analysis, there is a relative **concentration of interventions at the secondary level**. While the primary level is served as well, **pre-primary education is the least commonly addressed under Erasmus+**. Generally, transitions between education levels appear to be addressed only on a case-by-case basis. The newly launched Teacher Academies were found to have an overarching focus across levels.

A range of programmes intend to motivate students to go into STEM-related careers and studies, such as the MSCA and Citizens action, the ESTEAM projects and actions supported by the EIT. Initiatives such as Girls Go Circular and selected national RRF programmes such as Italy's School 4.0 initiative (which promotes digital and STEM-related learning environments in schools) also contribute to raising interest in STEM careers and equipping students with future-oriented skills.

([406]) At the same time, it should be underlined that responsibility for curriculum design and revision ultimately rests with the Member States; EU-level bodies can therefore play only a supportive and coordinating role.

#### 5.2.3.8. Multilevel governance and funding of schools

European-level interventions, within the competences of the EU, need to account for different challenges related to school education, which are not confined to STEM education. For example, primary and secondary schools often have limited financial and human resources, lower international engagement capacity and less experience with project-based work, making it more difficult for them to participate in EU-funded initiatives or implement EU-level results. Early childhood education and care providers face even greater constraints in these areas. This is also linked to lower institutional autonomy in schools than in higher education institutions and the rigid nature of national curricula, which restricts flexibility to integrate innovative practices. While project-based interventions – such as individual mobility or school-level partnerships – can help address these challenges by building capacity, fostering networks and introducing new practices, their impacts tend to be localised and incremental rather than systemic.

**EU-level programmes, such as ESIFs and the RRF, are available to support reforms and interventions at the regional or national level.** They also have the potential to affect policy aspects such as basic school and laboratory infrastructure or the working conditions of teaching staff, which are largely beyond the scope of the Erasmus+ and Horizon Europe programmes. To understand those programmes that already address STEM education, a better monitoring and evaluation approach may be beneficial.

**Challenges related to coordination** have also been identified by the Draghi report. It identifies structural aspects relating to policymaking, namely a 'lack of willingness among Member States … to go beyond soft forms of coordination' and a 'lack of systematic evaluations, preventing learning about the effectiveness of alternative strategies and refining of interventions' ([407]), which resembles the findings supported by this report.

#### 5.2.3.9. Promoting STEM professions and careers

A key factor stressed during the interviews was societal factors, which are crucial to motivate young people to choose STEM studies and careers. This concerns the visibility of STEM professions and careers. Various EU-level actions aim to address this gap. **Motivating teachers to take up STEM teaching roles, on the other hand, is rarely addressed in the initiatives and programmes analysed.** Erasmus+ projects are supporting teacher professional development, as a key element of different types of projects. Projects promoting STEM studies and careers may have indirect effects, but they do not address teachers' career conditions, such as pay, workload, career paths or professional recognition. Erasmus+ supports teacher development through mobility, partnerships and

([407]) Draghi, M., *The Future of European Competitiveness – Part A: A competitiveness strategy for Europe,* Publications Office of the European Union, Luxembourg, 2024, p. 37.

training, yet structural career conditions remain outside its scope and are the responsibility of national education systems. As of 2025, no EU programme directly targeted these aspects, although reforms funded under national RRF plans – such as investments in teacher careers and status – could indirectly support improvements.

Despite the range of EU instruments supporting STEM education, from Erasmus+ and Horizon Europe to the RRF, there remains a lack of overarching coordination, shared monitoring mechanisms and strategic alignment across programmes. This fragmentation limits the capacity of the EU to leverage its full potential in driving systemic change. The evidence from national practices and EU-level analysis points to a clear need for more integrated governance, sustained investment and consistent frameworks for evaluation and knowledge sharing. These insights set the stage for the following section, which synthesises key findings and reflects on the broader implications for the future of STEM education policy across Europe.

# 6. Conclusions

## 6.1. Summary of key findings

### 6.1.1. Key challenges and barriers to STEM education

This report presents a detailed analysis of the current state of STEM education across EU school systems. Drawing on EU and national reports, literature, vast stakeholder consultation work and policy documents, the study identifies a set of core structural and systemic challenges that hinder the delivery of inclusive, future-oriented STEM education. While progress is evident in some countries, significant gaps remain in ensuring coherence, quality and equity across national contexts. The key findings are structured around six overarching themes.

#### 6.1.1.1. Fragmented governance and weak policy alignment

STEM education remains hindered by fragmented governance structures, with overlapping responsibilities across ministries, regions and education levels. Many systems lack coherent national strategies or integrated frameworks that align the curriculum, teacher training and stakeholder engagement. This fragmentation extends to school-level governance, where limited mechanisms exist to coordinate partnerships with higher education, industry and civil-society actors.

#### 6.1.1.2. Persistent teacher shortages

The availability of qualified STEM teachers is a widespread concern, particularly in rural and disadvantaged areas. Early-career support is often insufficient, with

weak induction systems, poor mentoring and limited opportunities for career advancement. These conditions contribute to high attrition and uneven teaching quality.

#### 6.1.1.3. Gaps in teacher education and professional development

Initial teacher education (ITE) programmes frequently lack interdisciplinary and digital pedagogies, and continuous professional development (CPD) is often fragmented and project based. In many systems, CPD is not linked to incentives, school improvement plans or career progression. Promising practices include Estonia's integration of digital pedagogy into ITE and Finland's long-term CPD partnerships with universities and educational technology providers.

#### 6.1.1.4. Unequal access to infrastructure and learning environments

Outdated laboratory equipment, insufficient digital tools and geographical disparities in school resources continue to undermine equitable provision of STEM education. Urban–rural divides are especially pronounced in countries such as Belgium, Croatia and Poland.

#### 6.1.1.5. Limited integration of non-formal and informal learning

Opportunities for students to engage in non-formal and informal STEM learning, such as after-school clubs, science festivals and industry partnerships, remain inconsistently available and often dependent on ad hoc funding. More systematic integration into national policy frameworks is needed.

#### 6.1.1.6. Weak evaluation and limited use of evidence

STEM education initiatives across Europe often lack robust formal evaluation frameworks, hindering efforts to scale up what works and to inform policy design. National monitoring systems are underdeveloped in many countries, and few include longitudinal or impact-focused indicators for STEM education.

### 6.1.2. Actions identified across the country reports and EU-level instruments

Despite persistent challenges, a growing number of Member States are demonstrating progress through strategic reforms and targeted initiatives that promote STEM education in schools. While the pace and scope of change vary across contexts, a set of shared response patterns is emerging. They reflect a collective shift towards more coherent, inclusive and innovation-oriented

approaches to STEM education. The following summary outlines the main strands of action identified across the country reports and EU-level instruments.

#### 6.1.2.1. Strategic integration of STEM within national policy frameworks

An increasing number of countries are embedding STEM within national education strategies that align with broader economic, digital and sustainability goals. Ireland, Italy, Finland and Sweden exemplify this integrated policy framing, positioning STEM not only as a curriculum area but as a cross-cutting lever for inclusion, innovation and competitiveness. These strategies often include dedicated objectives for teacher development, digitalisation, infrastructure, and partnerships with industry and research.

#### 6.1.2.2. Expansion and reform of teacher education and professional development

Countries are progressively recognising the centrality of teacher competence in STEM education quality. Responses include reforming ITE to embed interdisciplinary and digital pedagogies (e.g. Estonia, Finland), scaling up CPD opportunities (e.g. Austria, France) and creating structured career pathways (e.g. the Netherlands). National teacher education programmes increasingly emphasise inquiry- and project-based methodologies, supported by digital tools and real-world problem-solving.

#### 6.1.2.3. Infrastructure modernisation and targeted investment

In response to disparities in access to high-quality learning environments, several Member States have launched national investment programmes aiming to upgrade laboratories, digital infrastructure and learning materials. Estonia's digital-first strategy, Italy's School 4.0 initiative and Spain's Recovery and Resilience Plan are examples of large-scale interventions that improve physical and digital conditions for STEM learning, especially in underserved regions.

#### 6.1.2.4. Curriculum reform towards interdisciplinarity and experiential learning

A growing number of systems are revising curricula to promote interdisciplinary approaches and real-world relevance. Czechia, Croatia and Lithuania have introduced reforms that encourage project-based learning, while Estonia and Sweden have embedded STEM within sustainability and digital transformation agendas. In some cases, the arts are being explicitly integrated (e.g. Lithuania, Slovenia), reflecting an emerging STEAM orientation.

#### 6.1.2.5. Strengthening cross-sectoral and multilevel collaboration

National strategies increasingly institutionalise partnerships across education, research, and industry sectors. Finland's LUMA centres, Germany's MINT platforms and Ireland's regional STEM networks exemplify coordinated governance models that align stakeholders across governance levels and sectors. These partnerships support curriculum development, teacher training and student engagement, and are often underpinned by EU funding instruments and policy platforms.

#### 6.1.2.6. Use of EU mechanisms and funding for STEM innovation

EU-level instruments, such as Erasmus+, the TSI and the RRF, play a significant role in supporting national reforms. Member States are leveraging these funds to modernise infrastructure, support teacher development and pilot interdisciplinary or digital STEM initiatives. Initiatives such as Scientix and the EU STEM Coalition provide platforms for mutual learning and transnational collaboration.

## 6.2. Reflections on the future of STEM education policies

As Europe confronts complex social, economic and environmental transformations, the role of STEM education is becoming increasingly strategic. The findings of this report point to both the potential and limitations of current approaches, underscoring the need for a more coherent, equitable and future-oriented policy framework. While progress is evident across Member States, the fragmented nature of many education systems, combined with persistent gaps in capacity, infrastructure and policy alignment, limits the systemic impact of reforms. The future of STEM education policy will depend on the ability of governments and the EU to sustain momentum, close implementation gaps and shift from isolated interventions to holistic, long-term strategies.

### 6.2.1. From policy ambition to system-level coherence

A major challenge for the next phase of STEM policy development lies in translating strategic goals into coherent system-wide practice. Many countries have articulated bold visions, emphasising interdisciplinarity, inclusion and innovation, but struggle to operationalise these at the classroom level. Moving forward, policies must embed STEM as a structural component of national education systems, not a thematic add-on. This requires aligning the curriculum, assessment, teacher development, funding and partnerships within an integrated governance framework.

### 6.2.2. Positioning teachers as central agents of change

The success of STEM reforms will hinge on sustained investment in teachers, not only in terms of professional development but also through recognition, career pathways and participatory leadership. Teachers must be empowered as curriculum co-designers, research partners and innovation agents. Future policy should support peer learning, professional communities and school autonomy, while ensuring national support systems are in place to reduce fragmentation and ensure equity of opportunity.

### 6.2.3. Redefining STEM education through equity and sustainability

Future-oriented STEM education must be inclusive by design. Policies should go beyond addressing gender imbalances to tackle deeper structural inequalities linked to geography, socioeconomic background, migration and disability. Furthermore, the sustainability agenda provides a powerful organising principle for STEM learning, linking scientific knowledge with civic responsibility and practical problem-solving. Embedding green skills, systems thinking and ethical reasoning into STEM education will be vital to prepare learners for an increasingly complex world.

### 6.2.4. Rethinking curriculum and assessment for real-world relevance

To meet the demands of future societies and economies, STEM education must move beyond disciplinary silos and high-stakes testing. Curriculum design should foreground inquiry, creativity, collaboration and digital competence, while assessments must change to capture transversal skills and project-based learning. National systems should explore new formats, such as portfolios, final year projects and formative digital tools, that better reflect students' capacities to apply knowledge in dynamic contexts.

### 6.2.5. Harnessing digital transformation responsibly

The rapid development of digital technologies presents both opportunities and challenges for STEM education. While STEM competences are distinct from digital competences, they intersect with each other: STEM education builds foundational skills that support the development of digital literacy, and includes technology as one of its core pillars. Emerging digital tools such as AI, data science, robotics and virtual laboratories can enrich STEM learning by enabling more personalised, interactive and inquiry-based approaches. However, these

benefits depend on equitable access, pedagogically grounded integration and targeted teacher training. Policymakers must ensure that digital tools are embedded in STEM education in ways that enhance – but do not replace – scientific reasoning, problem-solving and ethical awareness. At the same time, STEM policy should actively support students in building critical digital literacy, enabling them to navigate and shape technological developments responsibly and confidently.

#### 6.2.6. Towards a European learning ecosystem for STEM

The future of STEM education will increasingly depend on collaboration, not only within countries but across them. EU policy can play a stronger role in promoting shared standards, mutual learning and cross-border innovation. Initiatives such as the European Education Area, Digital Education Action Plan, and STEM Education Strategic Plan provide a valuable platform for shaping a European STEM learning ecosystem. These efforts should continue to foster cooperation between education systems, research institutions, industry and civil society, while respecting local contexts and capacities.

# 7. Recommendations

## 7.1. Recommendations for policymakers at the national level

Advancing inclusive and future-ready STEM education requires national action that supports not only individual initiatives but also system- and school-wide transformation. Policymakers should adopt integrated strategies that enable schools to develop and sustain a **whole-school approach to STEM education**, embedding STEM across leadership, pedagogy, curriculum, infrastructure and community engagement. Drawing on country experiences, the following recommendations outline key priorities for national action.

#### 7.1.1. Develop national STEM strategies that support system- and school-wide coherence

National STEM strategies should provide a clear and stable framework that enables schools to implement whole-school approaches. This requires alignment across ministries (education, labour, digital, environment), coordination between central and local authorities, and the integration of STEM education goals into school improvement plans. Particular attention should be paid to early years provision. Whole-school implementation should be supported through:

- guidance for school leadership teams;

- incentives for interdisciplinary collaboration among teachers;
- resources for engaging parents, local industry and community stakeholders.

### 7.1.2. Empower school leaders and leadership teams to drive STEM innovation

School leadership is a key enabler of the effective implementation of STEM education. National policy should recognise school leaders' role and support them to:

- coordinate interdisciplinary and cross-curricular STEM teaching;
- facilitate collaboration between STEM and non-STEM departments (e.g. STEAM);
- foster a shared vision for STEM education that involves inclusion, sustainability and digital innovation;
- create targeted leadership development programmes to equip head teachers and leaders with the ability to lead STEM-focused school improvement work.

### 7.1.3. Reform teacher recruitment, induction and career development in support of school-wide STEM education capacity

Addressing teacher shortages and enhancing retention is essential for enabling schools to build sustainable, team-based STEM education capacity. National actions should include:

- expanding and diversify teacher recruitment pathways, including alternative routes targeting STEM professionals;
- strengthening initial teacher education (ITE) and continuous professional development (CPD), with an emphasis on interdisciplinary pedagogy, digital competence and equity, including:
    - cross-disciplinary training modules and school-based CPD communities,
    - problem-solving and project work, which should embed both digital tools and physical working environments,
    - coherent training opportunities across all career stages and staff roles,

    - support for peer learning and teacher research networks, helping schools to become professional learning organisations for STEM education;
- establishing clear career progression and incentives to support long-term retention, particularly in rural and disadvantaged areas.

### 7.1.4. Reform curricula to support integrated STEM learning across the whole school

Rigid curriculum frameworks hinder schools' ability to take a whole-school approach. National reforms should:

- provide schools with the flexibility to design thematic, interdisciplinary modules that span multiple subjects and year groups;
- allow them to introduce project weeks, makerspaces or STEM inquiry blocks;
- enable them to embed sustainability and real-world challenges into the everyday curriculum;
- support them with exemplar units and shared resources that can be used to scale up effective practice.

### 7.1.5. Invest in infrastructure and resources that enable collaborative and applied learning

A whole-school approach requires physical and digital environments that support experimentation, teamwork and community engagement. National investment should prioritise:

- modern laboratories, flexible learning spaces and mobile STEM kits;
- equitable access to broadband, devices and digital content;
- infrastructure grants linked to inclusive and whole-school STEM development plans.

### 7.1.6. Promote equity and participation through whole-school culture and early intervention

Inclusive STEM education is achieved not through isolated outreach but through culture change across the school. National policy should:

- encourage whole-school equity strategies addressing gender, socioeconomic status, migration background and special educational needs;

- promote STEM activities from early years through to secondary education, integrated into whole-school planning;
- fund mentoring schemes, role model programmes and family engagement aligned with school-based inclusion strategies.

### 7.1.7. Build national evaluation systems that assess school-level implementation and outcomes

To support continuous improvement, evaluation should focus not only on outputs but on school-wide processes and impact. National systems should:

- include indicators on leadership, teaching practices, partnerships and learner engagement;
- enable schools to use data for self-assessment and planning;
- share examples of school-level innovation through national knowledge-sharing platforms;
- mandate the collection of disaggregated participation and achievement data (gender, socioeconomic status, region) across all STEM subjects and pathways;
- establish national dashboards that feed real-time information back to schools for self-evaluation.

### 7.1.8. Institutionalise partnerships that support schools in delivering comprehensive STEM experiences

Whole-school STEM education depends on sustained collaboration beyond the school gate. National policy can enable this by:

- funding intermediary organisations to broker partnerships with universities, research centres, industry and civil society;
- recognising and rewarding schools for participation in local STEM ecosystems;
- embedding non-formal and informal learning in school timetables and improvement frameworks.

### 7.1.9. Support strong STEM foundations in early childhood and primary years

Support should be provided to:

- introduce play-based, inquiry-rich STEM experiences in ECEC settings and lower primary;
- provide age-appropriate teaching guides and low-cost maker/science kits;
- offer targeted CPD so pre-primary and primary teachers feel confident dealing with hands-on science, coding and data literacy basics.

## 7.2. Recommendations for policymakers at the EU level

The EU plays a critical role in shaping the policy environment, funding structures and collaborative platforms that support national reform in STEM education. Building on the objectives of the **STEM Education Strategic Plan** (2025) and the **European Education Area**, the EU is well positioned to accelerate transformation by promoting policy coherence, fostering innovation and supporting equity across Member States. The following recommendations outline how EU-level actions can strengthen the impact and sustainability of STEM education reforms.

### 7.2.1. Consider initiating the development of a European STEM competence framework

The EU should steward a co-creation process that sets clear, yet flexible, reference points for what STEM learners should know and be able to do at each schooling stage. This could involve:

- co-designing the framework with Member States, teachers, researchers, learners and industry to define core knowledge, skills and attitudes – including inquiry, problem-solving, design thinking, data literacy and sustainability – while allowing national curricula to adapt the details;
- providing practical implementation packs (learning progressions, sample tasks, assessment rubrics) so countries can map existing standards to the framework rather than replace them;
- linking the framework to teacher professional development through microcredentials and to existing EU digital and green competence frameworks, ensuring specific transversal skills and distinct domains.

### 7.2.2. Strengthen EU-level coordination and integration of funding to support national STEM strategies

The EU should continue to provide strategic support for STEM education across Member States by:

- improving interoperability between Erasmus+, Horizon Europe, Technical Support Instrument and Recovery and Resilience Facility funding streams to support coherent, scalable STEM education initiatives;
- increasing the accessibility of EU funds for smaller schools, rural areas and emerging STEM education providers;
- implementing the STEM Education Strategic Plan in alignment with the green and digital transitions;
- encouraging coordinated target setting and progress monitoring in areas where shared challenges exist – such as teacher recruitment, (gender) equity and digital access – while fully respecting Member State competences.

The EU should ensure that key funding instruments are fully leveraged to support long-term investment in STEM education, including, for example:

- Erasmus+ for school partnerships, teacher and learner mobility, and cross-sectoral innovation;
- the Recovery and Resilience Facility, Digital Europe programme and ESF+ for infrastructure, digital transformation and inclusion;
- calls within Horizon Europe for STEM education research, policy experimentation and applied learning.

To ensure impact, funding criteria should prioritise systemic and sustainable reforms over short-term projects.

### 7.2.3. Promote whole-school STEM implementation through EU guidance and tools

EU institutions should champion the whole-school approach by:

- supporting Member States to adopt whole-system and whole-school approaches through country-specific recommendations, peer learning and mutual support;
- publishing practical frameworks and case studies on how to embed STEM across school leadership, pedagogy, infrastructure and community engagement;

- developing guidance on integrating STEM into school improvement planning, digital transformation strategies and equity initiatives;
- highlighting and scaling up innovative school-level practices through EU platforms such as eTwinning, the European School Education Platform and Scientix.

### 7.2.4. Enhance policy learning and innovation across countries through structured exchanges

Building on existing STEM initiatives, the EU should facilitate:

- thematic peer learning among Member States on priority areas such as curriculum integration, formative assessment, early years STEM education and teacher CPD;
- knowledge-sharing platforms and EU-wide networks of practitioners and policymakers;
- Horizon Europe and Erasmus+ projects that pilot and evaluate scalable models for interdisciplinary, inclusive and digitally enabled STEM education.

### 7.2.5. Support teacher education and professional learning at the European level

The EU can contribute to strengthening the STEM teaching profession by:

- promoting an EU STEM competence framework for learners and teachers;
- supporting the mobility of STEM teacher educators and school leaders through Erasmus+;
- facilitating digital and hybrid CPD provision across borders via platforms like the European School Education Platform and Scientix;
- funding joint curriculum design and CPD programmes between teacher training institutions and schools.

### 7.2.6. Foster inclusive and gender-transformative approaches across all EU STEM actions

To close persistent equity gaps, the EU should:

- expand outreach, mentoring and role model visibility through initiatives like Girls Go Circular, Women TechEU
- mainstream gender and inclusion criteria into all EU STEM funding calls;

- promote inclusive curricula through content development, teacher training and student engagement projects;
- prioritise regional convergence support, ensuring that funds reach underserved or rural communities.

### 7.2.7. Invest in robust monitoring, research and evidence use at the EU level

The EU should deepen its investment in knowledge generation and evidence-informed policymaking by:

- continuing to fund comparative studies and indicator development (e.g. through Eurydice – the information network on education in Europe – the JRC and the European Centre for the Development of Vocational Training);
- supporting applied research on STEM pedagogy, assessment and system change;
- supporting Member States in developing evaluation and monitoring frameworks by facilitating the exchange of practices and providing methodological guidance, while respecting national competences.

The EU can play a valuable role in collecting, aggregating and disseminating comparative data on STEM education across countries, and in developing non-binding reference indicators to inform policy dialogue and mutual learning.

### 7.2.8. Cultivate an EU-wide STEM learning ecosystem

The EU should act as an enabler of cross-border ecosystems that connect schools, higher education, research and industry, which will involve:

- supporting regional STEM hubs, university–school networks and science outreach initiatives;
- encouraging Member States to engage in coordinated experimentation and innovation aligned with shared EU priorities.

## 7.3. Recommendations for schools, educators and other stakeholders

Realising the full potential of STEM education requires action not only at the policy level but also across schools, classrooms and local ecosystems. Schools, educators and industry stakeholders are central actors in delivering inclusive, engaging and future-oriented STEM learning experiences. This section offers

targeted recommendations on how each of these groups can contribute to and benefit from a coherent and collaborative STEM education agenda.

### 7.3.1. For schools and school leaders

#### 7.3.1.1. Adopt a whole-school STEM education approach

Schools should embed STEM across their visions, leadership structures and pedagogical cultures. This includes:

- creating interdisciplinary teaching teams and allocating time for collaborative planning;
- integrating STEM education priorities into school development plans and self-evaluation frameworks;
- aligning STEM education with broader school goals, such as inclusion, digital transformation and environmental sustainability.

#### 7.3.1.2. Foster partnerships with external stakeholders

School leaders should actively build and sustain relationships with:

- local universities and teacher education institutions for curriculum co-design and CPD;
- businesses, science centres and civil society to enrich learning with real-world applications;
- municipal authorities and regional innovation hubs to access funding and shared infrastructure.

#### 7.3.1.3. Create inclusive, engaging STEM environments

Schools can promote equitable participation by:

- ensuring access to laboratories, makerspaces and digital tools for all students;
- embedding role models, career guidance and STEAM activities into the school calendar;
- supporting early engagement through playful STEM activities in early years and primary education.

### 7.3.2. For educators and teacher teams

#### 7.3.2.1. Engage in interdisciplinary and inquiry-based teaching

Teachers should experiment with pedagogies that:

- link STEM subjects to each other and to real-world challenges;
- foster creativity, problem-solving and teamwork through project-based learning;
- integrate sustainability and digital tools across STEM lessons.

#### 7.3.2.2. Participate in professional learning communities

Educators should take an active role in:

- peer-learning groups, lesson study teams and networks focused on STEM;
- online and cross-border CPD opportunities supported by national platforms and EU programmes;
- the co-development and sharing of teaching resources, assessments and classroom tools.

#### 7.3.2.3. Promote inclusion and learner-centred practices

Teachers play a crucial role in ensuring that STEM learning is:

- accessible to all learners, including those from disadvantaged or under-represented groups;
- culturally responsive and free from stereotypes, especially regarding gender and STEM careers;
- adapted to individual needs through formative assessment, feedback and flexible instruction.

### 7.3.3. For industry and employers

#### 7.3.3.1. Invest in long-term partnerships with schools and educators

Industry stakeholders should move beyond one-off outreach and towards:

- engaging in structured, curriculum-linked collaboration with schools, including work-based learning and mentoring;
- co-designing learning experiences such as maker projects, competitions and innovation challenges;
- offering teacher externships, site visits and access to up-to-date technological resources.

#### 7.3.3.2. Support STEM career awareness and progression

Businesses can help bridge the gap between education and work by:

- providing diverse and inclusive role models for in-school engagement;
- supporting career talks, internships and career guidance materials;
- partnering with schools to expose learners to emerging STEM fields, such as AI, green tech and advanced manufacturing.

#### 7.3.3.3. Contribute to local and regional STEM ecosystems

Industry actors should take an active role in regional coordination mechanisms by:

- joining or supporting local STEM clusters, public–private partnerships or regional innovation councils;
- co-funding infrastructure or outreach programmes in underserved schools and communities;
- advocating for inclusive STEM policies that align workforce development with educational equity.

## 7.4. Enhancing cross-border collaboration and synergies between EU and national/regional funding mechanisms

Achieving transformative impact in STEM education across Europe requires not only national leadership but also robust cross-border cooperation and more strategic use of the available EU and national funding mechanisms. While numerous programmes currently support STEM-related innovation and capacity building, efforts often remain fragmented or short-term in nature. There is a growing need to foster deeper alignment across initiatives, reduce duplication and promote greater complementarity and learning between funding streams. Enhancing these synergies will be essential for scaling up good practice, building shared infrastructure and sustaining inclusive and future-oriented STEM education reforms across Member States.

### 7.4.1. Strengthen alignment and complementarity between EU funding programmes

To maximise the collective impact of EU investment, stronger coordination is needed across key instruments, including:

- Erasmus+, for partnerships, mobility, teacher training and whole-school development;
- Horizon Europe, for research/practice/policy innovation and school–university–industry collaboration;
- the Technical Support Facility, for support for structural reforms related to STEM education in schools;
- the ESF+ and RRF, for infrastructure, equity and workforce upskilling.

The European Commission and national managing authorities should promote joint planning and communication across these programmes. Where possible, funding calls should highlight interoperability, cross-programme applications and pathways for scaling up.

### 7.4.2. Facilitate cross-border school and educator collaboration on STEM priorities

Transnational cooperation between schools, educators and local education authorities can strengthen shared learning and build communities of practice. EU institutions and national agencies should:

- expand thematic clusters within Erasmus+ and eTwinning focused on STEM integration, green skills and digital pedagogy;
- develop shared frameworks and toolkits for implementing whole-school STEM education approaches across diverse national contexts;
- support multilingual resources, online collaboration platforms and reciprocal teacher exchanges.

Such cooperation is particularly important in addressing common challenges, including gender equity in STEM, early years provision and digital inclusion.

### 7.4.3. Create cross-border synergies in regional innovation and STEM ecosystems

The EU can play a key role in connecting regional and local STEM education innovation hubs across borders. This includes:

- supporting cross-border pilot projects that link schools to regional economic and technological strategies;
- encouraging the pooling of resources (e.g. mobile laboratories, digital infrastructure, STEAM centres) across border regions with similar profiles.

These efforts can help build shared capacity, reduce duplication and promote inclusive access to STEM education opportunities, particularly in remote or underserved areas.

### 7.4.4. Enable long-term collaboration through multi-programme and multi-actor consortia

Many effective STEM interventions remain isolated within specific programmes or short-term project cycles. To address this, EU calls and national frameworks should:

- support multi-year, multistakeholder consortia involving schools, universities, civil society and employers;
- incentivise partnerships that draw on multiple funding streams (e.g. Erasmus+ for mobility, Horizon Europe for research, ESF+ for equity);
- include sustainability and upscaling strategies as key evaluation criteria in funded projects.

These approaches can foster integrated, durable collaborations that transcend individual projects and build structural capacity for system-level change.

### 7.4.5. Improve the transparency, accessibility and coordination of funding opportunities

Many schools, local authorities and smaller stakeholders face barriers in navigating EU and national funding systems. To address this, the European Commission and national agencies should:

- develop clearer, consolidated guidance on available STEM-related funding opportunities across programmes;
- establish national and regional coordination points to support project design, partnership development and access to blended funding;
- facilitate regular joint calls, thematic briefings and matchmaking events to build synergies and reduce competition between programmes.

# Appendix A EU-27 country reports

Provided as a separate document.

# Appendix B Six non-EU country reports

Provided as a separate document.

# Appendix C Erasmus+ report

Provided as a separate document.

# Appendix D EU-level report

Provided as a separate document.

## Appendix E List of stakeholder organisations consulted during Erasmus+ case study interviews

| Case study | Interviewee organisation |
|---|---|
| **1**<br>**STEM digital distance learning in university teaching** | University of Groningen |
| | Tallinn University |
| | Dublin City University |
| | Leibniz University Hannover |
| **2**<br>**Research in teacher education** | University of Groningen |
| | University of Southampton |
| | Paderborn University |
| **3**<br>**An interdisciplinary STEM approach connected to all around us (STE(A)M IT)** | European Schoolnet |
| | National Institute for Documentation, Innovation and Educational Research |
| | University of Cyprus |
| | Ministry of Science, Education and Youth (Croatia) |
| **4**<br>**Digital education readiness and collaborative virtual environment for math, informatics and physics education** | Slovak University of Agriculture in Nitra |
| | New Edu |
| | Cooperazione Territoriale Europea |
| | Secondary Technical School of Engineering and Construction, Tábor |
| **5**<br>**Future space** | Thessaloniki Science Center and Technology Museum |
| | Space Research Centre of the Polish Academy of Sciences |
| | Computer Assisted Education and Information Technology Centre (two interviews) |
| **6**<br>**SPICE academy** | Hellenic Open University |
| | University of Alicante |
| | Trakia University |
| | Bulgarian partner school |
| **7**<br>**Perspectives for lifelong STEM teaching – career guidance, collaborative practice and competence development** | University of Education, Freiburg |
| | Utrecht University |

| | |
|---|---|
| **8**<br>**Towards a European STEAM platform – EUSTEAM** | Platform Talent voor Technologie |
| | ZENIT Centre for Innovation and Technology in North Rhine-Westphalia |
| **9**<br>**Green STEAM incubator** | Citizens in Power |
| | Center for Social Innovation |
| | Centros Escolares de Ensino Profissional |
| **10**<br>**IN2STEAM** | European Centre of Studies and Initiatives |
| | Four Elements |
| | Istituto Comprensivo Statale Rita Borsellino |
| | Asist Ogretim Kurumlari |
| **11**<br>**The child is a researcher and a practitioner** | Rigas 224. pirmsskolas izglītības iestāde |
| | Vrije gesubsidieerde kleuterschool de kleuterark |
| | Kindergarten 8 Bodra Smyana |
| **12**<br>**Guidelines for developing and implementing STEAME schools** | Cyprus Mathematical Society |
| | Prof. Ivan Apostolov Private English Language Upper Secondary School |
| | Douka Ekpaideftiria AE – Palladion Lykeion – Douka Schools |
| **13**<br>**Fostering STEAM education in schools** | Ministry of National Education, Türkiye (two interviews) |
| | Helix 5 |
| **14**<br>**An interdisciplinary approach to mathematical education** | Faculty of Mathematics, University of Rijeka |
| | University of Primorska |
| | Centre of Technical Culture Rijeka (two interviews) |
| **15**<br>**Linguistically responsive biology and chemistry teaching – cross-disciplinary reflections on context and materials** | Gymnasium und FMS Lerbermatt |
| | Gymnasium ‘Walther von der Vogelweide’ |
| | Emil-von-Behring Gymnasium |
| | University of Innsbruck |
| | EduNet Europe |

# Appendix F List of stakeholder organisations consulted during the interviews informing the EU-level report

| Organisation | Date |
|---|---|
| European School Heads Association | 18 November 2024 |
| Lifelong Learning Platform | 8 November 2024 |
| Association for Teacher Education in Europe (ATEE) | 15 November 2024 |
| Directorate-General for Research and Innovation, Unit D4 – Democracy, Equality and Culture | 18 November 2024 |
| European Centre for the Development of Vocational Training | 28 November 2024 |
| Directorate-General for Justice and Consumers, Unit D3 – Gender Equality | 21 November 2024 |
| Directorate-General for Education, Youth, Sport and Culture, Unit A4 – Evidence-based Policy and Evaluation | 14 November 2024 |
| Directorate-General for Education, Youth, Sport and Culture, Unit B1 – Higher Education | 22 November 2024 |

# Appendix G List of stakeholders consulted for country reports

| Country | Organisation | Date of interview |
|---|---|---|
| Australia | Australian Parents Council | 12 November 2024 |
| | Australian Association of Mathematics Teachers | 4 December 2024 |
| | Australian Curriculum, Assessment and Reporting Authority | 7 November 2024 |
| | Science Technology Environment and Mathematics Research Group | 4 November 2024 |
| | Science and Technology Australia | 4 November 2024 |
| Austria | klasse!forschung | 14 November 2024 |
| | ScienceCenter-Netzwerk | 6 November 2024 |
| | *MINT-Regionen* | 27 November 2024 |
| | Federal Ministry of Education | 21 November 2024 |
| | Federation of Austrian Industries | 21 November 2024 |
| Belgium | VLAIO<br>STEM platform | 31 October 2024 |
| | iSTEM inkleuren | 13 November 2024 |
| | University of Louvain | 14 November 2024 |
| | Scholierenkoepel | 31 October 2024 |
| | Platform STEM-leerkrachten | 25 November 2024 |
| Bulgaria | European Institute for Technologies, Education and Digitalisation EduTechFlag (STEM educator for nearly 5 % of teachers in Bulgaria) | 14 November 2024 |
| | Syndeo Academy for Applied Education | 11 November 2024 |
| | Ministry of Education and Science | 22 November 2024 |
| | National STEM Center | 23 November 2024 |
| | 203. St. Methodius Language School | 29 November 2024 |
| Canada | Youth Science Canada | 20 November 2024 |
| | Natural Sciences and Engineering Research Council of Canada<br>Let's Talk Science<br>Science and Technology Awareness Network | 20 November 2024 |
| | Let's Talk Science | 29 November 2024 |
| | Science Teachers' Association of Ontario | 6 December /2024 |
| | New Brunswick Teachers' Association – Anglophone South School District Science | 4 December 2024 |
| | New Brunswick Teachers' Association – Anglophone West School District Science | 4 December 2024 |
| | Innovation, Science and Economic Development Canada | 13 December 2024 |
| | Innovation, Science and Economic Development Canada | 13 December 2024 |
| | Connected Canada Branch | 13 December 2024 |
| | Scientists in School | 6 January 2025 |
| Croatia | PISA researcher | 8 November 2024 |
| | University of Zagreb, Faculty of Science, Department of Physics | 6 November 2024 |
| | Ministry of Science, Education and Youth | 12 November 2024 |
| | Croatian Mathematical Society | 14 November 2024 |
| | Institute for Social Research | 19 November 2024 |

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| Cyprus | University of Nicosia | 6 December 2024 |
| | Dasoupolis Elementary School | 12 November 2024 |
| | Center for the Advancement of Research and Development in Educational Technology (NGO) | 12 November 2024 |
| | Ministry of Education, Sport and Youth | 6 December 2024 |
| | Ministry of Education, Sport and Youth | 14 November 2024 |
| Czechia | University of Hradec Králové, Physics Olympiad | 29 October 2024 |
| | Charles University, Prague, Mathematical Olympiad | 1 November 2024 |
| | Ministry of Education, Youth and Sports, Department for Secondary Education | 5 November 2024 |
| | Ministry of Education, Youth and Sports, Department for Pre-primary and Primary Education | 5 November 2024 |
| | Ministry of Education, Youth and Sports | 5 November 2024 |
| | National Pedagogical Institute<br>Prague Kunratice Primary School | 5 November 2024 |
| | FabLab Brno | 11 November 2024 |
| Denmark | Astra – National Centre for Science Education | 8 November 2024 |
| | NAFA | 5 December 2024 |
| | Danish Union of Teachers | 4 December 2024 |
| | Research centre for science education and dissemination LabSTEM+ | 20 November 2024 |
| | Confederation of Danish Industry | 6 January 2025 |
| Estonia | Study in Estonia | 12 November 2024 |
| | Estonian Research Council | 13 November 2024 |
| | Ministry of Education and Research | 18 November 2024 |
| | Estonian STEM Education Union | 18 November 2024 |
| | Estonian Physics Association, Physics Teachers Department | 29 November 2024 |
| Finland | Central Finland LUMA Centre | 4 December 2024 |
| | Tampere University | 14 November 2024 |
| | Tampere University | 21 November 2024 |
| | Tampere University of Applied Sciences | 22 November 2024 |
| | Teacher Training School, Tampere University | 23 November 2024 |
| France | Ministry of National Education<br>Limoges Academy | 27 November 2024 |
| | Ministry of National Education | 28 November 2024 |
| | Fondation La main à la pâte | 28 November 2024 |
| | Union of Professors of Sciences and Technology for Industry | 3 December 2024 |
| Germany | Federal state associations of Verband zur Förderung des MINT-Unterrichts | 4 November 2024 |
| | Leibniz Institute for Science and Mathematics Education | 26 November 2024 |
| | Ministry of Education of Rhineland-Palatinate | 28 November 2024 |
| | National MINT Forum | 29 November 2024 |
| | Little Scientists Foundation | 29 November 2024 |
| Greece | University of Crete | 15 November 2024 |
| | Elementary school | 15 November 2024 |
| | Stimmuli (NGO) | 15 November 2024 |

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| | Ministry of Education, Religious Affairs and Sports | 18 November 2024 |
| | Aristotle University of Thessaloniki | 29 November 2024 |
| Hungary | Eötvös Loránd University, Faculty of Natural Sciences | 27 November 2024 |
| | Hungarian STEAM Office<br>Hungarian STEM Platform | 26 November 2024 |
| | Ministry of Culture and Innovation | 30 October 2024 |
| | Educational Authority | 19 December 2024 |
| | Mathias Corvinus Collegium Learning Institute | 18 December 2024 |
| Ireland | Dublin City University, School of STEM Education, Innovation and Global Studies<br>ATEE | 15 November 2024 |
| | University College Dublin, SMARTLab Skelligs<br>Future Focus21c | 28 November 2024 |
| Italy | National Institute for Documentation, Innovation and Educational Research | 15 November 2024 |
| | Ministry of Education and Merit, University and Research, Directorate General for Structural Funds for Education, School Construction and Digital Schools | 20 November 2024 |
| | CIDA Lazio | 26 November 2024 |
| | Golinelli Foundation | 5 November 2024 |
| | National Interuniversity Consortium for Informatics, National Laboratory for Computer Science and School | 17 November 2024 |
| | School | 17 November 2024 |
| Japan | National Institute for Education Policy Research | 6 December 2024 |
| | Japan Science and Technology Agency | 20 November 2024 |
| | Otemon Gakuin Otemae Junior and Senior High School | 4 December 2024 |
| | Teikyo University Elementary School | 3 December 2024 |
| | Matsushige Town Board of Education | 3 December 2024 |
| | Tokyo Gakugei University, Children's Institute for the Future | 27 November 2024 |
| Latvia | Ministry of Education and Science | 6 December 2024 |
| | Riga TechGirls | 9 October 2024 |
| | University of Latvia<br>Riga Gymnasium No 1 | 5 December 2024 |
| | University of Latvia, School of Young Physicists | 4 December 2024 |
| | Latvian Mathematics Teachers' Association<br>Saulkrasti Secondary School | 3 December 2024 |
| | Latvian Mathematics Teachers' Association | 3 December 2024 |
| | Latvian Physics Teachers' Association<br>Riga School No 40<br>University of Latvia, Department of Physics, Mathematics and Optometry | 6 December 2024 |
| | Riga Technical University, Futurimo | 2 December 2024 |
| | University of Latvia, Interdisciplinary Centre for Educational Innovation | 16 December 2024 |
| | National Centre for Education<br>Curriculum department<br>Cooperation support department | 19 December 2024 |
| | Ministry of Education and Science | 6 December 2024 |
| Lithuania | National Agency for Education | 13 November 2024 |
| | Lithuanian Mathematics Teachers' Association, eLicay content development team | 11 November 2024 |
| | Utena Education Centre | 11 November 2024 |

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| | STEAM.lt Utena | |
| | Millennium schools programme | 22 November 2024 |
| | Vedliai | 22 November 2024 |
| Luxembourg | SCRIPT | 5 December 2024 |
| | ASBL Make It Luxembourg | 28 November 2024 |
| | University of Luxembourg, Department of Education and Social Work | 10 December 2024 |
| | National Representation of Parents | 3 December 2024 |
| Malta | University of Malta | 26 November 2024 |
| | Ministry for Education, Sport, Youth, Research and Innovation | 27 November 2024 |
| | Malta Union of Teachers | 2 December 2024 |
| | Malta Chamber of Scientists<br>University of Malta | 22 November 2024 |
| | University of Malta<br>Maltese Association of Parents of Students in State Schools | 22 November 2024 |
| Netherlands | Platform Talent voor Technologie | 31 October 2024 |
| | SLO | 8 November 2024 |
| | Akker Gramsbergen | 12 November 2024 |
| Peru | Cayetano Heredia University | 7 November 2024 |
| | National Council for Science, Technology and Technological Innovation | 11 November 2024 |
| | Peruvian Mathematical Society, Olympiad Commission | 11 November 2024 |
| | National Council for Science, Technology and Technological Innovation | 11 December 2024 |
| | Regional Directorate of Education of Amazona | 14 November 2024 |
| | Group for the Analysis of Development and Educa Aprende | 15 November 2024 |
| | National Council for Science, Technology and Technological Innovatio, the Science Popularization Unit | 25 November 2024 |
| Poland | Adam Mickiewicz University, Faculty of Educational Studies | 6 November 2024 |
| | Adam Mickiewicz University, Faculty of Biology | 8 November 2024 |
| | Primary School in Zamienie | 7 November 2024 |
| | STEAM Polska, | 15 November 2024 |
| | Public School No 58, Poznań, | 15 November 2024 |
| Portugal | Ministry of Education | 7 November 2024 |
| | Polytechnic Institute of Santarém / Portuguese Association for Science Education | 5 December 2024 |
| | National Confederation of Parent Associations, | 8 November 2024 |
| | National Association of Teachers | 13 November 2024 |
| | Aveiro STEAM city (urban network for upgrading STEAM skills and increasing jobs added-value through digital transformation in a new economic context), Economic Development and Innovation Division of the municipality of Aveiro | 15 November 2024 |
| Romania | National Center for Policies and Evaluation in Education | 7/11/2024 |
| | | 13 November 2024 |
| | Romanian-American Foundation | 11 November 2024 |
| | Polytechnic University of Timişoara | 14 November 2024 |
| | AspireTeachers | 26 November 2024 |

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| Singapore | Ministry of Education, Singapore Science Centre (serves as the parent body of STEM Inc.)<br>National University of Singapore | 16 December 2024 |
| | Sing-Ed Global Schoolhouse Pte Ltd<br>National Institute of Education<br>Ministry of Education | 18 December 2024 |
| | School | 30 December 2024 |
| | Ministry of Education, Curriculum Planning and Development Division | 2 January 2025 |
| | International School | 2 January 2025 |
| Slovakia | Pontis Foundation | 31 October 2024 |
| | Aj Ty v IT | 15 November 2024 |
| | University of Trnava, Faculty of Education | 15 November 2024 |
| | Indícia | 15 November 024 |
| | Ministry of Education, Research, Development and Youth | 15 November 2024 |
| Slovenia | Ministry of Education<br>Digital Education Service | 5 December 2024 |
| | Gimnazija Ledina, Ljubljana | 5 December 2024 |
| | National Education Institute of Slovenia | 17 December 2024 |
| | Educational Research Institute<br>TIMSS<br>PISA | 17 December 2024 |
| | University of Ljubljana, Faculty of Biology, Biophysics Faculty of Health, Socratic Lectures Symposium | 19 December 2024 |
| | Slovenian Student Union | 15 January 2025 |
| Spain | Coordinator of Student Representatives of Public Universities | 6 November 2024 |
| | Ministry of Education, Vocational Training and Sports | 11 November 2024 |
| | National Association of Teachers in Spain | 15 November 2024 |
| | Andalusian Regional Council of Education | 20 November 2024 |
| | Centre for Research in Science and Mathematics Education | 29 November 2024 |
| Sweden | Ministry of Education and Research | 23 October 2024 |
| | Royal Swedish Academy of Engineering Sciences | 17 October 2024 |
| | Technology Industries of Sweden | 21 October 2024 |
| | Swedish Teachers' Union | 14 November 2024 |
| Switzerland | UP4MINT, Federal Institute of Technology Zurich | 28 November 2024 |
| | TechLabs | 4 December 2024 |
| | Federal Department of Economic Affairs, Education and Research, State Secretariat for Education, Research and Innovation | 21 November 2024 |
| | Commission for the Promotion of Young Talents, Swiss Academy of Sciences | 21 November 2024 |
| | University of Applied Sciences and Arts Northwestern Switzerland | 15 November 2024 |

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