SpicE
Special EduCation STEAM Academy

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SpicE Inclusive STEAM Education Handbook

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SpicE's bundle of actions aims to enhance primary education teachers' ability to implement effective STEAM instruction to protect students with mild disabilities (special education) from educational and social exclusion. STEAM is used both as the means and the purpose for enabling a much-needed shift in special education in primary education both at an in-service and pre-service level. It sought to uplift barriers for a significant number of students that are silently, slowly and indirectly marginalised from early stages of European school systems due to the lack of teachers' STEAM skills and the lack of a methodological liaison (along with practical guidelines and curricula) between STEAM and special education educational models.

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Editors: Achilles Kameas, Natalia Spyropoulou, Magda Spella, Ioana Caraghiozov, Guillermo R Guerra, Eddy Grand-Meyer and Agueda Gras-Velazquez.

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Preface

We often picture the ideal classroom as a place where growth is encouraged and every individual feels valued. In reality, however, many students are excluded, hidden behind a lens of barriers and prejudices that we have grown used to wearing.

All across Europe, the picture is the same: the challenges faced by several learners, such as those with mild disabilities, are overlooked. As a result, their needs are neglected and their potential remains unexplored.

What if we could see things differently?

This book encourages readers to recognise the aspirations, creativity and potential of students who are often marginalised, even in the early stages of learning, by offering a view on how STEAM education can promote inclusion in the class. Because, when STEAM is done inclusively, it provides an individualised space where every child can experiment, cooperate, and express themselves. When paired with inclusion, STEAM becomes a bridge.

But building this bridge requires great effort at both the social and pedagogical levels. Many educators still feel unprepared to support students with mild disabilities. They may lack the necessary training, resources and confidence to adapt their strategies. Consequently, they rely on ineffective approaches that have long been inadequate for supporting all learners.

This is the reason why the SpicE project exists. Born from the urgent need to make STEAM a vehicle for inclusion, and prepare primary school teachers for this challenge, this initiative encourages us to view classrooms as spaces full of opportunity, rather than fixed environments. Not as we wrongly idealise them to be, but as they could truly become.

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Introduction

SpicE's bundle of actions aims to improve the ability of primary education teachers to deliver effective STEAM instruction, preventing students with mild disabilities from educational and social exclusion.

This book provides a thorough explanation of the key insights and outputs developed throughout the SpicE project. As each section is a self-contained unit that can be accessed and understood independently, readers are encouraged to proceed directly to the parts that align with their interests without having to go through all the content.

The first part of this book establishes the foundations. It begins by showcasing a variety of tools and methods for evaluating student performance in STEAM activities, recognizing its importance in the learning process, in the acquisition of transversal skills, and in students' engagement. The second chapter provides an introduction to notable inclusive STEAM initiatives in Spain and across Europe, showcasing what Inclusive STEAM looks like in practice, its benefits, and why it's needed to leave no child behind.

In the second part, readers will delve into the research results and lessons learned from the SpicE project experience, exploring the specific challenges, opportunities and training needs primary education teachers face when implementing Inclusive STEAM initiatives. The first chapter outlines the current challenges of inclusive STEAM implementation, drawing on a gap analysis conducted with pre- and in-service teachers. The second chapter explores what roles educators need to assume to develop solid Inclusive STEAM environments, and what skills they need to strengthen inclusion in STEAM education. The third chapter introduces a joint curriculum for STEAM in Special Education to help educators design activities. The fourth chapter provides a practical overview of how to apply active methodologies in STEAM classes, with examples. The final chapter focuses on the lessons learnt from upscaling the blended training programme implemented within SpicE, uncovering they key methodological aspects that ensure the success and accessibility of such professional development opportunities in inclusive STEAM.

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Part three of the book comprises a series of case studies on the implementation of inclusive STEAM in the classroom. These cases serve as a source of inspiration for both educators and teacher trainers, enabling them to expand their instructional approach and discover practical applications of the concepts presented in the book.

Designed for educators, policymakers, researchers and students alike, this book invites the reader to reconsider how STEAM can be taught without leaving anyone behind. It is a call for all educational stakeholders to join forces in designing learning environments where each and every student has a chance to acquire the necessary skills to shape the future.

Background

The 21st century has brought with it a range of global challenges, including climate change, digital transformation and rapidly evolving job markets. These developments have accelerated the need to foster a workforce composed of skilled workers and thinkers, prompting educational leaders to reassess the status quo of traditional education paradigms.

STEAM education, which integrates science, technology, engineering, arts, and mathematics, has since been recognised as a critical solution to addressing these pressing needs, as it prepares students for the challenges of today and tomorrow. By incorporating different inquiry-based teaching methods, STEAM provides students with many opportunities to connect what they learn to real-world scenarios, thereby nurturing their ability to apply their knowledge to new problems. In addition to academic benefits, STEAM can help to bridge the STEM competency gap for traditionally marginalised groups. Open-ended, creative STEAM experiences can be a powerful tool for unlocking creativity, confidence and empowerment among girls, ethnic minorities and low-SES students.

Despite its potential, STEAM education does not reach all learners equally. Structural barriers, a lack of teachers with the necessary skills and insufficient inclusive STEAM pedagogical resources continue to exclude students with diverse needs. Consequently, students' competence in key subjects such as science and mathematics is declining, and gender and socio-economic factors still influence

inequalities in STEM achievement, as showcased by PISA 2022 results (OECD, 2023). Therefore, the EU faces two challenges: reversing the negative trend in students' achievement and ensuring that students' background does not undermine their potential to develop a solid foundation in STEM subjects.

Inclusive STEAM education aims to provide every learner, regardless of their background or abilities, with access to meaningful, barrier-free STEAM learning environments. Combining the interdisciplinary, problem-solving nature of STEAM with inclusive educational principles, inclusive STEAM education adapts teaching practices to learner diversity and supports equitable access to knowledge and skills. While it is widely recognised as a valuable pedagogy, the implementation of inclusive STEAM education remains inconsistent and poorly monitored across Europe.

At the EU level, the drive towards Inclusive STEAM is determined by two distinct policy streams. On the one hand, the STEM Education Strategic Plan identifies STEM skills as essential for addressing EU challenges, particularly those related to economic competitiveness. While the Plan sets out gender-inclusive targets, it does not determine any quantitative benchmarks for learners with disabilities, from migrant backgrounds, or from low socioeconomic status (SES) groups. Inclusion in a broader sense is only considered qualitatively (European Commission, 2025).

On the other hand, a series of EU instruments focus on achieving inclusive education. The Council Conclusions on Equity and Inclusion in Education call for personalised support and innovative pedagogy to decouple attainment from socioeconomic background (Council of the European Union, 2021), and the Union of Equality: Strategy for the Rights of Persons with Disabilities 2021-2030 commits EU funding to inclusive, mainstream learning and teacher upskilling across EU programmes (European Commission, 2021). The result is a fragmented landscape: competitiveness-driven STEM strategies are beginning to take centre stage in European education policy, often addressing gender imbalance, whereas more comprehensive inclusion frameworks remain isolated from STEM Education.

The SpicE project (Special Education STEAM Academy) operates at the intersection of these efforts, demonstrating how creative, interdisciplinary teaching can encourage the participation of all students and equip them with the skills and attitudes needed to

overcome the challenges that society faces. Thanks to its consortium of 11 partners organised into four national clusters, the project has translated rigorous empirical research into clear frameworks to strengthen the mainstreaming of inclusive STEAM education.

The project began by conducting a multi-country gap analysis of pre- and in-service teachers, revealing a lack of STEAM competence and a high demand for training. Using this data and experience from the *STEAMonEdu* project, SpicE developed an *Inclusive STEAM Educator Competence Framework*, which provides the basis for the project's Education Framework for STEAM in Special Education, a seven-step meta-methodology that guides the design, testing and revision of teacher training.

Finally, the projects used these frameworks to create a joint STEAM curriculum for special education, implemented through a three-phase format comprising a massive open online course (MOOC), a blended learning programme and multiple teacher exchange programmes.

Fundamentally, SpicE supports educators in building competences, adapting methodologies and assessing students inclusively through its frameworks, practical tools and training modules. The project's work not only aims to raise the standards of teaching, but also to provide national and local governments with the research, methodology and tools required to promote stronger and fairer education systems.

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Part 1: Fundamentals

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STEAM in action: How to measure student progress and performance

Iva Boneva[1], Mariya Zhelyazkova[1]

[1]*Trakia University, Stara Zagora, Bulgaria*

Introduction

Assessment is a key element in the educational process of measuring students' preparation and development. It involves an ongoing and systematic process of setting educational goals, developing methods to measure progress toward the goals, and using the resulting information to inform decisions and revise educational programmes (Baker & Cope, 1993). Assessment is not just about evaluating student learning, but it also encompasses factors such as context, emotions and cultural influences that affect both teaching and learning processes (Rincon, 2019).

In the context of STEAM education (science, technology, engineering, arts, mathematics), assessment is particularly important as it encourages creativity, critical thinking and an interdisciplinary approach.

Assessment in education is the systematic process of collecting, analysing, and interpreting information to determine the extent to which students are achieving learning objectives. It is an ongoing process that is concerned with a student's informal academic growth as well as formal academic performance. It also takes into account the social emotional learning and well-being of all learners, as well as equity, equality, fairness and quality in education. Assessment is concerned with gathering and interpreting evidence of changes in behaviour for all pupils as they progress through school.

This chapter examines the nature and necessity of assessment, focusing on the underlying principles that guide it. Particular attention is given to evaluation methods

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in STEAM activities, which should take into account both the acquisition of knowledge and the development of practical skills and innovative thinking.

Principles of evaluation:

Evaluation is the systematic process of determining the extent to which development and learning objectives have been met. In education, as in other areas, it is important that evaluation processes are effective. When it comes to assessing teaching and learning in education, several key principles guide the process:

Multiple perspectives and tools

No method provides a complete picture of teaching quality. The integration of diverse data sources, including end-of-course feedback, interim feedback, peer review, and self-reflection, facilitates the construction of a more comprehensive representation. . A variety of assessment tools and techniques should be used in a comprehensive evaluation, as it is unlikely to be able to assess all aspects of achievement using a single technique. To ensure a more precise assessment, tools such as objective tests, essays and observation techniques should be used concurrently to provide a holistic picture of student achievement and development.

Validity and student outcomes

The validity of teaching effectiveness measures depends on their correlation with intended student outcomes. Effective assessment considers both quantitative and qualitative aspects. It is important and necessary for teachers to know the limitations of different assessment techniques. Assessment can be done using simple observation or highly developed standardised tests. But whatever the instrument or technique, limitations exist. For example:

- Lack of depth - quantitative methods often measure only rote knowledge (the first level of Bloom's taxonomy) without assessing soft skills such as critical thinking or creativity.
- Focus on outcomes - assessments provide a snapshot of a student's knowledge, but do not always reflect the learning process.

- Stress and pressure on students - some forms of assessment can cause anxiety and reduce motivation to learn.
- Risk of manipulation - students may aim for high grades without having actually mastered the material (e.g. through 'rote learning' or plagiarism).

To be effective, assessment needs to combine and alternate a variety of methods to realise the balance between quantitative and qualitative techniques, with the aim of achieving objectivity and tracking an overall picture of student progress.

Transparency and Fairness

Clear standards ensure fairness. Applying grading criteria consistently across courses and considering factors beyond the instructor's control (e.g. class size, student preparedness, demographics) promotes fairness. For example:

- **Differentiated benchmarks and individual progress** - it is important to not solely rely on standards to measure students' level of knowledge and development against their own abilities. Formative assessment (ongoing feedback) needs to be introduced alongside final assessments to track students' momentary state - what is challenging them, where they feel confident, etc.
- **Larger classes can use automated tests** to ensure objectivity.
- **Incorporate self-assessment and reflection** to enable students to evaluate their own progress.
- **Provide sample assignments** (at various levels) to be reviewed during the review of the test material so students understand what is expected.

Clearly stated subject of evaluation

Teachers need to be aware of the purpose of the assessment, to articulate the learning objectives and define them clearly in terms of the observed student behaviour. Before selecting performance measures, teachers should define clearly the expected learning outcomes. To guide this process, teachers should ask themselves the following questions:

- What aspects of students' behaviour should be considered in the evaluation? What dimensions of learning objectives can be identified?

- What do I want students to know and be able to do after this lesson/topic/course?
- What are the key concepts, skills and competencies they should learn?
- How will I recognise if the student has achieved the learning objectives?
- What criteria will I use to assess the outcomes?

Practicality

Assessment processes must be consistent with the capacity of the school. Practicality ensures that assessments can be carried out effectively. In addition, the assessment technique must be appropriate for the characteristics or performance to be measured. Each assessment tool is more appropriate for some applications and less for others. Therefore, while selecting an assessment technique, teachers should be aware of its strengths and limitations.

Individual context

The results of assessment are often used to make decisions about the direction a learner should take in their studies. For example, if gaps are found in the student's learning, the teacher should seek to create further opportunities for consultation and exchange aimed at improving their learning.

Necessity and principles of evaluation of STEAM activities

In STEAM education, the need for assessment is paramount to ensure that the approach is effective, that the teaching methods are appropriately used and that the student outcomes are achieved. The evaluation of STEAM activities can also support the teacher's work in organising follow-up activities to present the interconnections between theory and practice. Implementation of assessment is also important for the following reasons:

- It helps measure learning progress;
- It maintains students' interest in learning;
- It encourages the development of interdisciplinary skills;
- It prepares for future career opportunities;
- It evaluates students' creative process.

When evaluating STEAM activities, it is also critical to consider a few basic principles that help evaluate the effectiveness and impact of STEAM for competency acquisition.

1. **Start with Clear Objectives**: It is necessary to start by defining what success looks like for a given project or lesson or semester, depending on what needs to be assessed. Consider the intended outcomes and establish specific, measurable goals. Below are some guiding questions to help the teacher set clear objectives:

- What should students know and be able to do at the end of this lesson?
- What skills and knowledge will students demonstrate if they are successful?
- What specific outcomes do I expect from students?
- How will I know if students have understood and applied what they have learned?
- How will I measure their progress - through tests, projects, presentations, or some other method?
- How can I formulate goals so that they are specific, measurable, and achievable?
- What indicators will I use to assess student progress?

2. **Adopt Baseline Measurement**: Set a baseline at the beginning of the project (lesson, semester, etc.). This baseline serves as a starting point against which progress can be measured over time. For example, an entry diagnostic (test) can be administered to find out what students already know and can do in a given subject.

3. **Anticipate Impact:** Imagine the changes that would occur if your project (teaching during your lesson or the whole semester) had not taken place. Consider both the intended and unintended outcomes of your intervention.

4. **Implement Evidence-based Assessment:** Appropriate evidence is collected, including quantitative data (such as student performance indicators) and qualitative insights (such as participant feedback).

5. **Ensure Continuous Reflection:** regularly review faculty evaluation questions throughout the project. Analysing the strengths and weaknesses of the techniques and methods that worked, how success was achieved, and any valuable lessons learned, both positive and negative, is important.

Methods for evaluating STEAM activities

This section focuses on methods for evaluating STEAM activities. It will cover some of the most commonly used in practice.

Portfolios

Portfolios are a valuable method to check the effectiveness of STEAM activities, because they can be used to track student progress over a period of time. Nurhayani et al. (2023) highlight that portfolio assessment is a method of continuous assessment with different collections of information or documentation stored in a systematic and organised manner, particularly appropriate in the context of competency-based learning. The materials collected contain indicators of student performance in class and at home and provide information about student achievement. Moreover, materials mark students' development in the learning process. Portfolios may contain drawings, photographs, video and audio files, written work, tests, self-assessment data and student self-reflection. They serve as evidence of the student's development. Standardised assessment modes (such as tests) provide a quick and efficient check of knowledge and skills, but only at a certain point in time. In contrast, a portfolio quickly and easily tracks student development and the evolution of their strengths and weaknesses over time.

Portfolios are a valuable method of assessment, but there are some weaknesses to consider:

- Subjectivity in assessment: portfolio assessment often depends on the teacher's judgement, which can lead to some subjectivity. Different teachers may have different assessment criteria, making it difficult to be objective.
- Time-consuming: the teacher must analyse a large volume of material, which can be overwhelming, especially with large classes.
- Difficulty in standardisation: unlike multiple-choice tests, portfolios are more difficult to standardise. Defining clear and comparable assessment criteria can be challenging.

Reflection

Reflection leads to better, deeper and more theoretically grounded learning. It means turning to one's own thoughts, experiences and analysis of what has been achieved.

Reflection plays an important role in the educational process when applying the STEAM approach. It is a process of thinking deeply and rethinking the knowledge and experience gained as well as one's own actions, their results and their meaning. Through reflection, students have the opportunity to analyse their successes and failures, understand their strengths and areas of improvement and develop a better understanding of the processes and principles behind science, technology, engineering, arts, and mathematics, as well as the connections between them. This process helps students become more effective and competent in these areas, in addition to develop critical thinking and analytical skills that are essential for successful problem solving in STEM disciplines.

Table 1 Sample questionnaire for evaluation (Nikolova, M., 2012) of personal participation in project creation (self-evaluation).

Questions	Evaluation
1. I was involved in the planning and discussion of the activities.	1 2 3 4
2. All suggestions and ideas were carefully considered by me.	1 2 3 4
3. The work is distributed according to the abilities of each trainee.	1 2 3 4
4. I actively participated in the implementation of the project.	1 2 3 4

Reflection as an assessment method has many advantages, but also some weaknesses that need to be taken into account:

- Reflection is based on personal thoughts and experiences, which makes it difficult to measure objectively.
- Not all students are accustomed to or able to analyse their own learning and progress.
- Students may write or say what they think the teacher wants to hear rather than what they really think.

Testing

In STEAM education, testing is a method used to assess students' knowledge, skills and understanding in specific areas. Tests can include different types of questions:

- Alternate response (true/false) - often used because it does not take much writing time (on the part of the students). Two alternative answers are offered, one of which is correct. When the answer contains words such as *all* or *never,* misunderstandings and confusion can arise.
- Multiple choice questions - this type of question contains fixed ready-made answers. The examinee chooses the answer (there may be one correct answer or several) depending on their knowledge.
- Completion questions - most often, completion comes down to finding an appropriate phrase or word that is related and necessary to complete the meaning of a sentence.
- Practical exercises etc.

Tests can be used to measure various aspects of STEAM learning, such as understanding of concepts, ability to apply the scientific method, ability to solve problems, and application of mathematical or engineering principles. It is important that tests be constructed to reflect the real world and stimulate critical thinking and creative problem solving, which is essential in STEAM education.

Tests are a widely used method of assessment, but there are some weaknesses to consider:

- They often focus on memorising facts rather than understanding, analysing or applying knowledge.
- They make it difficult to assess creativity, critical thinking and practical skills.
- Some students may experience intense stress that negatively affects their performance.
- In written tests, there is a risk of prompting, copying or using unregulated aids.
- Standardised tests may encourage 'rote learning' rather than true understanding.

Project-based learning

The project-based method is not new to the educational system, as it was founded by educator John Dewey in the early twentieth century in the USA. Project-Based Learning (PBL) is an approach to education in which students solve real-world problems by creating projects and applying their knowledge from a variety of fields, including science, technology, engineering, art, and mathematics (STEAM). PBL is one of the main methods used in STEAM. This is due to the fact that STEAM relies on combining theory with practice, solving real-world problems, and gaining knowledge through first-hand experience and experiential learning. In both PBL and STEAM, the teacher and the textbook are not the main source of information, but the students' experiences, ideas and conclusions. To evaluate STEAM activities through project-based learning, the following methods and tools can be used:

- **Process assessment** involves evaluating the participatory, collaborative, problem-solving and communication skills that students demonstrate during the development of their projects. This can be done through observation, documentation of the activity, and feedback from students and peers.
- **Assessment of the final product**: Students may be assessed on the quality of the final product or outcome of their projects. This includes assessment of technical aspects, creativity, research involved, and demonstration of skills in STEAM areas.

The formulation of assessment criteria is a key stage of the assessment process. These criteria must be clear, objective and relevant to the learning objectives. Some steps can be followed to formulate assessment criteria:

1. Identify goals and expectations that need to be clearly articulated and measurable.
2. Define the important aspects. These may include knowledge, skills, understanding, creativity or other aspects dependent on the nature of the learning activity.
3. For each competency, identify specific criteria that you will use for assessment. These criteria should be clear, specific and measurable so that they can be applied objectively. You will test students' knowledge, for example, of a definition of a concept, theorem, etc.

4. Define the levels of achievement: for each criterion is necessary to identify the different levels of achievement or assessment. These levels should reflect different degrees of understanding, skills or competences. They may be scored at different stages.
5. Objectivity check: all previous steps need to be applicable to all students and be used in a fair way.

Example: if you are a science teacher and you want to assess problem solving, your criteria might include the correct use of knowledge and skills to conduct an experiment, report the results and the conclusions students have reached. Levels of achievement can be determined by the extent to which the problem is solved and the extent to which the solution is presented clearly and accurately.

Finally, Table 2 can be used to objectively evaluate the experiment, as it contains explanations of criteria that are applicable to all students.

Table 2 Examples of experiment evaluation criteria

Criteria	That's great.	A lot of good	Good	Medium	Weak
Correct use of knowledge and skills	Uses scientific knowledge and skills without errors; logically explains each step	Admits minor inaccuracies but demonstrates understanding	There are gaps in knowledge, but the basic idea is clear	Makes significant mistakes in the application of knowledge	Does not demonstrate an understanding of scientific principles
Conducting an experiment	The experiment was performed accurately, all data are correct	Slight deviation from the procedure, but the results are reliable	Follows the protocol, but there are gaps in implementation	Experimental errors that affect the results	The experiment is not implemented or has serious shortcomings
Formulation of conclusions	Conclusions are accurate, grounded in data and scientific principles	The conclusions are logical, but with slight flaws in the reasoning	The conclusions are partially correct but not well substantiated	Conclusions are unclear or poorly linked to results	Missing conclusions or not related to the experiment

Project-based learning has its disadvantages, some of them are:

- Projects require a significant amount of preparation and execution time from both the students and the teacher.
- In group projects, some students may not actively participate or may rely on others to do the bulk of the work.
- Without proper guidance and direction from the teacher, projects can become unstructured and lead to confusion and loss of focus.
- Evaluating projects can be complex and subjective as success cannot be measured by traditional tests alone.

Observation

Observation is an important method as it allows researchers to observe students' behaviours, interactions and reactions in a real learning environment. Here are some steps and tips to use observation in assessing student needs:

1. Plan the observation: Identify the goals and areas you want to explore through the observation.
2. Determine observable behaviours: Identify the specific behaviours, situations, or interactions you want to observe. These may include academic skills, social interactions, engagement in learning activities, etc.
3. Select observation methods: Choose appropriate observation methods and tools to help you record and document your observations. This may include, for example, notes, recordings, etc.
4. Be observant and neutral: Observe students carefully without influencing their behaviour. Try to remain neutral and objective in your assessment without making assumptions or drawing conclusions that are not supported by observations.
5. Document your observations: record or document your observations in as detailed and systematic a form as possible. Include specific scenarios, interesting observations, and important notes that can help in the analysis and interpretation of the data.

Observation can provide valuable information and opportunities to understand student needs by supplementing with other assessment methods, such as surveys, interviews and academic performance analysis.

Tools for evaluating STEAM activities

1. Google Forms

Google Forms is an integrated web-based application provided by Google Inc. It serves as a versatile tool for creating various forms of surveys, quizzes, questionnaires and tests, allowing users to gather information in a short, simple and efficient way. The application is widely used in educational settings, including for evaluating STEAM activities. Google Forms offers a user-friendly interface for creating, distributing and collecting responses for various types of assessments, surveys and data collection. It has 11 question types, such as: short answer, paragraph, multiple choice, check box, drop-down menu, file upload, line scale, multiple choice table, checkbox table, date and hour.

2. Microsoft Forms

Microsoft Forms is a Microsoft application for creating tests and survey forms. It is part of the Microsoft 365 suite and provides a user-friendly interface for designing and sharing forms. The platform is used for form assessments, data collection, event registration and feedback collection. The question types that are available are: short answer, paragraph, multiple choice, check box, drop-down menu, upload file, linear scale and date. These can be used to create mathematics problems.

3. Kahoot

Kahoot is a game-based interactive learning platform that is widely used in educational environments to engage students and assess their knowledge. It is an application that uses gamification to promote and assess learning, making it an effective tool for creating interactive quizzes, surveys and discussions. Kahoot options include:

1. Create training games: These games can be targeted to specific topics or learning materials.

2. Real-time user participation: Users can easily create custom learning games by adding questions, answers and graphics to them. These games can be targeted to specific topics or learning materials.

3. Interactivity and engagement: Kahoot offers an interactive way to learn by incorporating music, fun graphics and a competitive element to motivate students and engage them with the learning material.

4. Sharing games: Users can share their created games with other teachers or students, allowing for a variety of learning resources and learning ideas.

5. Data analysis: Kahoot provides analytics on student participation and success, helping educators assess student progress and tailor learning strategies to their needs.

4. Liveworksheets

Liveworksheets is a web-based application that provides interactive worksheets for educational purposes. It is a platform for creating and accessing digital educational materials including interactive exercises, puzzles and educational games. Liveworksheets allows educators to develop engaging and interactive learning resources that can be used in a variety of subjects and at different educational levels. Liveworksheets is used to improve students' math problem solving abilities, develop reading comprehension skills, and enhance formative assessment and flipped learning. The app offers features such as essay questions, multiple-choice questions, word puzzles, drop-down choices, checkboxes, drag-and-drop activities, listening sections, speaking exercises, and the possibility to insert multimedia elements such as videos and links. Liveworksheets can support the assessment process.

5. Mentimeter

Mentimeter is a software that allows users to create interactive presentations, polls, quizzes, word clouds, and Q&A sessions, making it a valuable tool for increasing audience participation and gathering immediate feedback. Mentimeter provides analytics and reporting features that allow presenters to analyse audience responses. The platform has been used in a variety of educational contexts, including classroom teaching, student engagement and formative assessment. Mentimeter possibilities:

- Surveys and questionnaires: Mentimeter allows the creation of different types of surveys and questionnaires, including multiple choice, open questions, ranking and others. This is useful for gathering feedback and assessing students on specific assignments.

- Graphs and charts: the tool offers the ability to visualise data in real time through graphs and charts. This makes the evaluation process more attractive and easier to understand.
- Real Time: Survey results and assessments are displayed in real time, allowing the teacher to immediately assess student progress and adapt the lesson to their needs.
- Interactivity: using Mentimeter can create an interactive and engaging learning environment by allowing students to actively participate in the assessment of assignments.

These features make Mentimeter a suitable solution for assessing assignments in the educational process, including STEM learning.

6. Socrative

Socrative is a web-based and mobile platform that offers interactive learning and assessment tools. It is designed for teachers and lecturers who want to engage their students in the learning process through various activities and analysis of their answers.

Here are some of the main features of the Socrative app:

- Questionnaires and Quizzes: Allows teachers to create questionnaires and quizzes with different question types, including multiple choice, open-ended, true/false, and more. These can be used to test students' knowledge or assess their understanding of the material.
- Teachers can create surveys and evaluations that they can use to gather feedback from their students about lessons or lectures. This might include assessing interest, understanding, or coverage of the material.
- Create Groups and Classrooms: Allows teachers to create groups and classrooms where students can join with unique access codes. This makes it easy for teachers to manage and control student participation in various activities.
- Results and Analysis: Provides detailed results and analysis of student responses that can help teachers understand their students' level of understanding and success.

Socrative is a useful tool for teachers who want to integrate technology into the learning process and engage their students in an active way. It provides opportunities for personalised learning and continuous assessment that can improve the learning process and student outcomes.

Conclusion

In conclusion, assessing STEAM tasks through different methods and tools is extremely important in the educational process. In this section, some basic methods and tools for assessing STEAM assignments are covered, which include:

- Principles of evaluation: Multiple perspectives and tools, validity and student outcomes, transparency and fairness, clearly stated subject of evaluation, practicality, individual context.
- Defining assessment criteria: Defining clear and specific assessment criteria is key to objective and fair assessment.
- Interactive tools: The use of tools such as Google Forms, Mentimeter and others presented in the chapter offer interesting ways to assess STEAM activities.
- Methods for evaluating STEAM activities: Portfolios, Reflection, Testing, Project-based learning, Observation. Project-based learning is a particularly relevant method for STEAM, in that allows students to apply their knowledge and skills to real-world situations by creating projects and solving real-world problems.

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Inclusive STEAM in practice: pedagogical innovation from Spain and broader European initiatives

Aitana Fernández-Sogorb[1], Copelia Mateo-Guillen[2]

[1]*University of Alicante, Alicante, Spain*
[2]*University of Alicante, Alicante, Spain*

Introduction

Inclusive STEAM (Science, Technology, Engineering, Arts, and Mathematics) education is gaining significant attention in the Spanish educational context, where equity and diversity are central to policy and pedagogical innovation. As highlighted in recent literature, STEAM is not only a pedagogical framework that integrates multiple disciplines, but also a transformative approach that promotes inclusive, student-centred practices. A core principle of inclusive STEAM education is equitable access for all learners, including those with mild disabilities. This requires an alignment with the principles of Universal Design for Learning (UDL), which advocate for multiple means of representation, engagement, and expression to accommodate diverse student needs (Lacruz-Pérez et al., 2021). In practice, this means adapting both the content and delivery methods to support learners with varied cognitive, linguistic, and physical abilities. Inclusivity in STEAM also involves addressing systemic barriers related to gender and socio-cultural background.

In Europe, although research on the inclusion of students with mild disabilities in STEAM environments is still in its early stages, there is a growing interest among educational institutions, researchers, and policymakers in exploring more equitable and inclusive approaches. In response to the need to ensure that all students—regardless of their abilities or learning styles—can benefit from interdisciplinary

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STEAM education, various initiatives and pilot projects have begun to emerge across different countries on the continent.

These initiatives aim not only to remove barriers to learning but also to transform educational practices by creating more flexible, engaging, and student-centred environments. In this context, the principles of Universal Design for Learning (UDL) are increasingly being adopted to promote learning environments that accommodate learner variability from the outset. Moreover, there is a strong emphasis on teacher training, equipping educators with the tools and methodologies needed to effectively address classroom diversity. These strategies include the use of visual aids, peer collaboration, personalized activities, and assistive technologies.

Studies conducted in Spanish primary education have shown that interdisciplinary learning not only improves students' scientific attitudes but also enhances competencies in mathematics and language, particularly in oral comprehension and calculation skills. Moreover, research in the field emphasizes the value of the arts in fostering motivation and meaningful learning experiences, especially among high-ability students.

Measuring student progress and performance within an inclusive STEAM framework requires comprehensive and adaptive assessment strategies. Traditional summative assessments must be complemented by formative and performance-based evaluations that reflect individual learning trajectories. For instance, the use of some platforms has demonstrated not only high engagement levels but also measurable learning outcomes in young children (Lara et al., 2020; Jurado et al., 2020). In these studies, the most effective results were linked to the proactive involvement of well-trained teachers, indicating the importance of teacher readiness in facilitating inclusive STEAM learning.

Assessment represents another critical dimension in the development of inclusive STEAM education. In particular, formative assessment plays a pivotal role in the creation of learning environments that are responsive to student diversity, as it facilitates the adaptation of instructional practices to individual learning needs and supports more meaningful, student-centred engagement. Unlike traditional summative assessments, which focus primarily on measuring outcomes, formative assessment prioritizes the learning process itself, offering continuous opportunities for feedback, reflection, and pedagogical refinement. Within this framework, a variety of assessment

strategies—such as ongoing observations, reflective practices, and the use of student portfolios—are being employed to foster both academic growth and the development of socio-emotional competences, especially among learners who benefit from differentiated instruction.

This chapter provides an overview of some representative projects and studies that are paving the way towards more inclusive STEAM education in the European context. Through these examples, it highlights the importance of an educational vision that combines pedagogical innovation with social justice, ensuring that science, technology, engineering, arts, and mathematics are truly accessible to all students.

European studies on inclusive STEAM education

Although the body of research on inclusive STEAM education for students with mild disabilities in Europe is still emerging, several noteworthy studies and projects have explored how STEAM approaches can support this population across different educational systems. In Finland, the INCLUSIVE STEM@SCHOOL Erasmus+ project implemented STEAM learning scenarios designed with accessibility in mind. While not exclusively focused on students with disabilities, the project emphasized Universal Design for Learning (UDL) principles to ensure all students could participate, including those with mild cognitive or learning difficulties. Project evaluations indicated increased engagement and participation from students who typically struggle in traditional STEM settings (Pokropek et al., 2024).

Germany’s "Haus der kleinen Forscher" initiative has also contributed to the field by incorporating inclusive STEM activities in early childhood education. This national program includes training for educators on adapting inquiry-based science lessons for diverse learners, including those with attention, communication, or sensory processing difficulties. Evaluations suggest that hands-on, inclusive STEM activities significantly improve attention span, problem-solving, and social interaction skills among children with mild developmental delays (Haus der kleinen Forscher, 2022).

In Italy, while not yet widely documented in academic literature, the STEM4Equality project has explored inclusive teaching strategies that support both gender equity and students with special educational needs (SEN). Initial findings from pilot schools indicate that STEAM activities adapted with visual aids, flexible grouping, and peer

tutoring contribute to improved engagement and comprehension among students with mild disabilities (STEM4Equality, 2021).

These examples reflect a growing European awareness of the need to design STEAM education with inclusivity at its core, particularly to support students with mild disabilities. The integration of adaptive tools, teacher training, and interdisciplinary content appears to be key for ensuring meaningful access and participation.

Spanish studies on inclusive STEAM education

There is a growing scientific interest in the STEAM pedagogical approach within Spanish educational research. Various studies have analysed the outcomes of its implementation in Early Childhood and Primary Education centres across the country, as well as teachers' perceptions regarding the training they received in STEAM education and its implementation. Two studies on the practical application of STEAM have been conducted in the second cycle of Primary Education, specifically with a community sample of 96 Spanish fourth-grade students (Bogdan & Greca, 2018) and another with 242 third-grade students (Duo-Terron et al., 2022). These studies found that the interdisciplinary use of STEAM fosters children’s positive attitudes towards science and enhances their skills in areas such as linguistic and mathematical competence, particularly in arithmetic and oral expression and comprehension. Moreover, Duo-Terron et al. (2022) identified greater effectiveness of this model among female students and those with Spanish parents.

In another study, Lage-Gómez and Ros (2021) assessed the efficacy of interdisciplinary STEAM application in a specific sample of 111 gifted Spanish students aged 11 to 12, enrolled in fifth and sixth grade. The study revealed that this interdisciplinary model promotes meaningful learning experiences for students, who in turn displayed high levels of motivation and satisfaction. The authors also highlighted the role of art as an integrating agent among the various developed areas.

Other research has examined the STEAM approach with a focus on the use of Information and Communication Technologies (ICT). In this regard, Lara et al. (2020) analysed the use of the intelligent platform "Sonríe y Aprende" ("Smile and Learn"), which includes more than 4,500 activities for children. The study was carried out in 43

groups of students with special educational needs, 311 groups from the first three grades of Primary Education, and 257 from the last three grades, all part of public schools in Spain. The results showed that, among all the educational activities offered by the platform, those based on STEAM registered a high usage rate. On another front, Jurado et al. (2020) conducted a study in which they trained teachers to facilitate interdisciplinary learning based on STEAM using the robotic platform KIBO and assessed its effectiveness. The 65 Spanish students aged 4 to 6 who participated in the intervention achieved average learning scores ranging from 7.1 to 7.7 out of 10. Furthermore, the highest scores were recorded among students whose teachers had shown the greatest interest in training during the preparation phase.

The above-mentioned example shows how the knowledge and attitudes of teachers towards STEAM education may be decisive for the success or failure of this model. For instance, in the aforementioned study by Bogdan and Greca (2018), while students' attitudes and learning improved with interdisciplinary STEAM use, teachers expressed reluctance to continue using the model, citing the need for more specific training for its proper implementation. Similarly, another study conducted with 32 active Spanish teachers (López et al., 2021) found that they believed gamified STEAM education activities had improved students' engagement with mathematics and fostered the development of essential skills in that subject. However, 34.4% of the teachers expressed concern and insecurity due to their lack of training in implementing these activities.

Findings from previous literature highlight the need for teachers to acquire the necessary knowledge and skills in STEAM from their initial university training. In this regard, Castro-Rodríguez and Montoro (2021) analysed 236 course syllabi from core and mandatory subjects within the Bachelor's Degree in Primary Education at Spanish public universities. These included three areas of STEAM: problem-solving, real-life application of knowledge, and interdisciplinarity. The authors concluded that problem-solving was the most prevalent area in the syllabi, and that Mathematics and Experimental Sciences were the subjects that most comprehensively addressed the three STEAM areas. A potential solution would be to integrate STEAM into the Primary Education degree in a multidisciplinary manner.

To ensure STEAM education reaches all students, including those with mild disabilities, teaching practices must be guided by a legislative framework that embraces educational inclusion. In Spain, educational practice is currently informed by international frameworks such as the Convention on the Rights of the Child (United Nations, 1989), the Convention on the Rights of Persons with Disabilities (United Nations, 2006), and the 2030 Agenda for Sustainable Development (United Nations, 2015), all of which promote equal opportunities for all students. Nationally, the Spanish educational system is governed by Organic Law 3/2020, of December 29, which amends Organic Law 2/2006, of May 3, on Education. This law aims to promote personalized learning and positions inclusive education as a fundamental principle. In addition, each autonomous community tailors the proposals of national legislation to its territorial and socio-cultural context. For example, in the Valencian Community, Decree 104/2018, of July 27, issued by the Consell (Council), sets forth four levels of inclusive response for the entire educational community: the entire class group, students needing differentiated responses (individually or in groups), and those requiring a personalized, individualized response.

The knowledge and attitudes of both in-training and in-service teachers toward the educational inclusion of students with mild disabilities have been widely studied in Spain in recent years. Based on the systematic review by Lacruz-Pérez et al. (2021) and the literature review conducted through December 2022 for this report, studies with students in Early Childhood and Primary Education teaching degrees indicate that future teachers' attitudes towards inclusion are more positive when they feel they are receiving better training (Anzano, 2015; Arvelo-Rosales et al., 2021; Sepúlveda et al., 2010). Also, students in the later years of their training tend to have more positive attitudes than those in the early years (Abellán, 2015; Álvarez & Buenestado, 2015; Hernández et al., 2017; Tárraga et al., 2013), and female students express higher levels of positive attitudes than male students (Navarro-Mateu, Franco-Ochoa & Prado-Gascó, 2020; Navarro-Mateu, Franco-Ochoa, Valero-Moreno et al., 2020).

Regarding the attitudes of in-service teachers toward inclusion, with the exception of two studies that found a negative correlation between years of teaching experience and positive attitudes toward inclusion (Campo et al., 2010; Solís et al., 2019), previous research has shown that experienced teachers generally display positive attitudes

(Anzano, 2015; Cornoldi et al., 2018; Fiuza-Asorey et al., 2021; González-Gil et al., 2016; Mónico et al., 2020), especially those specializing in Therapeutic Pedagogy or working in special education centres (Rodríguez et al., 2021; Rosado-Castellano et al., 2022). However, several studies report Spanish teachers' concerns about insufficient human and material resources (Chiner & Cardona, 2013; Fernández et al., 2020; Leiva-Olivencia et al., 2021) and emphasize the need to strengthen teachers' ongoing professional development (Leiva-Olivencia et al., 2021).

Given the essential role ICT plays in today's teaching and learning processes, teachers must have the knowledge and tools necessary to support students with mild disabilities and make inclusive education a reality. Despite this, most prior studies have found that Primary Education teachers have low levels of ICT skills when working with students with disabilities, due to inadequate training (Cabero-Almenara et al., 2022; Fernández-Batanero et al., 2019, 2020, 2022). Only one study reported good ICT use and teacher preparation, while also noting a shortage of resources and the need to enhance continuous training (Ortiz-Jiménez et al., 2020).

Lastly, it is worth noting that no previous research has reported the perceptions of in-training or in-service Spanish teachers on the implementation of STEAM education for students with mild disabilities in inclusive settings. This underscores the importance of Spain's participation in the SpicE European project. It is hoped that the findings will lead to the development of training initiatives and resources that enable teachers to use STEAM education inclusively for all students.

Conclusion

In conclusion, inclusive STEAM education, when rooted in equity, interdisciplinarity, and adaptive assessment, has the potential to transform educational experiences for diverse learners. Continued research and investment in teacher training, resources, and policy development are essential to making this vision a reality. In the European context, promoting inclusive STEAM initiatives aligns with broader EU objectives on social inclusion, digital literacy, and gender equality. By supporting inclusive STEAM projects, the European Union not only fosters innovation and competitiveness but also ensures that all citizens have the opportunity to actively participate in and contribute to

the knowledge economy. These efforts are instrumental in building a more cohesive, equitable, and forward-thinking Europe.

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Part 2: Lessons from the SpicE project

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Addressing the gaps: current challenges in the classrooms

Rosabel Martinez-Roig[1]

Rosabel Roig-Vila[1]

Mariya Zhelyazkova[2]

[1]*University of Alicante, Spain*

[2]*Trakia University, Bulgaria*

Abstract

This chapter analyses the main gaps and challenges in the implementation of inclusive STEAM education based on the gap analysis carried out in the project SpicE. Among the main gaps identified were a lack of a unified vision for inclusive STEAM, insufficient teacher training in adapted active methodologies, structural barriers in schools and an absence of assessment strategies tailored to the diversity of learners. In addition, the scarcity of accessible models of good practice makes it difficult for teachers to have clear references for adapting STEAM to inclusive contexts. To address these difficulties, four priority areas of action are proposed as challenges to be addressed: a) establishing a common framework with clear guidelines for integration in schools; b) improving teacher training with practical tools for STEAM-inclusive teaching and assessment; c) providing access to resources and strengthening institutional support by investing in accessible materials and specialised staff; d) developing flexible assessment strategies that address students' learning. Overcoming these barriers requires methodological and curricular adjustments, as well as institutional commitment to ensure their effective implementation. Progress in this direction will make it possible to consolidate a more equitable and accessible educational model that is adapted to the needs of students in the 21st century.

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Introduction

In recent decades, STEAM (Science, Technology, Engineering, Arts and Mathematics) education has gained prominence as an essential approach for preparing students to face the challenges of a changing society (Zhu et al., 2024). The integration of these disciplines seeks to foster technical and scientific competences, as well as develop critical thinking, creativity and problem-solving skills in real-world contexts. However, for STEAM education to be an effective and equitable tool, it is essential to ensure its inclusiveness, as pointed out by Álvarez & Hernández (2025). All students, regardless of their abilities or conditions, must be able to participate meaningfully in these learning experiences.

Despite the growing interest in STEAM, its adoption in diverse educational settings still faces significant barriers (Hsiao & Su, 2021). A lack of specific teacher training, a shortage of adapted resources, difficulties in assessing learning outcomes, and an absence of clear strategies for integrating STEAM into inclusive curricula are just some of the challenges identified. These shortcomings particularly affect students with mild functional diversity, who in many cases are denied the opportunities that STEAM could offer them.

To better understand and respond to these challenges, the SpicE project (https://spiceacademy.eu/) has conducted a comprehensive gap analysis across various countries and educational levels. Carried out in collaboration with project partners and validated through participatory processes, this analysis has made it possible to identify the main obstacles to inclusive STEAM implementation. The contribution of SpicE lies in offering a structured diagnosis that reveals key areas for improvement and sets the groundwork for concrete educational and policy recommendations to advance inclusive STEAM practices.

This chapter presents the main findings of the detailed Gap Analysis (SpicE Deliverable 2.1) performed in the SpicE project to identify the main challenges hindering the implementation of inclusive STEAM. It highlights the challenges that need to be addressed to achieve a more inclusive educational approach, and propose ways to strengthen STEAM practices from an inclusive perspective.

Gap analysis methodology and conceptual approach

The Gap Analysis carried out within the SpicE project was designed to provide a comprehensive understanding of the obstacles that hinder the effective implementation of inclusive STEAM education. The analysis aimed to detect shortcomings in teacher training, resources and institutional frameworks, as well as capturing the perceptions, experiences and needs of both pre-service and in-service teachers working in diverse educational contexts.

The analysis employed a mixed-methods approach, combining document analysis, surveys and partner feedback. First, a conceptual framework was built based on a literature review and previous research conducted by the University of Alicante, the institution leading this task. This framework helped identify key dimensions for analysis, including the integration of inclusive practices, teacher training gaps, curriculum barriers and challenges related to the accessibility and assessment of resources.

Once the initial draft of the gap analysis had been prepared, a collaborative and iterative validation process was implemented to ensure that the results reflected the realities and experiences across different national contexts. SpicE partners were actively involved in this process, providing critical insights and suggesting improvements through a dedicated consultation mechanism.

The questions that were addressed in the Gap Analysis are shown in Figure 1.

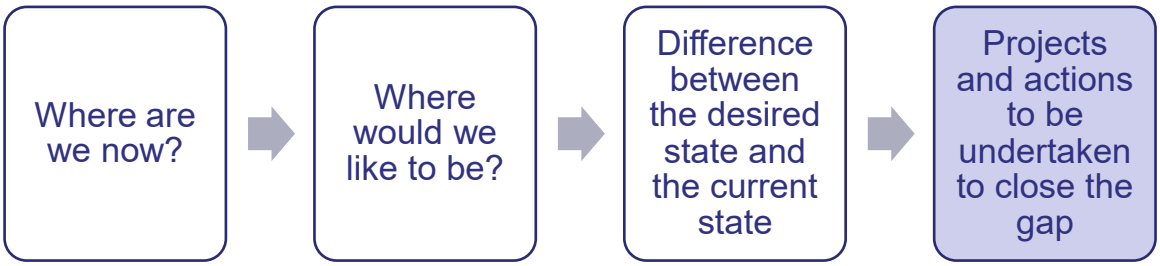

Figure 1 Diagram of the Gap Analysis

In summary, the above diagram shows how the Gap Analysis was implemented:

- The University of Alicante prepares the Gap Analysis on the basis of the phases described above.
- The validation mechanism involves publishing the document on the working platform. The partners provide feedback, make suggestions and ratify the Gap Analysis proposal through an ad hoc questionnaire.
- Based on the results of this validation, aspects of the report are corrected and the report is finalised.

This collaborative process provided the Gap Analysis with consistency and contextual relevance. The University of Alicante coordinated the development of the analytical framework, while the other partners contributed national-level perspectives and critical feedback. Thanks to this joint effort, the final version of the Gap Analysis managed to reflect common trends across Europe and the specific barriers of each educational system. This approach strengthened the validity of the results and enabled the SpicE project to formulate targeted and realistic proposals. The outcome is a solid foundation on which to build more inclusive STEAM practices and support educational stakeholders in adapting their strategies to better address diversity in classrooms.

Gap analysis. A quick look at the results

As an overall scheme that brings together the addressed aspects, the following table shows the shortcomings identified by the pre-service and in-service teachers who participated in the data collection for the SpicE project, in order to conduct the Gap Analysis (Table 3).

Table 3 Shortcomings in the implementation of inclusive STEAM education detected by pre-service and in-service teachers in the study carried out within the SpicE project.

Pre-service teachers	*In-service teachers*
- They have limited knowledge of STEAM Education but a better understanding of Inclusive Education. - Their perceived needs for training is for practical solutions to the educational inclusion of students with mild disabilities. - They believe that university training in STEAM and inclusive education should be updated to improve students' knowledge.	- They have limited knowledge of the specifics of STEAM education. - The perceived needs for training relates to experience in STEAM and mild disabilities. - In reference to Inclusion, they believe it is important to break down prejudices and myths. - In reference to STEAM and mild disabilities, they believe that teacher willingness and training are important. - They are aware of the demands of inclusive education.

Pre-service teachers	*In-service teachers*
- They have a strong interest in acquiring knowledge about STEAM, inclusive education and inclusive STEAM education. - The level of personal interest in learning to implement inclusive education for students with mild disabilities is high in all countries.	- They are interested in and willing to undergo training in STEAM Education and/or inclusive education. - They believe that the keys to strengthening interest in STEAM training and inclusive education are motivation, values such as respect, solidarity and trust, and socio-emotional engagement. - They possess skills for implementing inclusive programmes (entrepreneurship, innovation and group work, among others). - They are able to perform educational assessment of students with mild disabilities. - They consider a lack of resources and a heavy workload to be barriers to the implementing of STEAM in mild disabilities. - They are attracted to new opportunities for implementing STEAM and inclusive education. - They consider a lack of support from education authorities for STEAM education to be a factor of ineffectiveness. - They consider it important to be receive training in practical solutions for inclusive education.

The following table (Table 4) shows the challenges highlighted by pre-service and in-service teachers with regard to the implementation of the inclusive STEAM model. These were collected from the Gap Analysis carried out within the SpicE project.

Table 4 Results on the challenges detected by pre-service and in-service teachers in the study carried out within the SpicE project.

Pre-service teachers:	*In-service teachers:*
- Practical solutions for inclusion. To understand the practical solutions for the educational inclusion of students with mild disabilities. - The potential of STEAM in inclusion. To acquire the skills to use STEAM education for the inclusion of students with mild disabilities in general classroom learning activities. - Specific methodology. To receive training in teaching methodologies for pupils with mild disabilities. - School curriculum adaptation. To know how to adapt the general school curriculum to the needs of pupils with mild disabilities.	- Practical solutions for inclusion. To understand the practical solutions for the educational inclusion of students with mild disabilities. - Specific methodology. To receive training in teaching methodologies for pupils with mild disabilities. Active teaching staff from different countries acknowledged that they lacked sufficient knowledge of teaching methodologies for pupils with mild disabilities. - STEAM in daily school practice. To learn about ideas for incorporating STEAM education into everyday school practice. - The potential of STEAM in inclusion. To acquire the competences needed to use STEAM

Pre-service teachers:	*In-service teachers:*
- The school progress of pupils. To learn procedures to determine the school progress of all pupils. - STEAM in daily school practice. To learn about ideas for incorporating STEAM education into everyday school practice. - Assessment of students with mild disabilities. To understand the methods of educational assessment for students with mild disabilities. - STEAM integrated classes. To learn about organising integrated STEAM classes. - The integrating of learning objectives. To combine multiple learning objectives from different content areas. - Speciality STEAM fields. To acquire training in teaching methodologies for each of the STEAM fields. - Theoretical training in STEAM. To gain an understanding of the theoretical background of STEAM education.	education to include students with mild disabilities in general classroom learning activities. - School curriculum adaptation. To know how to adapt the general school curriculum to the needs of pupils with mild disabilities. - STEAM integrated classes. To learn about methods of organising integrated STEAM classes. - The school progress of pupils. To learn procedures for determining the school progress of all pupils. - Speciality steam fields. To acquire training in teaching methodologies for each of the STEAM fields. - Theoretical training in STEAM. To gain an understanding of the theoretical background of STEAM education. - Assessment of students with mild disabilities. To learn methods of educational assessment for students with mild disabilities. - Integrating learning objectives. To combine multiple learning objectives from different content areas.

Let's look at the main ideas around these results.

Inclusion and STEAM in education today

STEAM education and its relevance in educational system

STEAM is an educational approach that combines different disciplines to promote interdisciplinary and practical learning. Its incorporation into the education system is a response to the need to prepare students to tackle complex problems, develop their analytical skills and foster their creativity in a world driven by technological innovation. This model has proven effective in increasing student motivation and improving the connection between theoretical knowledge and its real-world application. In this regard, the active methodologies in STEAM education facilitate experimentation, problem solving and teamwork — key aspects for 21st century education (Wu et al., 2023).

However, the implementation of STEAM still presents significant challenges. As López et al. (2022) point out one of the main concerns is organizational issues. While this approach allows for new teaching methods to be explored, but its application in diverse profiles requires inclusive strategies toprevent the exclusion of certain groups.

STEAM and inclusion, a necessary tandem in the classroom

For the STEAM model to be inclusive, it must take into account the diversity of learners and ensure that everyone can actively participate in the proposed activities. This involves adapting resources and methodologies to meet different needs, such as ensuring technological accessibility and adopting teaching strategies that accommodate different learning paces, as pointed out by Kuo (2024). The inclusive approach in STEAM goes beyond removing physical or technological barriers, to provide real learning opportunities through accessible and meaningful experiences, as concluded by Álvarez & Hernández (2025). It is therefore essential to design activities that allow students with mild functional diversity to get involved in the processes of research, design and problem solving without limitations arising from a lack of adaptation.

In addition, inclusive STEAM education requires a transformation in teacher training, as pointed out by Galanti & Holincheck (2022). Teachers need tools to enable them to design adapted teaching approaches and assess learning from a perspective that values diversity. Without these elements, STEAM initiatives risk excluding some students rather than opening up new opportunities for all (Aghasafari et al. 2025).

Challenges in implementing STEAM for student diversity

Efforts to consolidate STEAM as an inclusive model face challenges both conceptually and in educational practice (Zhang & Jia, 2024). Theoretically, there are difficulties in defining a clear framework for inclusive STEAM education. Differing interpretations of the term STEAM, a lack of consensus on integrating art into the model, and an absence of shared strategies for linking STEAM with other areas of the curriculum lead to confusion and inequalities in its application. From a methodological perspective, the scarcity of specific resources and the lack of teacher training make it difficult to adapt STEAM practices to diverse contexts, (Zakariya, 2020). For these reasons, many teachers feel insecure about applying active methodologies in heterogeneous classrooms, which limits the potential for personalised teaching and ensuring the participation of all students.

Another key challenge is the assessment of learning. Most education systems rely on traditional assessment tools that do not always accurately reflect students' progress in STEAM contexts, especially when they have specific needs. Designing assessment tools that are more flexible and cater for a range of abilities is essential for the successful consolidation of STEAM as a inclusive education approach.

Gaps in the implementation of inclusive STEAM education

The Gap Analysis conducted in the framework of the SpicE project has revealed a number of difficulties that limit the effective implementation of STEAM in diverse educational contexts. Although the potential of this approach is undisputed, obstacles to its implementation exist in terms of curriculum design, teacher training and resource availability. These shortcomings compromise the inclusive nature of STEAM education and hinder its adoption in settings where students have different needs.

The main problems identified are presented below, structured into four key areas.

Lack of a unified vision on STEAM education

The concept of STEAM is not uniformly understood across education systems. There are significant differences in how the approach is conceived and implemented, which lead to confusion about its purpose and make it difficult to create common strategies for its inclusive implementation.

One of the most recurrent challenges is the difficulty of integrating art into STEAM. Although incorporating art has the potential to expand creativity and foster interdisciplinary learning, it is often perceived as an additional element rather than an integral part of the model. This lack of integration prevents art from acting as a link between scientific disciplines and the humanities, reducing learning opportunities for students with different cognitive styles.

In addition, STEAM literacy is not yet effectively linked to other areas of the school curriculum. The absence of clear strategies for connecting STEAM with other subject areas limits its impact on teaching as a whole. This also hinders its adoption in contexts where the diversity of learners demands more flexible and inclusive approaches.

Insufficient Teacher Training

The success of STEAM in the classroom hinges largely on teacher preparation, yet the data from the Gap Analysis show that inclusive STEAM is still lacking in terms of training. Many teachers have not received specific training in this approach, which leads to insecurity when designing and implementing teaching strategies adapted to the needs of diverse learners. Active methodologies, which are fundamental to STEAM teaching, require in-depth knowledge to be applied effectively in inclusive settings. However, a lack of preparation in this area hinders their effective use, thereby reducing learning opportunities for learners with specific needs.

Structural barriers in schools

Limitations in the resources available in schools are one of the main barriers to the effective implementation of inclusive STEAM. Without adapted materials, appropriate technological equipment and specialised support staff, it is difficult to provide learning experiences that are accessible to all students. Inequalities in access to educational technologies exacerbate this situation. While some schools have well-equipped laboratories and access to advanced digital tools, others lack the necessary means to develop high-quality STEAM projects. This digital divide restricts learning opportunities and perpetuates inequalities among students.

Beyond material resources, a lack of institutional support is also a significant obstacle. Without clear policies favouring STEAM inclusion, teachers find it difficult to implement this approach into the classroom. The absence of specific guidance from education authorities results in a lack of consistency in the implementation of STEAM, which reduces its effectiveness as an inclusive tool.

Challenges in assessment and curriculum adaptation

Assessing learning in STEAM can be more challenging when trying to ensure inclusion. Traditional assessment systems often focus on the acquisition of specific knowledge without considering the different ways in which learners can demonstrate their understanding and skills. This puts those who need more flexible assessment methodologies at a disadvantage. Furthermore, STEAM is not always integrated into the school curriculum in an inclusive manner. In many cases, difficulties arise in adapting content and learning dynamics to the needs of students with learning difficulties, which limits their participation in STEAM activities.

Finally, the scarcity of accessible models of good practice in inclusive STEAM prevents teachers from having clear references for its application in the classroom. Without concrete examples to guide the adaptation of STEAM for diverse learners, it is difficult to design effective inclusion strategies that ensure access for all. In many cases, inclusive STEAM initiatives are implemented in isolation, without a common framework from which to draw lessons and generate practical guidelines for dissemination. This means that teachers are left to develop their own strategies without access to proven models to serve as a reference. As a consequence, the opportunity for teachers to share knowledge and consolidate effective methodologies for dealing with student diversity is lost. Moreover, the lack of visibility of these experiences generates uncertainty regarding how to adapt STEAM for students with different profiles and needs. Without well-documented examples, it is difficult to understand which methodological adjustments can facilitate the participation of students with functional diversity, which technological tools can favour their integration and which assessment methods can be applied to fairly and equitable evaluate their progress.

This situation highlights the need of developing accessible repositories of good practices in inclusive STEAM, which contain detailed information on successful experiences about their implementation, the challenges encountered and the solutions applied. Without such resources, STEAM education will continue to face barriers that limit its reach and potential as an inclusive educational model.

SpicE proposals for advancing inclusive STEAM education

Overcoming the identified gaps in Inclusive STEAM education requires a comprehensive approach that addresses both the conceptual challenges and the practical implementation. To this end, progress must be made in four key areas: defining a common framework; improving teacher training; providing adequate resources; and developing inclusive assessment strategies. Let us examine each of these aspects in detail.

Towards a clear conceptualisation of inclusive STEAM

One of the main challenges in providing inclusive STEAM education is the lack of a homogeneous definition to guide its implementation in schools. The existence of multiple interpretations of what STEAM entails and how it should be applied makes it difficult to integrate it coherently into the school curriculum. Without a common

framework, each educational institution adapts the approach according to its own criteria, generating inequalities in its application and limiting its potential as an inclusive tool. To overcome this fragmentation, it is essential to develop clear guidelines that establish common principles and criteria for inclusive STEAM teaching. These guidelines should address key issues such as integrating art into the STEAM model, connecting science and humanities disciplines, and ensuring equitable access to STEAM activities. They should also provide examples of good practice to help teachers visualise their application in different educational contexts.

Developing a common frame of reference would favour greater coherence in the implementation of STEAM and allow more schools to incorporate it. Having clear guidelines would also facilitate the work of teachers, who would have concrete support for adapting this approach to the diversity of students. It should be noted in this regard that the SpicE project developed a frame of reference for competences linked to STEAM and inclusion.

Improvements in teacher training

The success of a model of inclusive STEAM hinges largely on teacher preparation. Without adequate training, teachers may struggle to design activities adapted to the diversity of learners and apply active methodologies effectively. Currently, many teachers are unaware of specific STEAM strategies for inclusive settings, which reduces learning opportunities for students with diverse educational needs. To address this, training programmes focusing on inclusive methodologies and assessment for learning in STEAM contexts are essential for in-service teachers. These programmes should provide teachers with practical tools for adapting STEAM projects to the needs of students with functional diversity, as well as strategies for managing classroom diversity. Furthermore, training in inclusive STEAM should not be limited to theory, but should also include practical experience, enabling teachers to experiment with active methodologies, accessible technological tools and adapted assessment strategies.

The creation of learning communities among teachers can also contribute to the exchange of experiences and the consolidation of good practices in this area. These spaces allow teachers to share strategies for motivation, resolve doubts about the implementation of inclusive STEAM and access resources developed by other professionals. In addition, they encourage collaboration between educational centres and facilitate the development of support networks where real-life cases can be

analysed and methodologies can be adapted to different contexts. In addition, interaction between teachers with varying degrees of experience in inclusive STEAM can enrich the learning process and help to overcome common barriers in teaching.

A clear example of this collaborative dimension is the Community of Practice (CoP) established as part of the SpicE project, accessible through the platform https://spiceacademy.eu/community-of-practice/. This virtual community was designed as a key instrument within the project to support professional exchange among in-service and pre-service teachers engaged in inclusive STEAM education. Through this space, educators from various countries have connected and shared experiences, questions and proposals related to the implementation of inclusive methodologies in the classroom.

Throughout its development, the CoP has fostered discussions focused on methodological strategies, the adaptation of materials for pupils with mild functional diversity, and the analysis of real-life cases. The platform also features a resource library, enriched by contributions from participants, which includes guidelines, teaching materials, assessment tools, and examples of good practice. This community stands as one of the main achievements of the SpicE project, as it promotes peer learning and strengthens a collaborative environment that helps sustain the project's long-term impact.

Resources and institutional support

Institutional support plays a key role in the consolidation of inclusive STEAM. Educational administrations must develop policies that promote this approach and provide incentives for schools to incorporate it into their curricula. In addition, it is essential to increase the support staff in schools, ensuring the presence of specialists in inclusion and STEAM who can advise teachers and guarantee effective implementation.

In addition, the implementation of inclusive STEAM requires investment in materials and in the training of specialised staff who can support teachers in its application. A lack of resources in schools limits the possibilities of developing accessible STEAM projects and makes it difficult to adapt activities to the diversity of students. To ensure equitable access to STEAM education, schools need to be equipped with accessible technological tools, adapted teaching materials and flexible learning spaces. In fact, the availability of specific resources, such as support software for students with

functional diversity or devices that facilitate interaction in STEAM environments, is key to broadening the participation of all students. The SpicE project has contributed to addressing this need by developing a set of accessible and practical resources designed to support the implementation of inclusive STEAM education. One of the key outputs is the SpicE MOOC, which offers structured training for in-service teachers and pre-service teachers on inclusive methodologies, adapted assessment strategies, and approaches to modifying STEAM content for pupils with functional diversity. In addition, the Community of Practice (CoP) provides a growing repository of shared materials, including lesson plans, assessment tools and case studies. These resources have been co-created with the involvement of educators from different countries, which increases their relevance and practical value. The SpicE Alliance (https://steamalliance.eu/) also ensures continued access to these outputs and promotes collaboration among institutions committed to advancing inclusive STEAM education.

Strategies for inclusive assessment

Assessment remains one of the biggest challenges in inclusive STEAM education. Traditional methods of assessment do not always accurately reflect students' learning in STEAM contexts, especially when they have specific needs that require alternative approaches.

To make progress in this area, it is necessary to design assessment tools adapted to the diversity of learners and aligned with STEAM principles. Assessment should consider different ways of demonstrating learning, including observation processes, flexible rubrics, digital portfolios and self-assessment strategies that allow students to reflect on their own progress. The development of accessible assessment tools is key to ensuring that all students have the opportunity to demonstrate their learning in STEAM. In addition, these tools should allow for customisation of the assessment criteria according to individual needs, ensuring that the diversity of learners is taken into account when assessing their performance.

Conclusion

In conclusion, ensuring that STEAM education is truly inclusive is a complex but essential challenge to guarantee that all students have access to equitable and enriching learning opportunities. The Gap Analysis carried out in the framework of the

SpicE project has revealed significant shortcomings in the implementation of this approach, especially in terms of teacher training, availability of resources, coherence in its conceptualisation and assessment strategies adapted to the diversity of learners.

One of the main challenges identified lies in the lack of a unified vision of what inclusive STEAM means and how it should be implemented in schools. The diversity of approaches and the absence of clear guidelines make it difficult to integrate STEAM into the school curriculum, resulting in inequalities in its implementation. A common framework with specific principles and guidelines would reduce this fragmentation and facilitate consistent implementation. In response, the SpicE project has developed a conceptual and pedagogical framework that defines the key principles of inclusive STEAM and offers practical guidance for implementation in different educational contexts.

Insufficient teacher training represents another significant obstacle. Many educators have not received specific preparation in active methodologies adapted to diversity, which limits their ability to design accessible and equitable learning experiences. It is essential to provide ongoing training that equips teachers with practical tools for delivering STEAM education in inclusive settings and to promote the exchange of experiences through professional communities. The SpicE project has addressed this need through a diverse training pathway that includes an open-access MOOC, a blended learning programme with tutor support, and in-person training sessions involving international mobility to Spain and Cyprus. During these visits, participating teachers engaged with real examples of inclusive STEAM implementation, collaborated with peers from other countries, and designed teaching proposals tailored to diverse classroom contexts. This training was further supported by the creation of a Community of Practice (CoP), where teachers shared real experiences, discussed common challenges, and accessed collaboratively developed resources.

A lack of material and human resources exacerbates implementation difficulties, especially in schools with limited access to technology and specialised support. Investment in accessible materials, inclusive technological tools and trained support staff is essential to ensure that the STEAM model can be applied in any educational context. To support this effort, SpicE has developed a repository of open-access teaching materials that are available via the project platform and the CoP. These resources have been designed to help teachers adapt their practice to diverse learners, even in contexts with limited infrastructure.

Finally, assessment remains an area for improvement. The need to design tools that reflect learning in STEAM contexts without excluding students with specific needs is a key issue in the move towards more equitable teaching. The incorporation of flexible assessment instruments, the use of portfolios and self-assessment strategies can support a more accurate assessment of student diversity. SpicE has addressed this challenge by identifying inclusive assessment principles and offering specific examples and tools that allow teachers to evaluate the learning process of all students more effectively, particularly those with functional diversity.

Addressing these shortcomings would improve the quality of STEAM education and contribute to consolidating a fairer and more innovative pedagogical model. This transformation requires the involvement of all educational stakeholders — administrations, schools and teachers — with the shared objective of ensuring that STEAM becomes accessible and enriching for all students. Through its training, resources and collaborative spaces, the SpicE project provides practical ways to achieve this.

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Describing the roles of Inclusive STEAM Educators using a competence-based approach

Georgia Sakellaropoulou[1], Natalia Spyropoulou[1], Achilles Kameas[1]

[1]*Hellenic Open University, Patras, Greece*

Introduction

Citizenship, sustainability, and rapid technological advances are some of the defining characteristics of the 21st century, that have changed the landscape of the knowledge and skills future citizens must develop to adapt to our rapidly changing world (Eprs, 2023; European Commission, 2020; Lafortune & Fuller, 2025). In this context, education has been evolving through the adoption of innovative pedagogical approaches, such as Inclusive Education and STEAM (Science, Technology, Engineering, Arts, and Mathematics) Education, where "Arts" broadly encompass all other disciplines. These approaches aim to ensure equal learning opportunities for all students while also equipping them with the necessary skills to meet future labour market demands. STEAM Education, in particular, promotes interdisciplinary learning, creativity, problem-solving, and critical thinking, preparing students for complex real-world challenges. At the same time, Inclusive Education focuses on accommodating diverse learning needs, ensuring that all students, regardless of background, ability, or socioeconomic status, can actively participate and thrive in the learning process. However, despite these advancements, not all students have been able to fully benefit from such opportunities (Tomar & Garg, 2021). In response to this challenge, the concept of Inclusive STEAM Education has emerged, seeking to bridge existing gaps by making STEAM learning accessible, equitable, and meaningful for diverse learners.

Inclusive STEAM Education, as an educational approach that values and embraces diversity, has started to be adopted so that all students would have equal opportunities to be competent future professionals and contribute to solving global open problems, as well as providing different perspectives (Tomar & Garg, 2021; Wade et al., 2023;

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Wu et al., 2023). Combining Inclusive and STEAM Education, Inclusive STEAM Education showed its dynamic potential in improving all students' (including those with Special Education Needs (SEN)) knowledge, skills and world understanding (Lu et al., 2022; Sari et al., 2024; Thoma et al., 2023; Wade et al., 2023; Wu et al., 2023). Nevertheless, realizing truly Inclusive STEAM Education comes with a variety of challenges for educators (Thoma et al., 2023; University of Macedonia, 2023).

These instructional, methodological, and training challenges have exposed significant gaps in existing professional development programs and highlighted the need for systematic support to help educators enhance their practices and acquire the necessary qualifications to manage diverse Inclusive STEAM classrooms (University of Macedonia, 2023). In response, two key frameworks have been developed to address these needs. **The Inclusive STEAM Educators' Competence Framework (Inclusive STEAMcomp Edu)** (Sakellaropoulou et al., 2023b) defines the essential competences, instructional strategies, and collaborative models required for educators engaged in Inclusive STEAM teaching, serving as a valuable roadmap for educators' professional growth, policymakers' decisions, and the design of Higher Education Institutions' (HEIs) programs. Complementing this, the **Inclusive STEAM Education Framework** (Agaliotis & Kartasidou, 2023) provides further guidance for HEIs in developing effective training programs, showcasing best practices, and offering relevant educational resources. Together, these frameworks contribute to a more structured and comprehensive approach to Inclusive STEAM education, ensuring that educators receive the necessary support to foster equitable and high-quality learning experiences (Agaliotis & Kartasidou, 2023; Sakellaropoulou et al., 2023b)

In this book chapter we will briefly refer to all the above subjects, presenting the results produced in the context of the Erasmus+ project SpicE (Special Education STEAM Academy). The rest of the chapter is structured as follows: In section 2, the theoretical background of the chapter (Conceptualization of Inclusive STEAM Education, students with mild disabilities, educators in Inclusive STEAM Education, the competence-based approach) is briefly described. In section 3, the Inclusive STEAM Educators' Competence framework is presented. In section 4, the different roles of educators in Inclusive STEAM Education are analysed, based on the framework's components. In section 5, further applications of the Inclusive STEAMcomp Edu are presented, along with the Educational Framework for educators' professional development. Finally, in Section 6, conclusions and further steps are discussed.

Theoretical background

Inclusive STEAM Education is a newly formulated approach that has started to be applied and researched over the last years. Showing its potential for the multidimensional development of all students, including those with SEN/ mild disabilities, the approach opened the ground for discussions concerning the parameters needed for its proper implementation (Lu et al., 2022; Sari et al., 2024; Thoma et al., 2023; Wade et al., 2023; Wu et al., 2023). Educators were put on the foreground of research, and the Erasmus+ project SpicE contributed to support them through the provision of various tools based on the competence-based approach. In addition, a conceptualization of Inclusive STEAM Education, offered solid ground for future discussions.

Conceptualizing Inclusive STEAM Education

In this conceptualization, Inclusive STEAM Education is an educational approach that combines knowledge and instructional frameworks of both Inclusive and STEAM Education. Inclusive STEAM Education begins with the integration of almost all STEAM disciplines alongside students' talents, interests, and needs (Sakellaropoulou, Spyropoulou, Agaliotis, et al., 2024). Through this combination, it aims to foster and guide all students in inquiry, dialogue, critical thinking, as well as diversity and disability awareness. Inclusive STEAM Education ensures equitable access, participation, engagement and success in authentic STEAM interventions addressing real-life community/ national/ global problems (Sakellaropoulou , Spyropoulou, Agaliotis, et al., 2024). Finally, the "A" in Inclusive STEAM Education represents all the other disciplines, apart from STEM, whereas the Inclusive component refers to all students, regardless of their cultural and socioeconomic background, special education needs and/ or any type of disability, such as mild disabilities.

Students with Mild Disabilities

Students with mild disabilities are a subgroup of SEN students who present impairments that affect some aspects of learning and everyday functions, while still allowing them to perform normally in other areas (Raymond, 2014, p.6). Due to the absence of severe limitations and impairment, educational systems failed to identify and support them before the 20th Century (Raymond, 2014, p.6). From the 20th century to the present, significant steps have been made to identify and offer special education

services to a higher percentage of students with mild disabilities (Edyburn, 2000). Consequently, students who usually present mild intellectual disability, emotional/ behavioural disorders and/ or learning disabilities (Henley et al., 2009) started receiving support aimed at facilitating their inclusion in mainstream classrooms (Henley et al., 2009). However, in the context of STEAM classrooms, some argue that students' inclusion is at initial stages (Tomar & Garg, 2021). Research on Inclusive STEAM Education is also in its early stages, focusing primarily on educational interventions (Lu et al., 2022; Sari et al., 2024; Thoma et al., 2023; Wade et al., 2023; Wu et al., 2023). Within these interventions, the roles of educators, alongside the aspects of qualifications, responsibilities, challenges and needs, have yet to be properly addressed.

Educators in Inclusive STEAM Education

Educators, nevertheless, play a crucial role in any educational intervention, acting as pillars of success (N. Spyropoulou & Kameas, 2024). In the case of Inclusive STEAM Education, the combination of two educational approaches entails combined challenges and needs as well. Indeed, according to the literature on Inclusive STEAM and STEM Education, educators seem to confront several challenges, including accommodating diverse learners' abilities (Klimaitis & Mullen, 2021), assessing and empowering them (Thoma et al., 2023), all while facing time constraints (Klimaitis & Mullen, 2021; Thoma et al., 2023) and a lack of support from other educators and guidance counsellors (Klimaitis & Mullen, 2021). Furthermore, there is a recognized need for professional development across various aspects of Inclusive and STEAM Education, as well as their combination (Klimaitis & Mullen, 2021; University of Macedonia, 2023). In addition, educators may also present harmful beliefs and biases on SEN students and their potential, especially in STEM fields (Clements et al., 2021), which could result in a lack of opportunities for the SEN students in Inclusive STEM classrooms, as identified in one study (Clements et al., 2021).

The competence-based approach as a roadmap for identifying their roles

The SpicE project employed a competence-based approach (N. Spyropoulou & Kameas, 2020a, 2023) to address educators' challenges and needs and to support the creation of STEAM environments that value and accommodate any form of diversity (with a focus on students with mild disabilities). The competence-based approach is a

descriptive tool for identifying the competences -in terms of knowledge, skills, attitudes - (European Agency for Special Needs and Inclusive Education, 2022) needed in a specific context. The approach is "*a vital factor in integrating education and training with labour market needs*" (Škrinjarić, 2022, p.3). In the next section, the Inclusive STEAM Competence Framework, developed through a competence-based approach, will be presented along with its methodology.

The Inclusive STEAM Educators' Competence Framework

Competence frameworks are descriptions of proposed competences that specific professionals should develop and apply in a specific sector (N. Spyropoulou & Kameas, 2024). Consequently, the Inclusive STEAM Educators' Competence Framework (Inclusive STEAMcomp Edu) is a description of the competences (knowledge, attitudes and skills), educators should develop and be able to apply in Inclusive STEAM classrooms. Focusing on qualified educators, the Inclusive STEAMcomp Edu exploits the existing STEAM Educators' Competence Framework (STEAMcomp Edu) (N. Spyropoulou & Kameas, 2024), to capture the needs and requirements of Inclusive educational classrooms (Sakellaropoulou et al., 2023a).

The methodology for the competence framework development

An established methodology for competence framework development (Fong et al., 2013) was adapted to expand and explore additional directions for the initial STEAM Educators' Competence Framework in inclusive environments. The adapted approach is depicted Figure 2.

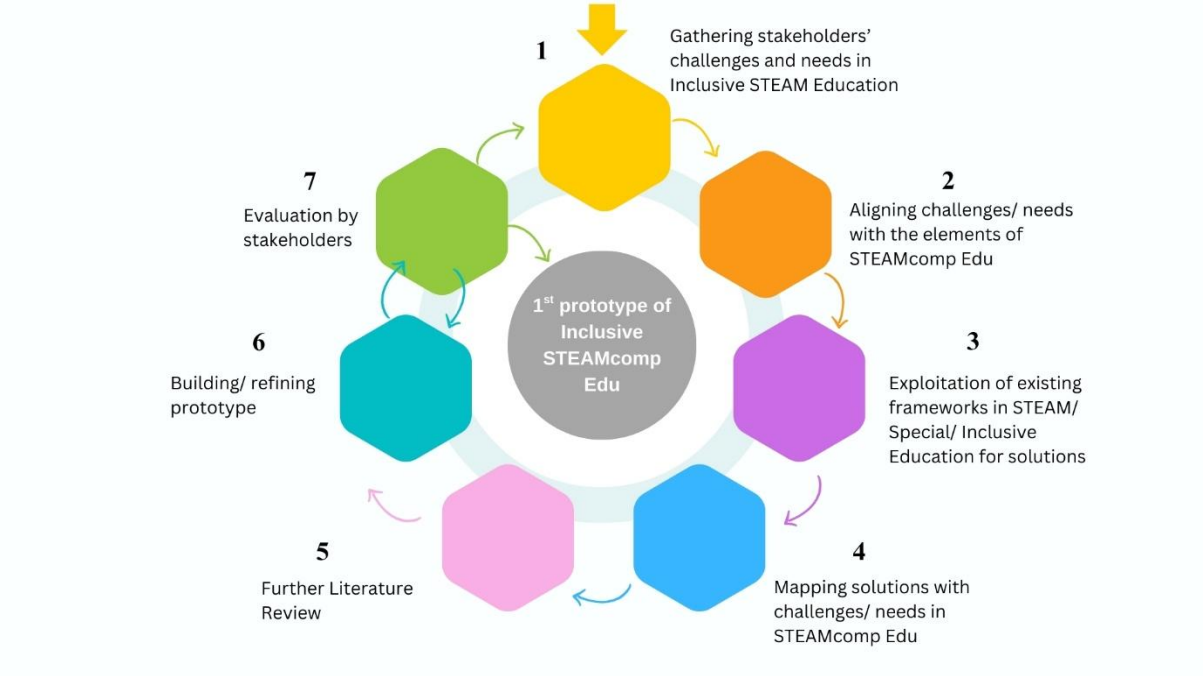

Figure 2 The adapted research method

At the first methodological circle that led to the development of the first prototype of Inclusive STEAMcomp Edu, seven (7) different steps were implemented (Sakellaropoulou et al., 2023a; Sakellaropoulou et al., 2023b). At first, educators' challenges and needs in Inclusive STEAM Education were gathered through a survey and literature review. In the survey, primary in-service and pre-service teachers from Bulgaria, Cyprus, Greece and Spain participated, providing significant insights (University of Macedonia, 2023), whereas in the literature review, further investigation was implemented in educators' challenges and needs. In the second step, the identified educators' challenges and needs were aligned with the elements of STEAMComp Edu. In the third step, educators' competence frameworks in STEAM/ STEM/ Special and Inclusive Education were exploited in order to provide solutions to educators' identified challenges and needs. In the fourth step, such solutions were aligned with the challenges/ needs that were, already placed in STEAMComp Edu. In the fifth step, an additional literature review was implemented, to retrieve further solutions on the identified challenges/ needs. In the sixth step, the first version of the Inclusive STEAMcomp Edu was developed. Then different loops of steps 7 and 6 were implemented. At the first loop, the newly formulated framework was evaluated by a convenience sample of Greek experts. In the second loop, the framework was evaluated by the partners of the project SpicE through two evaluation rounds. At the final loop, a modified Delhi technique was implemented with experts from Bulgaria,

Cyprus, Greece and Spain. The end of the third loop, led to the first prototype of the Inclusive STEAMcomp Edu.

The elements of Inclusive STEAMcomp Edu

The Inclusive STEAMcomp Edu concluded to consist of 4 different hierarchical levels (N. Spyropoulou & Kameas, 2020b), as depicted in Figure 3.

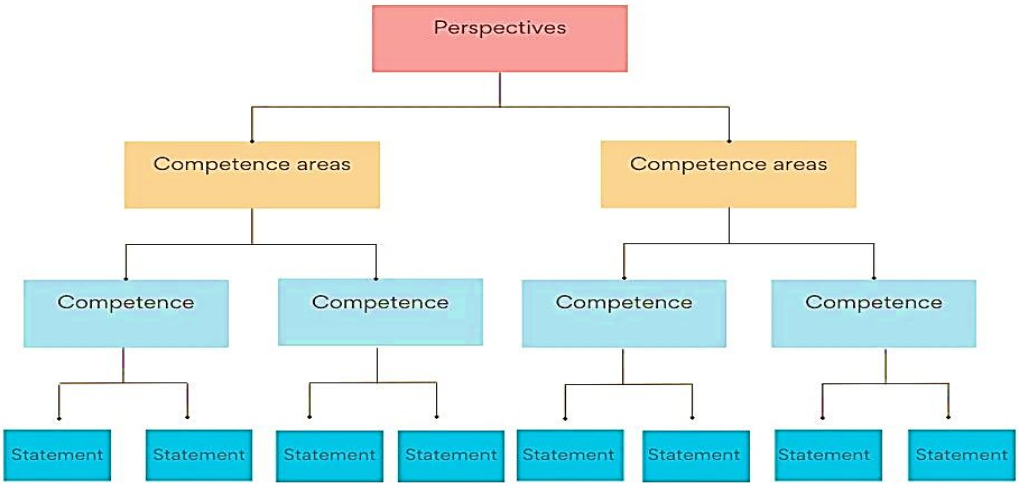

Figure 3 The hierarchical levels of Incl. STEAMcomp Edu

The highest framework level presents the perspectives, namely the roles of educators in Inclusive STEAM Education. The second level consists of the competence areas, which expound the dimensions of educators' roles. The third level introduces the competences that are associated with each dimension. Finally, in the fourth level, several statements provide practical descriptions and examples of each competence and can be directly used by educators in their everyday practice.

The roles of educators in Inclusive STEAM Education

For the first level, which presents the roles of educators within Inclusive STEAM Education, five different roles have been identified. The role of:

a) educator as an Inclusive STEAM teacher- trainer- tutor;

b) educator as an Inclusive STEAM Education designer and creator;

c) educator as an Inclusive STEAM Education orchestrator;

d) educator as a community member;

e) educator as an Inclusive STEAM growing professional.

The five framework roles place educators in different contexts (inside/ outside classrooms and at community level), highlighting, in parallel, the necessity of their professional development to be continuously updated and competent. Those roles along with their dimensions are depicted in Figure 4.

Figure 4 The roles of educators in Incl. STEAMcomp Edu and their dimensions

The role of educators as Inclusive STEAM Teachers- Trainers- Tutors

The role of educators as Inclusive STEAM teachers- trainers- tutors places them within the classroom, during the implementation of the Inclusive STEAM Education procedure. Inclusive STEAM teachers- trainers- tutors play a vital role in fostering and maintaining inclusion, equity, accessibility and engagement of all learners in their STEAM classrooms. For this reason, educators within this role remain continuously aware of the importance and theoretical background of Inclusion, STEAM and of Inclusive STEAM Education, fostering positive attitudes towards all approaches. In addition, they are familiar with the learning profiles, needs and talents of all their students, continuously assessing and monitoring them and involving, in such process, different stakeholders, such as other educators, special educators, families/ legal guardians and other special education professionals.

Furthermore, educators use constructivist techniques to investigate each of their students' prior knowledge, using them as the foundation to create meaningful learning experiences. Concerning teaching methods and practices, educators combine Inclusive teaching with STEAM teaching techniques, such as Universal Design of Learning (UDL), Differentiation of Instruction (DI), Individualized lesson plans (ILP), project-based learning, inquiry-based learning, research- based learning, game-based learning and outdoor learning, accordingly. Additionally, they implement appropriate teamwork methods and group dynamic techniques, such as peer-tutoring and learning, alongside the dynamic formation of heterogenous teams.

In addition to teaching techniques, resources, tools and instructions are also vital to the success of any Inclusive STEAM Education procedure. Regarding resources and tools, the selection and use of appropriate materials, tools and Assistive Technology tools can facilitate students' access to and acquisition of new knowledge. For this reason, educators use a variety of resources tailored to their students' learning styles and needs. Moreover, they use appropriate language, combining different modes of language expression (visual, spatial, aural and gestural) and instructions (whole class, one-to one and one- to -small group instructions).

Finally, in this role, educators use different assessment tools for the evaluation and monitoring of students and groups, including engagement, performance and progress, but also the dynamics, the collaboration and communication within groups. To monitor

students' and groups ' progress, the development of both individualized and group STEAM portfolios is used. This form of evaluation allows educators to easily inform all stakeholders (students, other educators, and students' official guardians) about individual and group achievements, providing appropriate feedback.

The role of educators as Inclusive STEAM Education Orchestrators

Similarly to teachers, trainers and tutors, the role of educators as Inclusive STEAM Education orchestrators places educators within the classroom and requires providing them with the necessary recommendations for the coordination and management of Inclusive STEAM procedures, resources and classroom's members. In this role, educators organize the classroom and laboratory environment to be accessible for students and groups. In addition, educators organize their materials, resources, and equipment in advance to facilitate the proper implementation of upcoming Inclusive STEAM activities and projects.

Time management is another key aspect orchestrators are tasked to manage during the implementation of Inclusive STEAM activities and projects, as they need to respect each students' pace and facilitate the implementation of (individualized) lessons plans. Finally, the framework also highlights the importance of coordinating students, identifying and addressing challenging behaviours with the use of appropriate behaviour management techniques. Coordination skills are also important to manage the team of general and/ or special educators that participate in Inclusive STEAM Education procedure, by fostering collaboration among all, assigning responsibilities and guidance for the proper implementation of the educational procedures.

The Role of Educators as Inclusive STEAM Education Designers and Creators

Educators also assume significant roles outside classrooms. One of such roles is that of educators as Inclusive STEAM Education designers and creators of curricula, courses/ lessons, activities/ projects and resources/ instructions, to facilitate the development of all students' Inclusive and STEAM competences.

Within this role, educators create flexible and transdisciplinary STEAM curricula, formulating, also, clear, observable and measurable goals. In addition, they adapt said curricula to Inclusive STEAM, by integrating Inclusive Education goals for all learners

and using Inclusive educational frameworks such as UDL. After designing the curriculum, educators define specific, measurable, achievable, realistic, and time-bound (SMART) objectives to support all learners. These objectives ensure that learning goals are clear, realistic, and can be effectively monitored within a set timeframe. Those objectives also provide them directions for the desired knowledge, skills and attitudes all and each learner should develop at the end of each Inclusive STEAM Intervention. They also help them create appropriate lesson plans in the classroom, in groups or on individualized level. These lesson plans guide educators to design appropriate activities and projects that are based on real-life situations, in accordance with the school infrastructures and responding to society's and labour market's needs. Educators also select appropriate STEAM methodologies, content, digital tools, applications, assistive technologies, and assessment instruments to support the activities and projects they design, ensuring they address the diverse needs of their students. Furthermore, when existing resources do not adequately meet the defined learning objectives for all learners, educators develop and adapt new instructional materials and resources to ensure inclusive and effective learning experiences.

The role of educators as community members

The Inclusive STEAMcomp Edu framework highlights the necessity of the role of educators as community members, which places educators outside classrooms and within communities, showing the necessary interactions they make with their environment. In this role, educators participate in local, national and international educational communities, that support them in the exchange of experiences, knowledge, good practices, teaching methods and educational resources. Those support networks can facilitate both the design and implementation of Inclusive STEAM Educational procedure, as well as the coordination of learners. Support networks help educators gain expertise and knowledge from others, and allow them to share their own accomplishments and challenges.

Support networks can also welcome diverse professional figures, such as industry professionals and businesses, as well as community organizations and institutions. These alternative networks can help educators bring real-world relevance to their Inclusive STEAM education activities and projects, creating enriching learning opportunities for their students. Furthermore, interaction with businesses and organizations allows educators to disseminate their work or petition for grants or

equipment. For all these reasons, educators participate in and build these networks. Moreover, educators within this role apply existing educational policies and procedures for Inclusive and STEAM Education and contribute to the formation of new ones, sharing their experiences and expertise. Furthermore, educators raise Inclusive STEAM Education awareness in the educational community, highlighting its added value in unlocking all students' potential.

The Role of Educators as Inclusive STEAM Growing Professionals

Finally, the last role of educators is that of Inclusive STEAM growing professionals. This role places educators outside the classrooms, highlighting the necessity of their self-improvement and ongoing professional development of specific skills. The framework has identified and proposed transferable personal, social and learning-to-learn skills, digital skills and self-reflective and life-long learning skills. Consequently, educators within this role are continuously developing and applying personal skills, such as critical thinking, adaptability, design thinking, resiliency, self-control and emotions regulations. Moreover, they develop and apply social skills such as empathy and communication, collaboration skills, as well as learning- to learn skills, such as the organization, monitoring and review of own learning and its use in different contexts.

Digital skills are also key to educators in the role of Inclusive STEAM growing professionals, and they are encouraged to develop and apply digital information and data literacy skills as well as digital tools' management and use skills. Finally, educators, within this role, invest in the development of reflective and self-reflective skills that could further lead them to both the improvement of their teaching practices and their self-improvement. Such a process guides educators to the selection and participation in appropriate STEAM, Inclusive and Inclusive STEAM professional development programs, as well as to the development of their research skills, in areas of interest.

Applications of the Incl. STEAMcomp Edu

The showcased roles, as well as all the associated elements of the Inclusive STEAMcomp Edu that describe them, were further specified within the descriptions of four occupational profiles. These profiles were found to be important for the success of any educational intervention in Inclusive STEAM classrooms. These profiles, which

were developed with the use of a similar methodology such as the one used for the framework development (Sakellaropoulou, Spyropoulou, & Kameas, 2024), are as follows:

a) Inclusive STEAM primary school teacher;
b) STEAM special educational needs primary school teacher;
c) Inclusive STEAM learning support teacher;
d) Inclusive STEAM pedagogy expert.

The framework was used not only for the specification of the roles, the responsibilities, and the competences each educator should develop, but also to showcase the instructional, methodological and collaboration approaches that educators should apply to ensure the effectiveness of any Inclusive STEAM intervention in which they are part (Sakellaropoulou, Spyropoulou, & Kameas, 2024).

In addition, educators' roles and the Inclusive STEAMcomp Edu were further used as one of the tools for the formation of the Inclusive STEAM education framework (Inclusive STEAMedu) (Agaliotis & Kartasidou, 2023). The Inclusive STEAMedu describes the important parameters of appropriate pre- and in-service teacher training for implementing Inclusive STEAM Education for primary students with mild disabilities (Agaliotis & Kartasidou, 2023). The Inclusive STEAMedu presents the following parameters: a) the policy context for Inclusive STEAM/ STEM Education for MD students, b) the stakeholders involved, c) the instructional management of STEAM fields in Inclusive settings, d) the educators' roles in them, e) procedures, resources and tools for educators' training in Inclusive STEAM Education as well as f) meta-data (Agaliotis & Kartasidou, 2023).

All those framework parameters act as a coherent set of principles, methods and approaches that can either guide or be directly used in the design, formation, implementation and evaluation of future professional development programs for educators. These programs aim to equip them with all the tools necessary to effectively and successfully include students with mild disabilities in their STEAM classrooms (Agaliotis & Kartasidou, 2023). Along with the Inclusive STEAMcomp Edu, and the teachers' occupational profiles, the Inclusive STEAMedu further guides and supports HEI's and ongoing education providers by equipping them with practical tools on why and how educators' competences should be developed, and informing them of the challenges educators could face and should address.

Finally, the educators' roles and the other elements of the Inclusive STEAMcomp Edu, were used as a reference point for the formation of the joint educational curriculum of Inclusive STEAM Education (Pavlou et al., 2023), as well as the educational program of project SpicE (Pavlou et al., 2024).

Conclusions

In summary, this chapter outlined the roles of educators in Inclusive STEAM Education, as identified through the development of the Inclusive STEAM Educators' Competence Framework. These roles have been further investigated during the subsequent two years of the SpicE project, with the evolving findings to be presented in future publications.

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A joint curriculum for STEAM in Special Education

Yvoni Pavlou[1], Marilena Savva[1] & Marios Papaevripidou[1]

[1]University of Cyprus, Research in Science and Technology Education Group (ReSciTEG), Nicosia, Cyprus

Abstract

In this chapter we present the instructional design process of the Joint Curriculum for STEAM (Science, Technology, Engineering, Arts and Mathematics) in Special Education, designed to foster pre- and in-service teachers' competences in implementing STEAM frameworks and approaches to support the inclusion of all learners - including learners with mild disabilities - in the mainstream classroom. The Curriculum development was based on a comprehensive, team-oriented approach (Spyropoulou et al., 2019; 2022). Central to this approach was the Analyse, Design, Develop, Implement and Evaluate (ADDIE) model that ensures the systematic development and ongoing enhancement of a training program. This chapter presents the process followed during the Analyse and Design phases, emphasizing the importance of a needs-driven, iterative approach to teacher training curriculum design. The first phase, Analyse, involved identifying the professional development (PD) needs of pre- and in-service teachers in the participating countries (University of Macedonia, 2023), as well as developing learning pathways a participating teacher could follow during the three phases of the program: (i) a Massive Open Online Course (MOOC), (ii) a Blended Learning Program, and (iii) two Exchange Programs. In the Design phase, an outcome-based approach was employed by firstly selecting competences from the STEAM Educator Competence Framework and Profiles for Special Needs (Sakellaropoulou et al., 2023) that could be fostered during each training phase and then by developing clear and measurable learning outcome(s) for each competence. Each phase progressively develops teachers' competences, from foundational knowledge and skills to more advanced competences relevant to Inclusive STEAM education. The chapter concludes with suggestions and guidelines for educators and institutions aiming to use or adapt this Curriculum in their own educational contexts.

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Introduction

Teachers are fundamental to the effective execution of educational reforms, and research underscores the importance of providing them with adequate support and PD opportunities (Darling-Hammond et al., 2017). STEAM education requires educators to be well-equipped with the necessary skills to effectively implement innovative teaching methodologies (Moghal et al., 2020). At the same time, fostering inclusive learning environments that cater to diverse student populations is essential for ensuring equal access to education. Incorporating STEAM education into general classrooms poses substantial difficulties for both aspiring and practicing teachers (Herro et al., 2019). Educators must devise strategies that not only address the varied learning needs of their students, including those with mild disabilities, but also maximize the potential of STEAM-based teaching methodologies (Beaton et al., 2021). To achieve this, strengthening and enhancing teacher training for both pre- and in-service teachers is essential to ensure educators are well-equipped to implement effective and inclusive STEAM instruction.

A crucial aspect of overcoming these challenges is prioritizing both initial teacher education and ongoing PD. By cultivating expertise in STEAM-based instruction, educators can create more engaging learning experiences. Additionally, promoting inclusive teaching methods is necessary to accommodate all students effectively. STEAM functions not only as a pedagogical tool but also as a transformative approach that drives innovation in education (Ramesh, 2025). Meanwhile, inclusive education ensures that every learner, regardless of their abilities, can fully participate in the learning process. Addressing these two dimensions in parallel is key to advancing effective teaching practices. Given that inclusive STEAM education remains an underdeveloped approach in teaching (University of Macedonia, 2023), it is of pivotal importance that appropriate and effective PD opportunities are provided to teachers.

Developing an effective PD training for teachers necessitates a structured instructional design approach to ensure coherence, relevance, and sustainability. Instructional design is the systematic process of creating learning experiences that enhance knowledge acquisition, skill development, and professional growth through intentional planning (Wenger, 1998). In the context of teacher PD, this involves an initial needs

assessment to identify educators' professional learning gaps, followed by the establishment of clear, measurable objectives that align with both institutional goals and teachers' pedagogical contexts (Opfer & Pedder, 2011). The planning phase must also integrate a collaborative and context-specific approach, as research has shown that professional learning is most effective when it is embedded in teachers' daily work and structured within a community of practice (Bergmark, 2023). The iterative nature of instructional design, often supported by models such as the ADDIE (Analysis, Design, Development, Implementation, and Evaluation), allows for flexibility in adapting the training based on emerging needs, ensuring that teachers are not passive recipients but active participants in shaping their learning trajectory (Timperley, 2011). Furthermore, studies highlight that top-down, one-size-fits-all training models often fail to resonate with educators due to their detachment from classroom realities (Lloyd & Davis, 2018). Developing a structured yet flexible PD program allows teachers to construct a shared repertoire of strategies, strengthening their collective efficacy and reinforcing the sustainability of professional learning communities (Lloyd & Davis, 2018; Wenger et al., 2002). Positioning teachers as co-constructors of knowledge rather than mere consumers of training content fosters a culture of continuous learning and innovation in educational settings.

In this chapter, we provide an overview of the process we followed to develop the Joint Curriculum for STEAM in Special Education which served as the underpinning of the SpicE training program. The planning phase of the SpicE training program prioritized the development of research-informed, contextually relevant, and adaptable content, ensuring that teachers could tailor and apply these strategies to diverse educational settings. By grounding our approach in instructional design principles and a collaborative professional learning framework (Spyropoulou et al., 2019; 2022), we established a structured yet flexible training program to support teachers in integrating inclusive STEAM practices into their classrooms. This approach not only enhances the quality of STEAM instruction but also ensures that professional learning is sustainable, reflective, and responsive to teachers' evolving needs.

Below, we outline the approach taken to develop the Joint Curriculum for STEAM in Special Education. We provide an overview of the instructional design process with indicative examples, focusing on the two initial stages of this process. Additionally,

suggestions for adapting the Curriculum to other educational contexts are provided. For a comprehensive presentation of the Joint Curriculum for STEAM in Special Education and the SpicE training program, readers are encouraged to refer to Pavlou et al. (2023, 2024), which offers a more detailed account.

Instructional design approach

A well-designed curriculum serves as the foundation for effective PD, ensuring that educators are equipped with the necessary knowledge and skills to implement inclusive STEAM education. The Joint Curriculum for STEAM in Special Education was developed with this goal in mind, offering a structured learning experience that supports teachers in integrating STEAM methodologies within diverse classrooms. The instructional design approach followed for designing the Curriculum was facilitated by the ADDIE model. The ADDIE model is a widely used approach that ensures systematic and effective PD development through its five iterative phases (Handrianto et al., 2021; Shrivastava & Shrivastava, 2020). During the **Analyse** phase, learners' needs, knowledge gaps, and instructional goals are identified, ensuring that the training is aligned with specific learning objectives. In the **Design** phase, these findings are translated into a structured instructional plan by outlining learning outcomes, assessment methods, and instructional strategies. In the **Develop** phase, instructional materials, lesson plans, and assessment tools are created, ensuring that content delivery aligns with the intended learning objectives. The **Implement** phase involves delivering the instruction, ensuring that educators are prepared, and gathering initial feedback on the effectiveness of the training. Finally, the **Evaluate** phase concerns the assessment of the impact of the training, incorporating both formative (continuous) and summative (final) assessments to measure learning outcomes and improve future iterations of the program (Shrivastava & Shrivastava, 2020). The ADDIE model has been effectively applied in various educational settings (e.g., Adeoye et al., 2024; Handrianto et al., 2021; Szabo, 2022), to ensure alignment between training objectives and professional competences, thereby enhancing learning experiences and instructional effectiveness. This chapter focuses on presenting the steps taken and necessary considerations during the Analyse and Design phases to develop the Curriculum.

The analyse phase

Conducting a needs analysis

When designing the Curriculum and the content of a PD program, the initial step involves identifying the areas where teachers have expressed interest or need further learning and improvement, ensuring alignment with their professional goals (Burns, 2023; Cordingley et al., 2015; Schachter et al., 2019). As Sandholtz and Scribner, (2006) noted, “Teachers need to see links and benefits between what they are learning and their own classrooms” (p. 1112).This need analysis can subsequently guide the goal setting and planning process of the PD program (Ayvaz-Tuncel, & Çobanoğlu, 2018), along with relevant EU and national policies and priorities, as well as current literature and methods of instruction (Burns, 2023). For the purposes of the SpicE project, a comprehensive needs analysis was carried out (see University of Macedonia, 2023) to identify the needs of both pre-service and in-service teachers regarding Inclusive STEAM education. Pre- and in-service primary school teachers from the four participating countries (Bulgaria, Cyprus, Greece and Spain) reported the need for developing more in-depth understanding, strategies and skills concerning STEAM Education (e.g., to know the theoretical background of STEAM education), Inclusive Education (e.g., to know methods of educational assessment of students with mild disabilities), and Inclusive STEAM Education (e.g., developing competences on how to employ STEAM education as a way for including learnings with mild disabilities in the mainstream classroom). This thorough needs analysis provided essential insights into the key areas for PD, to ensure that the training is both relevant and impactful.

Developing learning pathways

The Joint Curriculum for STEAM in Special Education was set to be implemented through three sequential training phases, delivered in different settings:

- **Phase 1:** MOOC delivered in an asynchronous online setting (self-paced learning).
- **Phase 2:** Blended learning program, delivered in both synchronous and asynchronous settings (online self-paced learning course that incorporates synchronous sessions).

- **Phase 3:** Two exchange programs, delivered in synchronous learning settings with physical presence of all participants and tutors.

The STEAM Educator Competence Framework and Profiles for Special Needs (Sakellaropoulou et al., 2023) framework, developed as part of the SpicE project, defines five key educator roles in inclusive STEAM education, each addressing different aspects of pedagogy, instructional design, and professional growth. Each role encompasses several competences that cover a wide range of knowledge and skills, that require systematic teacher training for their development (Agaliotis & Kartasidou, 2023). The Curriculum was designed to foster these roles through a progressive, iterative learning approach, ensuring that each training phase builds upon prior knowledge and skills. The five educator roles are outlined below:

1. **Educator as an Inclusive STEAM Teacher-Trainer-Tutor**: This role encompasses the implementation of inclusive STEAM educational **procedures**, ensuring that educators are equipped with the necessary pedagogical strategies to adapt STEAM activities for learners with diverse needs.
2. **Educator as an Inclusive STEAM Education Designer and Creator**: This role focuses on the development and customization of inclusive STEAM learning experiences, requiring educators to design innovative and accessible educational opportunities.
3. **Educator as an Inclusive STEAM Education Orchestrator**: This role involves the management and coordination of inclusive STEAM learning environments, including the organization of resources, differentiation of instruction, and facilitation of collaborative learning among students.
4. **Educator as a Community Member**: This role emphasizes the importance of collaboration and engagement within educational communities, fostering partnerships among teachers, policymakers, and stakeholders to enhance inclusive STEAM education practices.
5. **Educator as a Growing Inclusive STEAM Professional**: This role underscores the need for continuous professional development, reflective practice, and self-assessment, enabling educators to refine their competences and remain responsive to evolving educational demands.

To ensure the spiral development of these roles and the provision of flexibility and adaptability to participants, learning pathways were generated (see Table 5) that a participating teacher could follow during the SpicE training program.

Table 5 . The learning pathways of the SpicE training program

Phase of the training:	1. MOOC	2. Blended learning	3. Exchange programs
Learning pathways:	All teachers →	Pre-service teachers (primary school) In-service teachers (primary school)	→ Pre- and in-service primary school teachers
Main objective:	Build foundational understanding, strategies, and skills for Inclusive STEAM education	In-depth understanding, strategies, and skills for Inclusive STEAM education	Deepen understanding and skill development of previous phases and introduce country-specific good practices
Educator role emphasized:	Educator as an Inclusive STEAM Teacher-Trainer-Tutor	Educator as a Designer and Creator, Orchestrator, and Community Member	All educator roles

Given that the MOOC served as the initial phase of the teachers' training, it focused on building a foundational understanding, strategies, and skills, particularly emphasizing the role of Educator as an Inclusive STEAM Teacher-Trainer-Tutor. It was open to all teachers with an interest in Inclusive STEAM education.

The second phase of the training program, aimed at addressing competences of the Designer and Creator, Orchestrator, and Community Member roles to develop more in-depth understanding, strategies, and skills relevant to Inclusive STEAM education. In this phase, the distinct needs of pre-service and in-service teachers were considered.

Pre-service and in-service teachers have distinct professional learning needs, necessitating differentiated approaches to their training and development. Pre-service teachers require a strong foundation in pedagogy, curriculum design, and classroom management to prepare for the complexities of teaching. Their training is typically structured within formal teacher education programs, where theoretical knowledge is emphasized and gradually integrated with practical experiences through supervised teaching placements (Loughran, 2014). At this stage, professional learning focuses on equipping novice educators with essential instructional strategies and theoretical frameworks to support effective teaching practice.

In contrast, in-service teachers benefit more from ongoing PD that is embedded in daily practice and responsive to evolving classroom challenges; Their learning is best

supported through continuous engagement in collaborative learning communities, action research, and reflective practice (Opfer & Pedder, 2011; Timperley, 2011). Unlike pre-service training, which is primarily preparatory, in-service PD must address the immediate and context-specific needs of experienced educators, fostering sustained growth and adaptation to changing educational landscapes.

To accommodate these differences, two distinct learning pathways were developed, one for the pre-service teachers and one for the in-service teachers to respectively address the needs that were most dominant for each group. Therefore, the Blended learning phase concerned pre- and in-service primary school teachers who successfully completed the MOOC and expressed interest in continuing their training, following the respective pathway.

The third and final phase of the training program, which comprised of two mobility programs, concerned 48 selected primary school teachers who successfully completed the previous phases and adhere to requirements set nationally by partners. All five educator roles were prioritized during the mobilities with the goal to deepen understanding and skills developed in the previous phases and introduce country-specific good practices.

The learning pathways, as well as the insights of the needs analysis were translated into a structured instructional plan, outlining competences and learning outcomes during the Design phase.

The design phase

For the *Design phase* of the Curriculum, we employed an outcome-based approach, following two steps (see Figure 5). The first step was to select competences from the STEAM Educator Competence Framework and Profiles for Special Needs (Sakellaropoulou et al., 2023) that could be fostered during the implementation of each phase of the training program and that aligned with the PD needs expressed by the pre- and in-service primary school teachers. The second step of the *Design phase* was to develop clear and measurable learning outcome(s) for each competence. These outcomes define what participants are expected to know, understand, or be able to do by the end of the activities.

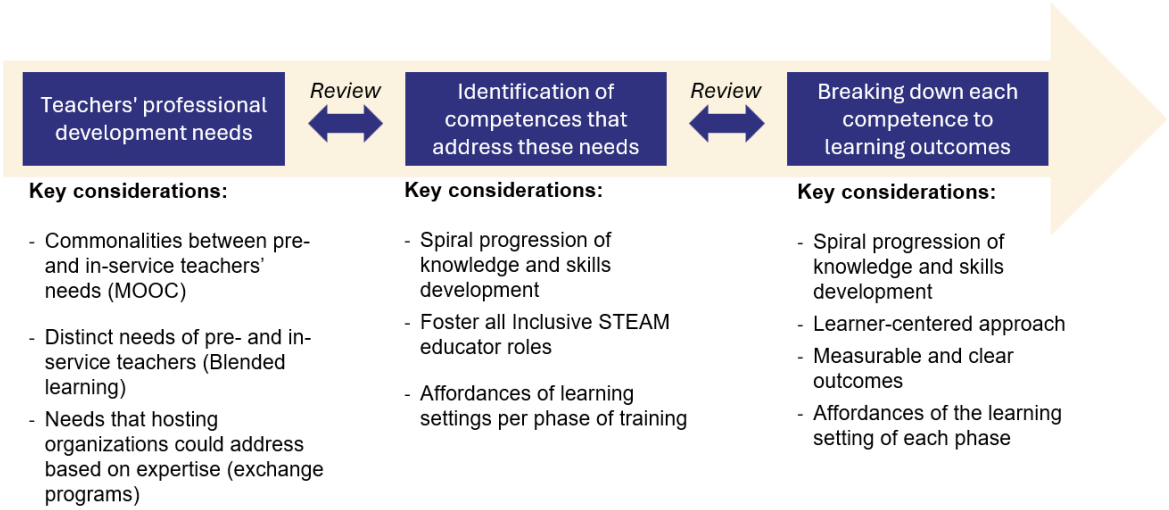

Figure 5 The steps and key considerations in the Design phase of the Joint Curriculum for STEAM in Special Education

Our key considerations during both steps were to ensure the progressive development of knowledge from the first to the third phase of the training, to maintain a learner-centred approach (Burns, 2023) throughout the program and to provide ample opportunities for community building. In addition, leveraging the different modes of learning to meet diverse needs was a key consideration during this phase.

The affordances of asynchronous and synchronous learning environments influence how learners engage with content and interact with each other. Learners can benefit from both the flexibility of asynchronous learning and the collaborative, interactive opportunities provided by synchronous formats. Asynchronous learning provides independence, while synchronous formats foster community and real-time interaction. The learning environment shape curriculum design by determining the types of materials and interactions that can be effectively utilized. Asynchronous settings allow for text-based resources, multimedia content, and self-paced activities that support flexibility and autonomy, whereas synchronous environments enable real-time discussions, collaborative problem-solving, and immediate feedback (Burns, 2023).

During the *Design phase*, the Curriculum was reviewed in two rounds by the consortium partners to ensure: (a) its relevance and alignment with national and institutional educational policies, (b) its adaptability to the specific educational contexts of each participating country, and (c) its suitability for both asynchronous and synchronous learning formats.

In the next sections, we provide an overview of the process we followed to align the teachers' expressed needs with competences and learning outcomes for each of the phases of the SpicE training program (MOOC, blended learning and exchange programs). The examples presented were carefully chosen to illustrate how the training supports the ongoing and progressive development of knowledge and skills from the first to the third phase.

Defining learning outcomes for the MOOC

The MOOC was structured over five weeks, covering key thematic areas of the SpicE training program:

- **Week 1 - The SpicE project:** Introduction to the course structure, the SpicE project, and the importance of inclusive STEAM education.
- **Week 2 - STEAM education:** Theoretical background of STEAM education, strategies for developing students' STEAM competences, and assessment methods.
- **Week 3 – Inclusive and Special Education:** Key principles of inclusive and special education, practical solutions for inclusion, and assessment methods.
- **Weeks 4 and 5 – Inclusive STEAM Education:** Integration of inclusive and special education strategies into STEAM activities, EU educational policies, and best practices.

The competences addressing needs expressed by both pre- and in-service teachers were selected for inclusion in the first phase of the training program. An example of how needs were translated into learning outcomes for this phase is presented in Figure 6.

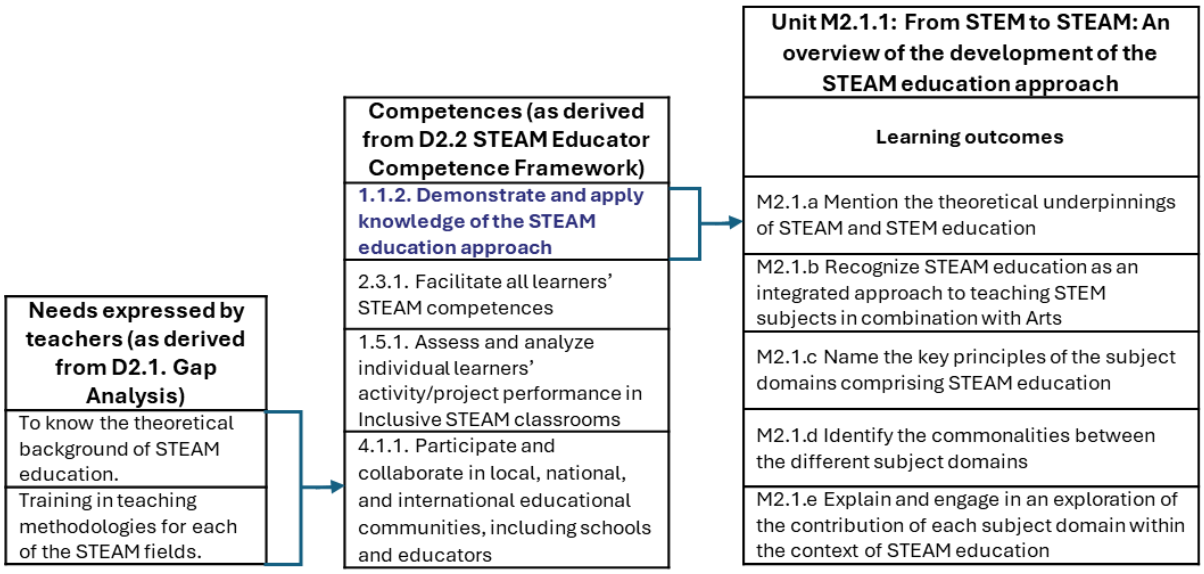

Figure 6 Indicative examples illustrating the breakdown from teachers' needs to learning outcomes in the first phase of the SpicE training program

As shown in Figure 6, two key needs expressed by pre- and in-service teachers were: (a) developing an understanding of the theoretical foundations of STEAM education and (b) exploring relevant methodologies. To address these needs, four competences were identified, as shown in the Figure. For each competence, measurable learning outcomes were developed for Week 2 of the MOOC, focusing on STEAM education. In the figure, the learning outcomes regarding the competence *Demonstrate and apply knowledge of the STEAM education approach* are presented which were developed for the initial Module of Week 2 (Module 2.1. The STE(A)M educational approach; Unit M2.1.1: From STEM to STEAM: An overview of the development of the STEAM education approach).

Defining learning outcomes for the Blended learning

The Blended Learning Program spanned five weeks and featured one Module for pre-service and one Module for in-service primary school teachers respectively. An example of how teachers' needs were translated into learning outcomes for the Blended Learning phase of the SpicE training program is presented in Figure 7.

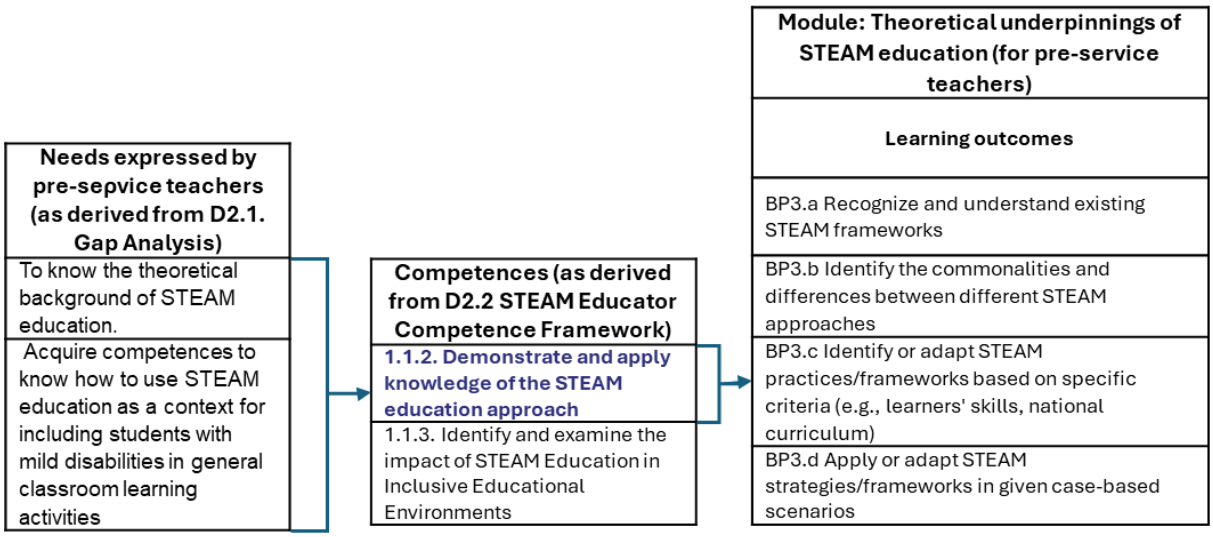

Figure 7 Indicative examples illustrating the breakdown from teachers' needs to learning outcomes in the second phase of the SpicE training program

The two PD needs presented in the Figure were expressed as a high priority of the pre-service teachers, whereas in-service teachers considered them as important but not necessarily their highest priority in terms of PD goals. The example provided in the Figure presented concerns the pre-service learning pathway, specifically the breakdown to learning outcomes for the competence *Demonstrate and apply knowledge of the STEAM education approach* (addressed in the Module Theoretical underpinnings of STEAM education). Although this competence was also covered in the MOOC (see Figure 6) the learning outcomes for the second phase foster a deeper development of relevant understanding and skills, ensuring a spiral and iterative process of knowledge and skills development.

Defining learning outcomes for the exchange programs

For the third and final phase of the training program, which comprised of two mobility programs for selected primary school teachers, certain competences from previous phases were revisited to deepen understanding and skill development, while new competences were introduced through country-specific good practices selected by the hosting organizations based on their expertise. In Figure 8, we provide an example of the competences and respective learning outcomes for the second day of one of the exchange programs specifically addressing the need—previously highlighted in Figure 6 and Figure 7 - for a strong theoretical foundation in STEAM education.

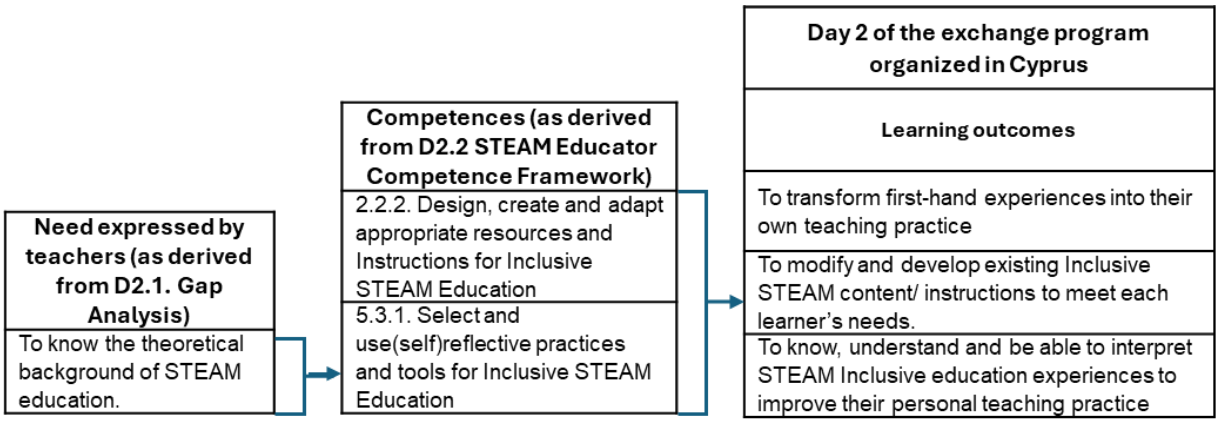

Figure 8 Indicative examples illustrating the breakdown from teachers' needs to learning outcomes in the third phase of the SpicE training program

The design of the exchange programs considered both the expertise of the hosting organizations and the unique opportunities offered by in-person participation. Face-to-face interactions allowed for immediate feedback, enhanced peer collaboration, and hands-on engagement with physical materials, all of which played a critical role in shaping the learning outcomes.

How to utilize the Curriculum

Below, we provide some guidelines for educators or institutions who want to use or adapt this Curriculum to their own context, as a foundation for developing PD programs concerning Inclusive STEAM education. The recommendations concern actions that could be taken primarily during the Analysis and Design phase of the instructional design process.

The first essential step is to conduct an analysis of the PD professional development needs of your target learners (e.g., background, prior knowledge, PD needs). In the needs analysis conducted in the context of the SpicE project (University of Macedonia, 2023), we explored the needs for PD for Inclusive STEAM education of pre-service and in-service primary school teachers from Bulgaria, Cyprus, Greece and Spain. Therefore, an institution or an organization established in these countries can set this needs analysis as a starting point as well. Nevertheless, it is also important to examine the educational landscape (e.g., current PD opportunities, national and institutional standards and policies) to decide whether a needs analysis - new or supplementary - is needed. This first step ensures that the Curriculum will be tailored to meet the

specific needs and expectations of the target group while aligning with the broader educational context in which it will be implemented.

In addition, by embedding the Curriculum within current training programs or policies, its relevance and sustainability over time can be strengthened. Overall, the Curriculum was developed to have a strong connection to the national policies of the involved countries and to resonate with EU initiatives and policies concerning Inclusive STEAM education. In the Pavlou et al. (2024), policies and professional development actions of the partner organizations of the SpicE project are provided, which can serve as examples and recommendations on how to align institutional and national goals to the SpicE training program.

For instance, the partner Universities suggest that the program can be offered as an elective course or material can be integrated in existing courses concerning areas such as Inclusive, or STEAM education. Such endeavours are facilitated the three-phase modular structure of the Curriculum and training. The modular structure allows customization, enabling institutions to adapt the flow of training to better suit the learners' progress and priorities. The Curriculum and training program was developed for asynchronous online, blended, and synchronous learning formats, therefore offering a variety of resources (e.g., videos, e-documents, presentations, interactive tools). Specific training phases or even modules can be implemented as standalone workshops, seminars, or online courses, ensuring flexibility and adaptability in implementation. Therefore, competences and relevant topics can be easily prioritized or re-sequenced based on identified needs.

Reviewing the Curriculum's learning outcomes is an essential next step in identifying the aspects most relevant to institutional goals, national educational standards, and the specific needs of target learners. If additional skills or knowledge areas are required, institutions or individuals can adapt or define complementary learning outcomes that complement the core elements of the Curriculum. Adapting the learning outcomes ensures that the Curriculum remains flexible and responsive to emerging needs or specific areas of focus within the target group. For example, if interdisciplinary collaboration in inclusive STEAM education is uncommon and fostering competences related to the role of Educator as a Community Member is a priority, the first step may be to define learning outcomes that emphasize building foundational knowledge in inclusive education within each discipline before introducing cross-disciplinary STEAM projects. This phased approach ensures that learners build a solid base of knowledge

before tackling more complex, integrative tasks. Additional learning outcomes focused on collaborative teaching strategies can then be integrated and the training can be structured to gradually foster interdisciplinary teamwork.

Gradual progression in building skills and knowledge allows participants to develop confidence and mastery in each phase before moving to the next, supporting a more natural learning curve. In long-term training programs, ensuring that learning outcomes build progressively allows participants to develop confidence in co-teaching and interdisciplinary practices before engaging in more complex collaborative processes. A step-by-step progression minimizes overwhelm and encourages learners to apply new skills incrementally. Fon instance, when designing for a broader audience (such as a MOOC), a gradual or spiral use of learning outcomes may be more effective. This approach allows participants to build confidence and engage progressively with the content. For example, in the SpicE training program, the MOOC modules were structured in a way that introduced core concepts gradually across the five weeks (Week 1: STEAM education, Week 2: Inclusive education, etc.), aligning with a gradual development of competences. This spiral progression was maintained in the next phases of the program by further developing the key competences addressed in the MOOC, while also introducing additional competences that support more in-depth understanding and skills.

This progression can be reinforced by explicitly defining learning outcomes that support reflection and peer feedback as essential components of collaboration, ensuring that educators develop the skills to critically assess and refine their teamwork strategies over time. In the context of the SpicE project, community development and engagement were integral aspects of the training program by fostering relevant competences and learning outcomes throughout the three training phases (e.g., learning outcome developed for Week 1 of the MOOC: “Propose methods for ongoing collaboration and networking within the Inclusive STEAM education community”), while considering the restrictions and opportunities provided by each learning setting. For instance, forum discussions and platform tools were used to support this process during the MOOC, in the Blended learning phase additional activities during online workshops and lectures were incorporated and during the exchange programs the face-to-face interaction and group activities greatly supported the enhancement of the SpicE community.

Finally, customizing the resources and content of the training ensures its relevance to the specific cultural and educational context in which it is delivered. It is noted that the resources developed for the SpicE training program based on the Joint Curriculum for STEAM in Special Education are Open Educational Resources available under the CC BY-NC-SA 4.0 DEED Attribution-NonCommercial-ShareAlike 4.0 International License. These resources may be used, reused, adapted, and shared. You can use or adapt existing resources where possible or create new content that is culturally and contextually relevant (e.g., case studies, reflection assignments). Contextual relevance is key in ensuring that the Curriculum resonates with learners and their specific educational environments. Our suggestions on how to utilize the Joint Curriculum for STEAM in Special Education offer a strategic approach for developing training materials based on the ADDIE model, emphasizing the need for alignment with the PD needs of target learners and institutional priorities with the content and format of the training program. However, this chapter is not exhaustive. Additional aspects should be explored, such as time restrictions, determining the digital readiness of learners and addressing potential barriers to engagement must also be considered when adapting or implementing the Curriculum (see for example Bergmark, 2023; Burns, 2023; Darling-Hammond, et al. 2017; Opfer & Pedder, 2011).

Conclusions

This chapter outlined the outcome-based approach followed for developing the Joint Curriculum for STEAM in Special Education of the SpicE project, emphasizing the need for alignment of learning outcomes and content with the PD needs of teachers. The Curriculum supports the spiral and progressive development of Inclusive STEAM education competences of both pre- and in-service teachers in three modular phases (i.e., MOOC, Blended learning and exchange programs). This approach renders the Curriculum highly adaptable: institutions can re-prioritize phases, re-sequence modules, or change delivery modes, while retaining the same underlying competence structure to guarantee alignment with local needs and policy contexts. Moreover, the three-phase structure illustrates how different delivery formats can be deliberately selected to match targeted competences: asynchronous online modules for foundational knowledge; blended workshops for deeper application and reflection; and in-person exchanges for hands-on practice, peer collaboration, and contextualized, country-specific examples. Such flexibility, coupled with an explicit competence framework as the organizing spine, enables curriculum designers and policymakers to

tailor inclusive STEAM training to local policy contexts, teacher needs and resource constraints, thereby maximizing both uptake and impact.

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Transforming the STEAM classroom: applying active methodologies for inclusion

Rosabel Martinez-Roig

[1]*University of Alicante, Spain*

Abstract

This chapter addresses the intersection between STEAM education, active methodologies and inclusion, with a focus on their impact on teacher education. the first part presented theoretical foundations of active methodologies and their relevance to teaching and learning processes. Building on this foundation, the relationship between active methodologies and STEAM education is analysed in order to highlight its potential to promote inclusive environments. Next, we describe a training experience carried out at the University of Alicante, in which twelve teachers from different countries participated in the framework of the project SpicE.

The chapter details the objectives, activities and resources used in each training day to illustrate how to apply the combination of active methodologies, STEAM and inclusion in real teaching contexts. This experience provides a practical insight into teacher professional development in this area, with strategies that enable meaningful learning for all students.

Introduction

STEAM (Science, Technology, Engineering, Arts and Mathematics) education is key to preparing students for the challenges of a changing society (Aghasafari et al., 2025). Its integration in the classroom allows for the development of technical and scientific skills while strengthening critical thinking, creativity and problem-solving skills in real-life situations. To make this approach inclusive, it is essential to use active

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methodologies that facilitate the participation of all learners and ensure that learning opportunities are adapted to their needs.

Active methodologies have proven to be effective tools in STEAM teaching, as they favour experimentation, project-based learning, collaborative work and motivation (Hsiao & Su, 2021). Such strategies not only transform the way students learn, but also redefine the role of teachers as facilitators of learning. In this context, inclusion means more than just adapting materials or content; it involves designing accessible and meaningful educational experiences for all, while respecting their different abilities and interests.

The SpicE project has addressed these challenges through a training proposal focused on STEAM teaching from an inclusive perspective. This chapter presents a concrete example of this strategy: a part of the training mobility that 12 teachers and teacher training students have carried out throughout the project. Specifically, in this chapter we present the part of the training developed by the teaching team of the University of Alicante during teachers' stay in the university, which corresponded to 3 of the 6 days of stay in Spain. During these three days, the proposed activities allowed participants to experiment, design and reflect on educational practices based on STEAM and active methodologies with an inclusive approach.

Active methodologies and STEAM

Active methodologies in STEAM projects

Active methodologies have transformed teaching by placing students at the centre of the learning process. Instead of adopting an approach based on the unidirectional transmission of content, these strategies promote active participation, knowledge construction and problem solving in real-life contexts (Lage-Gómez & Ros, 2021). Their application favours meaningful learning and, at the same time, boosts the development of key competences such as autonomy, creativity and critical thinking.

Among the most widely used active methodologies in education are project-based learning, cooperative learning, gamification, flipped classroom, service-learning and challenge- or problem-based learning. Each of these methodologies allows for learning experiences to be structured so that students are no longer passive recipients of

information, but instead take on a leading role in their learning (Ruiz Vicente et al., 2021). Interaction with the environment, teamwork and direct experimentation facilitate a deeper understanding of subject contents and their application in different situations.

In STEAM education, these methodologies are essential. The integration of science, technology, engineering, art and mathematics in interdisciplinary learning experiences requires approaches that encourage exploration and problem solving from multiple perspectives (Conde et al., 2021). The use of active methodologies makes it possible to connect this knowledge with real-life situations, facilitating dynamic learning that is adapted to the challenges of today's world.

Project-based learning, for example, facilitates the planning of experiences in which students develop innovative solutions to specific problems. Gamification introduces game-like elements to motivate and reinforce learning, which is particularly useful in teaching science and technology concepts (Aurava & Meriläinen, 2022). Other strategies, such as cooperative learning, encourage collaboration and the exchange of ideas, which promotes the integration of different areas of knowledge in a STEAM framework.

WebQuest and its possibilities in a STEAM context

One of the most widely used tools within active methodologies is the WebQuest (Adell et al., 2015), a teaching strategy based on guided research and the use of digital resources to develop key competences in students. Its structure facilitates autonomous learning and critical thinking, as it poses a challenge or problem that must be solved by exploring information previously selected by the teacher.

A WebQuest consists of the following sections:

- Introduction. This section presents the general topic and places pupils within the context of the activity. Its purpose is to motivate, spark interest and provide an overview of the challenge to be addressed.
- Task. This explains clearly and specifically what pupils are expected to do. It refers to the final product and should be formulated in a way that is meaningful and achievable.

- Process. This outlines the steps to be followed in order to complete the task. It includes a sequence of activities along with the resources provided by the teacher (links, documents, videos, etc.). This section acts as a guide to help pupils progress independently.
- Evaluation. This describes the criteria that will be used to assess the work. It is often presented in the form of a rubric, allowing pupils to understand in advance which aspects will be considered and how their performance will be measured.
- Conclusion. This section brings the learning experience to a close by offering a summary of what has been done. It encourages pupils to reflect on the knowledge acquired and how it might be applied in other educational or real-life contexts.

This methodology encourages autonomy and collaboration. It also allows the teaching-learning process to be organised in a structured way and ensures that students advance in the construction of knowledge through enquiry, decision-making and the application of what they have learned in meaningful contexts.

An example of a WebQuest is the one we have developed for the online teacher training in the SpicE project: https://sites.google.com/view/spice411/introduction (see Figure 9).

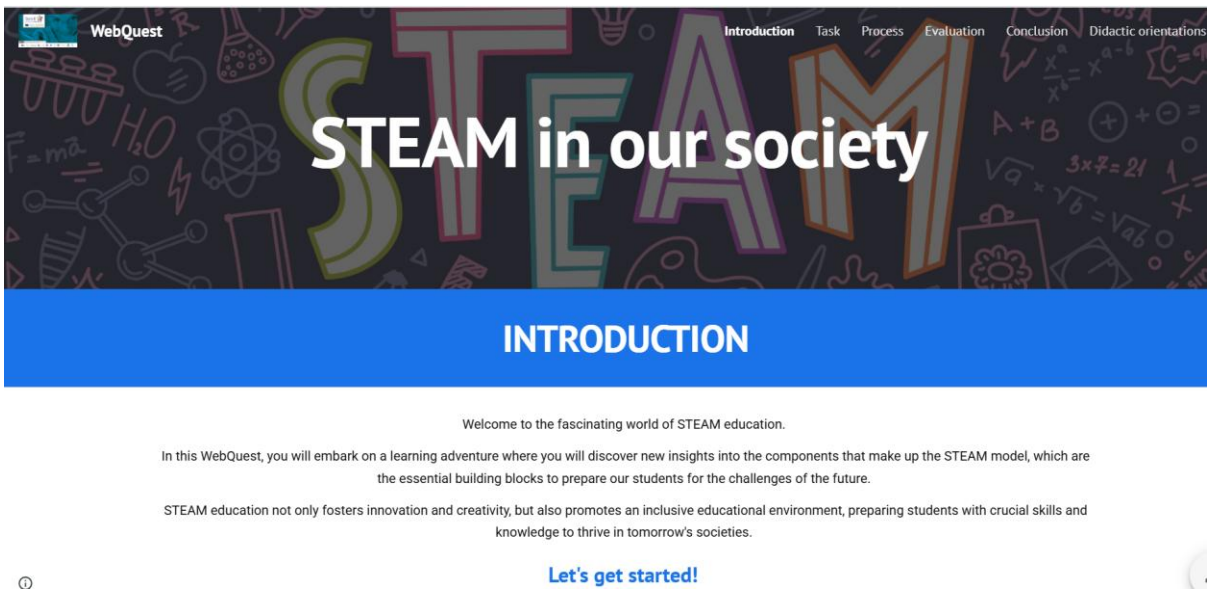

Figure 9 Screenshot of the WebQuest "STEAM in our society" developed by the team of the University of Alicante for the SpicE project.

Active methodologies and inclusion

A truly inclusive approach in education requires methodologies that make it possible to cater for students' diversity and guarantee equitable learning opportunities. Active methodologies facilitate this objective by proposing flexible strategies that adapt to different educational styles, paces and needs (Arvelo-Rosales et al., 2021).

Instead of following a homogeneous teaching approach, these methodologies offer multiple forms of access to knowledge, participation in activities and demonstration of learning (Cabero-Almenara et al., 2022). For example, project-based learning, cooperative learning or gamification allow the design of experiences in which students take an active role in their training, which favours motivation and involvement in the educational process. These strategies are particularly effective in inclusive contexts, as they facilitate the personalisation of content and encourage interaction between peers with different skills and perspectives (Ribeiro Silva et al., 2024). In addition, they provide opportunities for the development of social and emotional competences, which are essential in building learning communities where each person feels valued.

From this perspective, the combination of active methodologies and STEAM education contributes to transforming teaching and broadening the possibilities for inclusion (Duo-Terron et al., 2022). Flexibility in the organisation of learning, the possibility of working with different formats and the variety of tools available encourage the participation of all learners. Adapting projects to different abilities and interests creates learning environments in which everyone finds accessible and meaningful ways to develop their potential.

Exchange program in Alicante during the project SpicE. An example of STEAM, inclusion and active methodologies

Description of the training

The exchange program at the University of Alicante within the SpicE project was an opportunity to put into practice the principles of STEAM education, active methodologies and inclusion. For one week, twelve teachers from different countries participated in an intensive training programme that combined theory and practice to explored innovative approaches to teaching. The University of Alicante was

responsible for the organisation and development of the first three days, which were structured around dynamic and collaborative learning experiences.

In these sessions, teachers worked on the application of active methodologies to design and evaluate STEAM projects with an inclusive approach. The activities promoted experimentation and analysis of teaching strategies that favour the participation of students with diverse needs and learning styles. The training combined the use of educational technologies, project-based learning and gamification (Li et al., 2024) with the aim of showing how these tools can be integrated into the classroom to enhance STEAM teaching from an inclusive perspective.

Full information on the Alicante training, including materials and examples of activities carried out is available on the event website: https://sites.google.com/view/spice-alicante/home (see Figure 10).

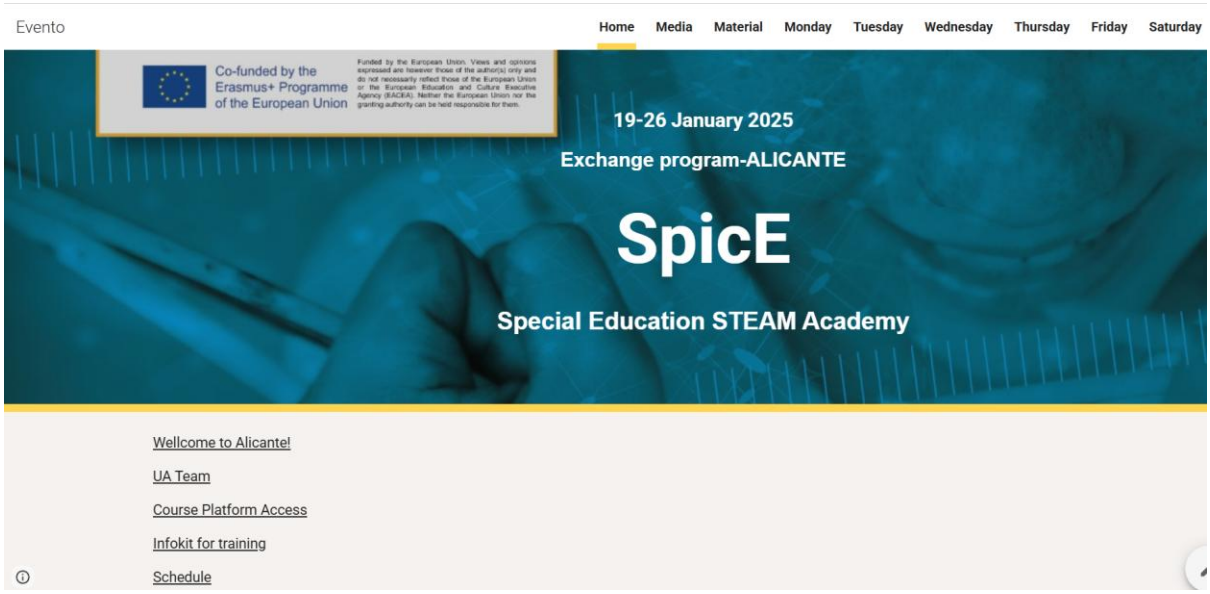

Figure 10 Screenshot of the website developed by the team of the University of Alicante for the Exchange program-ALICANTE.

The following sections detail the objectives, contents and dynamics of each day, and highlight the key methodologies used, as well as their application in real educational contexts.

Objectives, activities and resources used

The exchange programme of the SpicE project was structured on the basis of a planned pedagogical approach, where each day responded to a defined general

objective. Based on this framework, and with regard to the training that the University of Alicante had to develop as a partner in the project, specific learning objectives were established. These were designed to guide the activities and select the most appropriate resources. The combination of these strategies allowed for the creation of a dynamic learning environment linked to the principles of STEAM, inclusion and active methodologies. The key elements of each day are presented below.

Day 1: "We know and apply active methodologies in inclusive STEAM projects"

On day 1, the general objective was to apply educational resource management methods in STEAM inclusive education activities and projects. The learning objectives were:

- Apply teaching organisation methodologies for inclusive STEAM education.
- Design, create and adapt appropriate resources and instructions for inclusive STEAM education.

The following activities were carried out:

- A dialogue-based activity, combined with a quiz-style game using Kahoot, was carried out to explore participants' initial ideas. The objective was to identify their prior knowledge and perceptions regarding the organisation and use of educational resources in inclusive STEAM contexts.
- Presentation of the WebQuest (WQ) as a model based on active methodologies to organise resources in an inclusive STEAM project. The session alternated explanations and work in small groups to understand the WQ concept, structure and usefulness.
- Design and elaboration of a WQ. In small groups, participants created a WebQuest on a project and presented it. Examples of projects include building a bridge, organising a sustainability campaign and designing an inclusive playground..
- Usefulness of Creative Commons licenses in inclusive STEAM activities/projects. The Alicante team presented the use of Creative Commons licences for the publication on the Internet of the resources created in the classroom, in this case the WQ and any other product resulting from it. Each group created its own licence and added it to its WQ.

Day 2: "Volcano Adventure"

In Day 2 the general objective was to evaluate and analyse individual students' performance in activities/projects in inclusive STEAM classrooms. The learning objectives were:

- Know how to incorporate appropriate assessment tools and methods into inclusive STEAM activities and lessons to monitor the progress and performance of all learners.
- Select and apply multiple forms and alternative ways of assessing student performance in inclusive STEAM activities/projects.

This day was approached from an active approach. Specifically, more than 50 children from the Infant and Primary School came to the Faculty of Education to Aigües de Busot, a town near Alicante, to work with SpicE teachers on a gamification project that they designed together with their teachers. This activity took place in various classrooms in the Faculty. Each of them was a station where teachers needed to pass a test. For each test, a group of children explained to the adults what they had to do to succeed. These tests included inclusive activities such as programming with educational robots, Kahoot games, collective games, etc. SpicE participants were able to interact through rewards, badges, levels, points, etc. of the proposal (see Figure 11), which can be viewed at https://goo.su/EtHtw (a Genially account is required).

Figure 11 The steps and key considerations in the Design phase of the Joint Curriculum for STEAM in Special Education.

Participation in this gamified activity not only served as an example for the SpicE teachers but was also used to work on the topic of evaluation in inclusive STEAM projects. To this end, work was carried out in the training classroom before and after the gamification. This work was based on the following activities:

- As a pre-work, participants engaged in a brainstorming session on assessment in school to get ideas, knowledge and build on previous experiences. Key concepts in inclusive STEAM classroom activities/projects were discussed.
- During the gamified activity, participants discussed what, how and when to evaluate concretely an inclusive STEAM project.
- Once the was activity finished, participants returned to the training room and discussed the analysis carried out. Procedures and instruments for evaluating classroom practice were proposed.

Day 3: "How do we evaluate?"

The overall objective of this workshop was to develop, select and use (self-)reflective practices and tools for inclusive STEAM education. The learning objectives were:

- Understand the need for the development of learner portfolios in the assessment and design of inclusive STEAM education.
- Identify and select the type(s) of portfolio(s) appropriate to the needs of each learner.
- Know how to interpret and use evaluation results to improve inclusive STEAM activities/projects.

During this day, collaborative learning was encouraged through several activities. To encourage teachers to collaborate, they had to work in groups. The sequence of work was as follows:

- Participants reflected on and discussed their ideas, knowledge and previous experiences of the using of portfolios at school.
- In pairs, participants searched the Internet for examples of portfolio use.
- They later grouped into small groups and participated in a digital mural by adding posts with the examples they considered most relevant. Everyone saw each other's examples and was a dialogue on the examples to discuss their use.

- Participants took on the role of teachers. They selected either the WebQuest developed on Day 1 or the gamified activity from Day 2 as the basis for their work. They then designed a portfolio adapted to the selected activity. Each group chose the format they considered most appropriate (digital or printed).
- Participants presented their proposals and discussed these (self-)reflective practices and tools for inclusive STEAM education.

As a final activity, participants carried out an evaluative self-reflection on the experiences and knowledge acquired during the training programme, as well as on how to integrate them into everyday life in the classroom.

Conclusion

In conclusion, the SpicE project exchange programme at the University of Alicante allowed participating teachers to explore in a practical way the intersection between active methodologies, STEAM education and inclusion. Throughout the three days, strategies that facilitate student participation in diverse environments were addressed, fostering collaborative and accessible learning. The combination of innovative approaches with experiential activities demonstrated how teaching can be adapted to meet different needs and enhance the development of key competences.

This training process provided concrete tools for inclusive STEAM teaching and highlighted the importance of pedagogical reflection and networking among teachers from different contexts. The experience made it clear that educational transformation requires continuous training and flexible strategies capable of effectively integrating diversity into the classroom.

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Upscaling Inclusive STEAM Teacher Education: Evidence from the SpicE Project

Marilena Savva[1], Yvoni Pavlou[1] & Marios Papaevripidou[1]

[1]University of Cyprus, Research in Science and Technology Education Group (ReSciTEG), Nicosia, Cyprus

Introduction

The upscaling of educational innovation has emerged as a critical concern in efforts to transition pilot initiatives into sustainable, system-wide practices. Moving beyond mere quantitative expansion, upscaling constitutes a multifaceted process of adapting, embedding, and institutionalising interventions across heterogeneous cultural, linguistic, and policy landscapes (Buhl et al., 2018; Garcés & O'Dowd, 2021). This dual imperative—horizontal replication across contexts and vertical integration into institutional structures—demands both pedagogical coherence and systemic agility. For initiatives such as the Special Education STEAM Academy (SpicE), which seeks to advance inclusive STEAM education across Europe, upscaling is not reducible to replication. Rather, it necessitates iterative, context-sensitive adaptation that empowers educators while preserving core pedagogical principles (Hassler et al., 2018). Central to this endeavour is a design framework that harmonises structural fidelity with localised flexibility, enabling semi-scripted resources to serve as adaptable scaffolds rather than rigid prescriptions (Hassler et al., 2018).

Sustainability hinges on institutional anchoring - the strategic alignment of innovations with policy priorities, professional incentives, and systemic infrastructures (Garcés & O'Dowd, 2021). Formal mechanisms such as accredited certification pathways, career progression credits, and workload recognition are instrumental in securing institutional buy-in, transforming participation from discretionary engagement into a valorised component of professional practice (Garcés & O'Dowd, 2021). Concurrently, blended

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learning models must transcend transactional content delivery by embedding social scaffolding: peer mentoring, localised learning hubs, and transnational collaboration networks counteract the fragmentation inherent in purely digital formats, fostering resilient professional communities (Buhl et al., 2018; Hassler et al., 2018). Crucially, upscaling demands participatory evaluation frameworks that privilege formative feedback loops, enabling stakeholders to iteratively refine implementation in response to emerging contextual challenges (Buhl et al., 2018).

Equity constitutes a foundational pillar of effective upscaling, ensuring that efforts to expand programme reach do not inadvertently reproduce or exacerbate existing disparities. Infrastructure disparities, linguistic barriers, and risks of technological exclusion necessitate proactive countermeasures to democratise participation (Hasler & Mays, 2015). Within this framework, upscaling emerges not merely as a growth strategy but as a transformative praxis, embedding inclusive, context-responsive innovation into the institutional fabric of education systems. The SpicE project exemplifies this approach, integrating a MOOC with blended learning and community-driven professional development. Yet its long-term efficacy depends on sustained design innovation, policy responsiveness, and the cultivation of self-sustaining pedagogical networks - conditions that ensure scalable solutions remain equitable, adaptive, and pedagogically robust.

The strategic priorities for upscaling outlined above - balanced design, institutional anchoring, blended learning with social scaffolding, and equity-driven technology - are not merely theoretical propositions. Their efficacy must be empirically interrogated through the experiences of educators engaging with the SpicE project. The mixed-methods analysis that follows evaluates how these upscaling principles manifest in practice, examining both the quantitative patterns of participant engagement and the qualitative nuances of adaptation challenges. By correlating questionnaire responses with the programme's design features and contextual variables (e.g., national infrastructure, participant roles), this analysis identifies critical enablers and barriers to sustainable scaling. For instance, variations in endorsement rates for semi-scripted materials across countries may illuminate tensions between fidelity and flexibility, while thematic insights from open-ended responses could reveal how institutional incentives or peer networks shape long-term adoption (Buhl et al., 2018; Garcés & O'Dowd,

2021). In this way, the data serves not only to assess immediate outcomes but to refine the iterative, context-sensitive upscaling model that SpicE advocates.

Method

Demographic data of participants

A total of 931 participants completed the post-training evaluation surveys for the SpicE programme. Of these, 826 were involved in the MOOC and 105 in the blended learning format. Participants came from four main country groups - Greece, Cyprus, Spain, and Bulgaria - as well as a fifth group designated as “Other countries”, which included Turkey, Romania, the Dominican Republic, Croatia, the Netherlands, and others. In the MOOC cohort, the majority of participants identified as female (79%), while 20% identified as male. A small proportion (1%) chose not to disclose their gender. In the blended learning group, the gender distribution was similar, with 80% of participants identifying as female and 20% as male. No participants opted not to disclose their gender in this group. Overall, female participants represented the vast majority in both delivery formats, 79% in the MOOC and 80% in the blended learning cohort. This pattern is consistent with gender trends observed in the teaching profession, particularly within early childhood and primary education sectors.

In terms of professional affiliation, the sample included a mix of pre-service teachers, in-service educators, and other professionals such as school psychologists, educational consultants, and postgraduate researchers. In the MOOC cohort, 15% of participants identified as pre-service teachers, 78% as in-service educators, and 8% as belonging to other professional roles. In the blended learning group, 9% of participants were pre-service teachers and 91% were in-service educators. This distribution highlights a strong representation of experienced practitioners across both formats, while also capturing the perspectives of those in earlier stages of their professional development. Such variation allows for comparative insights into how teaching experience may influence perceptions of course relevance, adaptability, and scalability.

The SpicE training was delivered through two complementary formats aimed at promoting inclusive STEAM education across Europe. The MOOC was designed as a fully asynchronous experience, comprising modular units on inclusive pedagogy, STEAM principles, inclusive STEAM practices, and reflection. Each module included

video content, interactive quizzes, case studies, and opportunities for reflection. The blended learning format followed a hybrid model. It combined access to asynchronous course materials similar to those in the MOOC with live online sessions, peer collaboration activities, and tutor-guided discussions. This version placed additional emphasis on community building and localised adaptation of course content, allowing participants to share classroom experiences and co-develop inclusive teaching strategies. Both formats were aligned with a shared pedagogical vision but varied in structure to accommodate different implementation contexts and levels of professional support.

Timing of evaluation instruments

Evaluation instruments were administered at the conclusion of each training modality. Participants in the MOOC completed the post-training questionnaire upon completing the final module, which served as both a reflective and evaluative step in the course sequence. For the blended learning group, the post-survey was distributed following the final synchronous session and before the official closing of the course. This ensured that participant feedback was gathered while the training experience was still recent and could be accurately recalled. The timing enabled the collection of data on the full range of participant experiences, including engagement with content, instructional support, and perceived applicability in their professional settings.

Data collection instruments

The post-surveys used in the MOOC and blended learning components were tailored to their respective delivery modes but shared several structural similarities. The MOOC questionnaire was composed mainly of closed-ended items, including dichotomous (Yes/No) questions and 5-point Likert scale statements. These items were designed to assess participants' perceptions of course relevance, alignment with national educational policies, adaptability across contexts, and priorities for upscaling. The blended learning questionnaire included both closed-ended and open-ended items. The quantitative items mirrored those in the MOOC survey to enable comparison, while the open-ended questions provided opportunities for participants to elaborate on contextual factors, implementation barriers, and policy recommendations.

Data analysis methods

A mixed-methods analytical approach was applied to the post-survey data. Quantitative responses from both the MOOC and blended learning post-questionnaires were analysed using SPSS. To examine relationships between participants' country of origin, professional status, and their perceptions of the course's alignment, relevance, and adaptability, non-parametric Kruskal–Wallis H tests and Mann–Whitney U tests were employed due to the ordinal nature of the Likert-scale data and unequal group sizes. For dichotomous (Yes/No) questions related to upscaling priorities, chi-square tests of independence were conducted to identify significant differences between countries. Descriptive statistics, including frequencies and percentages, were calculated to summarise responses related to upscaling priorities and perceived course strengths.

For the blended learning data, open-ended responses were analysed qualitatively using thematic analysis. A coding process was followed, beginning with open coding to identify initial categories grounded in participant language. These categories were then grouped into overarching themes reflecting structural, pedagogical, and policy-level considerations. This qualitative layer added depth to the quantitative findings by revealing nuanced insights into how participants experienced the training and what they believed was required for its sustainable scaling across national contexts.

Results

MOOC

Likert-scale questions of pre-questionnaire

Alignment of MOOC Content with National Educational Policies

To assess the perceived alignment between the MOOC content and participants' national educational policies and practices, a cross-tabulation was conducted. Participants (*n*=826) from various countries responded to the statement: *"The MOOC content aligns with the current educational policies and practices in my country".* Table 6Table 1 presents the frequency and percentage distribution of responses by country. Given the ordinal nature of the response variable, a Kruskal-Wallis test was conducted to assess whether there were statistically significant differences in perceived adaptability between countries. The Kruskal-Wallis test was appropriate, as it

compares the median ranks across more than two independent groups (i.e., countries). Post-hoc comparisons were conducted using Mann-Whitney U tests.

Table 6 Crosstabulation of perceived alignment of MOOC content with educational policies by country (n=826)

Alignment Level	Greece	Cyprus	Spain	Bulgaria	Other Countries
Not at all	3 (1%)	1 (4%)	1 (1%)	0 (0%)	0 (0%)
Slightly	22 (6%)	1 (4%)	5 (6%)	3 (4%)	1 (0%)
Moderately	73 (21%)	7 (29%)	12 (13%)	8 (10%)	28 (10%)
Very much	112 (32%)	11 (46%)	25 (28%)	17 (22%)	70 (25%)
Completely	139 (40%)	4 (17%)	47 (52%)	49 (64%)	187 (65%)

To assess differences in perceived alignment of the MOOC content with national educational policies across countries, a Kruskal-Wallis H test was conducted. The results revealed a statistically significant difference between groups, $H(4) = 65.335$, $p<.001$. Post-hoc pairwise comparisons using the Mann-Whitney U test with Bonferroni-adjusted significance ($p<.005$) indicated that participants from Greece perceived significantly lower alignment than those from Bulgaria and Other Countries. Similarly, participants from Cyprus reported significantly lower alignment than those from Spain, Bulgaria, and Other Countries. No significant differences were observed between Spain and Bulgaria or Bulgaria and Other Countries. These findings suggest meaningful cross-national variation in how the MOOC was perceived in terms of alignment with national policy.

Overall, most participants rated the alignment as “Very much” or “Completely”, yet important differences emerged: Greece had a comparatively lower proportion selecting “Completely” (40%), while Cyprus reported the lowest (17%), showing a stronger preference for “Moderately” or “Very much”. In contrast, participants from Other Countries, including Turkey, Romania, Dominican Republic, Croatia, and the Netherlands, reported the highest agreement, with 65% selecting “Completely”.

These results reinforce the influence of national context on the reception and evaluation of educational initiatives such as MOOCs. Differences in alignment perceptions may reflect varying degrees of compatibility with national digital education strategies, pedagogical traditions, and policy priorities surrounding STEAM and inclusive education. Consequently, while the MOOC demonstrates adaptability across diverse settings, the findings highlight the importance of tailoring cross-national online programmes to account for local educational structures and practices.

Alignment of the MOOC with National Educational Challenges

To evaluate participants' perceptions of the extent to which the MOOC addressed challenges specific to their national educational systems and policies, a cross-tabulation was conducted based on country of origin. Table 7 presents the distribution of responses across five levels of agreement with the statement: *"The MOOC addresses **challenges** specific to my country's educational system and policies".* As with the previous analysis, the Kruskal-Wallis test was used to assess overall differences between countries, followed by Mann-Whitney U tests for post-hoc comparisons.

Table 7 perceived alignment of the MOOC with national educational challenges (n=826)

Degree of Agreement	Greece	Cyprus	Spain	Bulgaria	Other Countries
Not at all	0 (0%)	1 (4%)	1 (1%)	1 (1%)	2 (1%)
Slightly	18 (5%)	2 (8%)	4 (4%)	2 (3%)	0 (0%)
Moderately	63 (18%)	4 (17%)	14 (16%)	6 (8%)	29 (10%)
Very much	133 (38%)	13 (54%)	25 (28%)	18 (23%)	68 (24%)
Completely	135 (39%)	4 (17%)	46 (51%)	50 (65%)	187 (65%)

A Kruskal-Wallis H test revealed significant differences among countries in perceptions of the MOOC's relevance to national educational challenges, $H(4) = 61.38$, $p < .001$. Post-hoc Mann-Whitney U tests indicated that participants from Bulgaria and the Other

regions rated the MOOC significantly higher than those from Greece (both $p<.001$). Respondents from Cyprus reported the lowest levels of perceived relevance, with significantly lower scores compared to Spain ($p=.010$), Bulgaria ($p<.001$), and Other Countires ($p<.001$).

While 78% of respondents from Greece (38% “Very much” and 39% “Completely”) and 88% from Bulgaria (23% “Very much” and 65% “Completely”) endorsed strong relevance, Cypriot participants showed more moderate agreement, with 71% reporting “Moderately” or lower (54% “Very much” and 17% “Completely”). Similarly, 79% of Spanish respondents marked “Moderately” or higher, with a notable 51% indicating “Completely.” The "Other" category showed strong endorsement, with 89% perceiving the MOOC as relevant (24% “Very much” and 65% “Completely”).

These disparities suggest that while the MOOC was seen as highly relevant in some contexts (e.g., Bulgaria and broader international settings), it was perceived as less relevant in others (e.g., Cyprus and Spain).

These findings underscore the MOOC’s uneven responsiveness to diverse national systems. To enhance cross-border efficacy, future iterations should integrate region-specific examples, case studies, and adaptable frameworks that better reflect Europe’s heterogeneous educational landscapes.

Addressing Country-Specific Educational Opportunities

To evaluate the extent to which the MOOC addressed opportunities specific to participants’ national educational systems and policies, a cross-tabulation was conducted. Participants ($n=826$) were asked to indicate their level of agreement with the statement: *“The MOOC addresses **opportunities** specific to my country’s educational system and policies”.*

Table 8 Crosstabulation of perceived addressing of country-specific educational opportunities by country (n=826)

Alignment Level	Greece	Cyprus	Spain	Bulgaria	Other Countries
Not at all	1 (0%)	1 (4%)	1 (1%)	1 (1%)	1 (0%)

Alignment Level	Greece	Cyprus	Spain	Bulgaria	Other Countries
Slightly	19 (5%)	0 (0%)	5 (6%)	3 (4%)	0 (0%)
Moderately	77 (22%)	8 (33%)	11 (12%)	8 (10%)	27 (9%)
Very much	126 (36%)	10 (42%)	27 (30%)	20 (26%)	70 (25%)
Completely	126 (36%)	5 (21%)	46 (51%)	45 (58%)	188 (66%)

A Kruskal-Wallis test revealed a statistically significant difference in how participants perceived the MOOC's alignment with opportunities specific to their country's educational system and policies, $H(4) = 71.96$, $p < .001$. Overall, 80% of respondents rated the MOOC as strongly relevant ("Very much" or "Completely"), but there was significant cross-national variation. Greece and the Other category showed high agreement, with 72% and 90% of respondents, respectively, perceiving strong relevance. In contrast, Cyprus reported lower endorsement, with only 20% of respondents marking it as "Completely", and a substantial portion (33%) rating it "Moderately" or lower. Post-hoc tests revealed significant differences between Greece and other countries, especially Bulgaria ($p < .001$) and Spain ($p = .015$), with Bulgaria showing stronger agreement (84%) and Spain 78%.

These findings suggest that while the MOOC's generic frameworks generally resonated with participants, its relevance varied greatly across countries. This underlines the need for adaptable design to better address country-specific educational opportunities and challenges.

Perceived Adaptability and Transferability of the MOOC Content

A cross-tabulation was conducted to explore participants' perceptions of the adaptability and transferability of the MOOC content across different regional and national contexts. Participants responded to the question: *"To what extent do you believe the content presented in the MOOC (the ideas, information, and lessons) can be easily adapted, expanded, or replicated to suit the needs of a broader audience across different regions and countries?"*. Table 9 presents the frequency of responses

across participating countries. To examine differences in perceived alignment across countries, a Kruskal-Wallis H test was conducted, followed by Mann-Whitney U tests for post-hoc comparisons.

Table 9 Crosstabulation of perceived adaptability and transferability of MOOC content by country (n=826)

Adaptability Level	Greece	Cyprus	Spain	Bulgaria	Other Countries
Not at all	4 (1%)	0 (0%)	1 (1%)	0 (0%)	0 (0%)
Slightly	14 (4%)	2 (8%)	2 (2%)	0 (0%)	1 (0%)
Moderately	63 (18%)	4 (17%)	13 (14%)	6 (8%)	22 (8%)
Very much	128 (37%)	13 (54%)	28 (31%)	24 (31%)	72 (25%)
Completely	140 (40%)	5 (21%)	46 (51%)	47 (61%)	191 (67%)

A Kruskal-Wallis test was conducted to assess whether there was a statistically significant difference in participants' perceptions of the adaptability and transferability of the MOOC content across different countries. The results indicated a significant difference between the countries ($H(4)=63.879$, $p<.001$). This suggests that participants from different countries had varying perceptions of the adaptability of the MOOC content.

Post-hoc pairwise comparisons using the Mann-Whitney U test revealed several notable differences between specific countries. For instance, Greek participants demonstrated a significantly higher percentage of favourable responses compared to Cyprus, Spain, Bulgaria, and other countries. Specifically, Greece showed a 76% favourable response rate, significantly higher than Cyprus's 64%, Spain's 62%, and Bulgaria's 58%. This indicates that Greek participants rated the MOOC content as more adaptable compared to participants from the other national groups. Similarly, Cyprus showed a significantly lower percentage of favourable responses (64%) compared to Bulgaria (58%), highlighting a difference in perceptions between these two countries. Additionally, there were significant differences between Spain and

Bulgaria, with Bulgaria exhibiting a higher favourable response rate of 58% compared to Spain's 52%.

These findings highlight the impact of contextual factors, such as national educational infrastructure, digital readiness, and cultural differences, on participants' perceptions of the adaptability and transferability of MOOC content. As such, the results suggest that MOOCs may need to be tailored to better suit the specific needs and preferences of participants from different countries, ensuring they are adaptable to various regional and national contexts.

Perceived Priorities for MOOC Upscaling by Country

To explore regional differences in upscaling priorities, 826 participants from Greece, Cyprus, Spain, Bulgaria, and other regions were asked to indicate (Yes/No) which of five measures they considered necessary: (1) expanding accessibility, (2) providing post-course support, (3) forming institutional partnerships, (4) developing localised content, and (5) incorporating participant feedback.

Table 10 Percentage of respondents endorsing each upscaling measure, by country (Yes responses only; n=826)

Upscaling Measure	Greece (*n*=349)	Cyprus (*n*=24)	Spain (*n*=90)	Bulgaria (*n*=77)	Other (*n*=286)	Total
Expanding the accessibility of the online course	50%	50%	66%	61%	62%	57%
Providing follow-up support after completion	55%	46%	50%	65%	61%	57%
Creating institutional partnerships	70%	79%	77%	78%	76%	74%
Developing localised content	47%	54%	51%	52%	53%	50%
Incorporating participant feedback	44%	63%	40%	34%	44%	43%

Institutional partnerships received the strongest support across all regions (74%). Expanding the accessibility of the online course showed statistically significant

variation by country ($\chi^2(4, n=826) = 13.84$, $p=.008$), with Spain, Bulgaria, and Other regions rating it higher than Greece and Cyprus. Post-course support (57%) and localised content (50%) saw moderate endorsement. Incorporating feedback was the least prioritised (43%), though country-level differences were notable but not statistically significant.

Overall, while institutional partnerships were a common priority across countries, strategies like accessibility and post-course support may require regional adaptation to reflect the varying needs and priorities of participants in different countries.

Perceptions of Necessary Steps to Upscale the MOOC by Teacher Status

Participants' views on MOOC upscaling were examined across three groups: pre-service teachers, in-service teachers, and others (e.g., school psychologists, PhD students). As shown in Table 11, levels of support for each proposed measure were broadly similar across groups. Institutional partnerships received the highest endorsement overall (74%), followed by expanding accessibility (56%) and providing post-course support (57%). Developing localised content (50%) and incorporating participant feedback (43%) were less frequently endorsed. No statistically significant differences were found between groups for any strategy (all p-values > .05), indicating that teacher status did not meaningfully influence perceived priorities for upscaling the MOOC.

Table 11 Perceived importance of MOOC upscaling measures by teacher status (Yes responses only; n=826)

Strategy	Pre-Service (*n*=120)	In-Service (*n*=644)	Other (*n*=62)	Total
Expanding the accessibility of the online course	61%	56%	58%	56%
Providing follow-up support after completion	55%	58%	53%	57%
Creating institutional partnerships	76%	73%	76%	74%

Strategy	Pre-Service (*n*=120)	In-Service (*n*=644)	Other (*n*=62)	Total
Developing localised content	54%	49%	55%	50%
Incorporating participant feedback	48%	43%	42%	43%

Blended learning results

Participant-driven priorities for enhancing and scaling blended learning

A descriptive frequency analysis was conducted in SPSS to evaluate responses from 105 participants to two binary (yes/no) survey questions. The first question identified aspects of the blended learning course requiring greater emphasis for international adoption (Table 12); the second assessed perceived necessities for upscaling (Table 13). Responses were coded dichotomously (1=yes, 0=no), and percentage distributions were calculated to determine endorsement rates for each item.

Table 12 Priorities for international adoption of blended learning (n=105)

Aspect	Yes (%)	No (%)
Practical examples/resources	82	18
Live online workshops/lectures	51	49
Separate courses for pre-/in-service	51	49
Accreditation via certificates	39	61
Self-paced content	41	59
Continued peer collaboration	45	55

The analysis of participants' priorities for improving and scaling the blended learning course (*n*=105) revealed distinct preferences. Practical, example-based activities and resources emerged as the most critical aspect to emphasise for international adoption, with 82% of respondents endorsing this focus. This underscores a strong demand for applied, contextually relevant content that bridges theory and practice. Live online workshops and separate course pathways for pre-service and in-service teachers received moderate support (51% each), suggesting a dual emphasis on interactive engagement and role-specific tailoring.

In contrast, accreditation through certificates (39%) and self-paced content (41%) were less prioritised, challenging assumptions that credentialing or flexibility alone drive adoption. Similarly, continued peer collaboration options (45%) received limited endorsement, potentially reflecting challenges in sustaining informal peer networks post-course.

Table 13 Strategies for scaling the blended learning course (n=105)

Strategy	Yes (%)	No (%)
Institutional partnerships	74	26
Localised content development	59	41
Post-course support/resources	58	42
Standalone course delivery	44	56
Peer feedback sessions	31	69

Regarding upscaling strategies, institutional partnerships were overwhelmingly endorsed (74%), highlighting the perceived necessity of anchoring the course within formal educational systems. Localised content development (59%) and follow-up support (58%) also ranked highly, reinforcing the need for contextual adaptation and sustained engagement. Conversely, peer feedback sessions (31%) and standalone course delivery (44%) were less favoured, indicating hesitancy toward collaborative evaluation and a preference for integrating the course with existing structures like

MOOCs. These findings collectively prioritise practical utility and structural integration over formal accreditation or peer-driven models. The results advocate for a design framework that balances interactive, applied learning with institutional partnerships and regional customisation to enhance scalability.

Policy priorities for Inclusive STEAM Education: A qualitative analysis

Inclusive STEAM education has become a key objective in educational policy reform globally. As part of the blended SpicE training programme, a post-survey was conducted to gather participants' views on the most critical national policy changes needed to support inclusive STEAM approaches. Participants (*n*=89) were asked to identify what they believed to be the three most important policy reforms.

An open coding analysis was conducted on the qualitative responses using an inductive thematic approach. Each individual statement was coded and grouped into emerging themes based on conceptual similarity and frequency. Six key categories were identified: (1) Teacher Training, Certification & Mentorship, (2) Curriculum Design & Development (Inclusive, Flexible), (3) Equitable Access to Digital Tools, Infrastructure & School Resources, (4) Collaboration & Policy-Backed Support, (5) Interculturality & Culturally Responsive Pedagogy, and (6) Time Management & Administrative Burdens. The following table presents the frequency and percentage distribution of statements across these categories, followed by a discussion interpreting these findings in relation to existing literature and policy challenges (Table 14).

Table 14 Frequency and percentage of responses by category (n=89)

Theme/Category	Frequency (Number of Statements)	Percentage	Representative Ideas and Quotes
Teacher Training, Certification & Mentorship	43	24%	"Ongoing professional development", "Mentoring programmes", "Specialised STEAM training"

Theme/Category	Frequency (Number of Statements)	Percentage	Representative Ideas and Quotes
Inclusive Curriculum Design	41	23%	"UDL principles", "Curriculum reform for inclusion"
Equitable Access to Resources	40	22%	"Assistive technologies", "STEAM labs", "Digital resource libraries"
Collaboration with Stakeholders	21	12%	"Partnerships with universities/industry", "STEM ambassador programmes"
Culturally Responsive Pedagogy	17	10%	"Culturally inclusive content", "Diverse role models"
Time Management & Administrative Burdens	16	9%	"Lack of planning time", "Overworked teachers"

Participants identified clear priorities for advancing inclusive STEAM education through national policy reform. The most prominent theme (24%) was *Teacher Training, Certification & Mentorship*, reflecting the belief that educators are the linchpins of inclusive practice. Respondents emphasised the need for continuous professional development in inclusive pedagogies, with particular attention to mentorship and professional networks to support sustained growth. This underscores the necessity of embedding inclusive education into teacher preparation and in-service training.

The second most cited category (23%) was *Inclusive and Flexible Curriculum Design*. Participants called for the adoption of Universal Design for Learning (UDL) principles and reforms enabling curricula to accommodate diverse learning pathways. The emphasis was on flexible, cross-disciplinary STEAM content that supports differentiated instruction and engages a broader spectrum of learners.

Closely following, at 22%, was *Equitable Access to Digital Tools, Infrastructure, and School Resources*. Respondents stressed the disparities in access to technological and material resources, especially in under-resourced schools. National policies were seen as needing to invest in digital inclusion, assistive technologies, and fully equipped STEAM environments to enable genuine participation for all students.

While less frequent, *Collaboration with Stakeholders* (12%) remained significant. Participants advocated for stronger partnerships between schools, universities, industries, and community organisations. They also called for leadership structures and policy frameworks that facilitate teacher collaboration and integrated support services.

Interculturality and Culturally Responsive Pedagogy (10%) focused on representing diverse identities and experiences within teaching and learning. Participants called for culturally inclusive content, diverse role models, and pedagogical practices that validate learners' backgrounds—highlighting a broader conception of inclusion that extends beyond disability to encompass cultural relevance.

Finally, *Time Management and Administrative Burdens* (9%) captured the structural constraints teachers face. Comments pointed to large class sizes, excessive paperwork, and insufficient time for inclusive planning and collaboration. These barriers underline the need for policies that acknowledge the real-world conditions of teaching and provide adequate support.

Taken together, these findings suggest that fostering Inclusive STEAM education requires systemic reform that addresses human, material, cultural, and structural dimensions. Policy efforts must extend beyond isolated initiatives and instead adopt a multi-layered strategy that empowers educators, ensures equitable resource distribution, promotes cultural responsiveness, and mitigates institutional constraints. Participants' insights reflect an understanding of inclusion as a comprehensive, cultural shift within education systems, one that must be fully supported through coherent and realistic policy frameworks.

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Discussion

The findings of this study provide a nuanced understanding of the complexities involved in upscaling transnational educational innovations, using the SpicE training programme as a case study. While the programme was broadly well-received, its perceived effectiveness and relevance varied significantly across national contexts. These variations were most evident in how participants assessed the alignment of the MOOC with their national educational policies, its capacity to address local challenges and opportunities, and the adaptability of its content. Greece consistently reported higher levels of agreement, while Cyprus and Spain showed more moderate responses. These discrepancies suggest that educational policy environments, digital infrastructure, and cultural expectations significantly shape the reception of online learning initiatives. This pattern reinforces the idea that successful upscaling requires more than replication of content. It must also involve adaptation to specific national and institutional contexts. The findings support existing literature that advocates for scalable educational design to be both pedagogically coherent and contextually flexible (Garcés & O'Dowd, 2021; Hassler et al., 2018).

A key point of distinction emerged between the national context and the professional role. While the country of residence had a statistically significant impact on participants' perceptions, professional status - whether pre-service, in-service, or other - did not. This suggests that while local systems and structures influence how MOOCs are received, teachers at different career stages share similar views on what is needed to upscale such initiatives. Institutional partnerships, post-course support, and localised content were widely endorsed across all groups. The strong support for institutional partnerships (74%) indicates a shared understanding of the importance of embedding digital learning into formal education systems, where recognition and sustainability are more likely. The blended learning component further supported these conclusions. Participants showed a clear preference for practical, example-based activities, with 82% indicating that these should be a priority in future iterations. This finding reflects a demand for applied learning resources that are easily transferable to classroom practice. In contrast, formal accreditation and peer feedback mechanisms received lower levels of support, possibly due to structural limitations or a lack of institutional culture around collaborative evaluation.

The qualitative data on policy priorities also revealed key areas of concern. Participants identified teacher training and mentorship, inclusive and flexible curriculum design, and equitable access to digital resources as critical areas for reform. These priorities reflect a systemic view of inclusion, where success depends not only on pedagogical tools but also on material conditions and institutional support. Themes such as intercultural pedagogy and stakeholder collaboration, although less frequently cited, highlight the broader cultural and governance issues that influence educational equity. Participants also pointed to practical barriers such as administrative burden and time constraints, which can undermine even well-designed initiatives if left unaddressed. Together, these findings suggest that while the SpicE programme provides a strong foundation for digital teacher education training, its scalability depends on sustained, context-sensitive adaptation. The interplay between universal strategies and national differences must be carefully managed to ensure long-term relevance and effectiveness.

Conclusion

This study confirms the value of the SpicE training programme as a model for inclusive, scalable STEAM teacher education. The data reveal broad agreement on its relevance and adaptability, alongside clear evidence that national context plays a central role in shaping its reception. While the core design can be standardised across different teaching roles, national disparities in infrastructure, policy alignment, and digital readiness demand targeted strategies. The consistent endorsement of institutional partnerships across all groups reflects their importance in embedding innovations into existing systems. These partnerships help transition digitally delivered STEAM education from isolated experiments into established components of professional development. Similarly, the preference for practical resources over certification or peer feedback points to a widespread need for actionable, classroom-ready content.

Qualitative insights further reinforce the need for comprehensive policy reform related to the integration of digital and STEAM education into national curricula. Investment in teacher preparation, curriculum flexibility, equitable access to digital infrastructure, and culturally responsive pedagogy are essential for meaningful inclusion. Without attention to these systemic factors, even well-intentioned innovations risk being unevenly implemented or unsustainably scaled.

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In conclusion, the SpicE project demonstrates how STEAM education, when delivered through thoughtfully designed digital platforms, can be both inclusive and scalable, provided it is supported by institutional collaboration and responsive policy. Future initiatives should continue to prioritise adaptability and relevance, while embedding mechanisms for local engagement and ongoing evaluation. This approach offers a credible path towards achieving lasting and equitable change in teacher education across diverse educational systems.

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Evaluating a multi-phase professional development framework for Inclusive STEAM Education

Natalia Spyropoulou[1], Sofia Tsitou[1] , Achilles Kameas[1]

[1]*Hellenic Open University, Greece*

Introduction

Building upon the preceding chapters, which outlined the theoretical underpinnings of Inclusive STEAM Education and presented the development and structure of the SpicE professional development programme, this chapter shifts focus to the empirical evaluation of its implementation. The SpicE programme was conceptualised as a comprehensive, three-phase model of professional learning, designed to foster competences for inclusive and interdisciplinary education among both pre-service and in-service educators (Pavlou et al., 2023). Following the establishment of its pedagogical foundations and course design principles (Sakellaropoulou et al. 2023a, 2023b; Agaliotis & Kartasidou, 2023b), this chapter explores how each training component, the Massive Open Online Course (MOOC), the Blended Learning Course, and the Exchange Mobilities, was experienced by participants and what impacts were observed. Drawing upon extensive quantitative and qualitative data, it presents key findings on participant engagement, learning outcomes, and perceived impact, and concludes with evidence-informed recommendations for future professional development initiatives in the field of Inclusive STEAM Education.

Methodology

The evaluation of the SpicE training programme employed a mixed-methods research design, combining quantitative and qualitative approaches to provide a comprehensive understanding of participant experiences, learning outcomes, and programme

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effectiveness. A series of structured pre- and post-course online surveys were developed for each of the three phases, MOOC, Blended Learning Course, and Exchange Mobilities, based on validated models of educational programme evaluation and adapted to the specific content and pedagogical goals of each training component.

Quantitative data collection included closed-ended questions using 5-point Likert scales to assess participants' prior knowledge, confidence, expectations, satisfaction, and perceived impact. Qualitative data were gathered through open-ended survey items, allowing participants to provide in-depth feedback on their motivations, challenges, perceived benefits, and suggestions for improvement. Participation data were monitored throughout the course delivery via the Learning Management System (LMS), providing insights into engagement levels, dropout rates, and completion statistics.

Evaluation of the SpicE MOOC

The MOOC was designed to offer a scalable, accessible, and self-paced learning experience focused on the foundational knowledge and pedagogies of Inclusive STEAM Education. It comprised modules delivered over five weeks, integrating video lectures, readings, self-assessment quizzes, interactive activities, and discussion forums.

A total of 1,421 participants enrolled in and engaged with the MOOC, representing 57 countries. Of these, 826 successfully completed the course and received a certificate of participation. This strong completion rate reflects both a high level of initial interest and sustained engagement throughout the learning journey.

The demographic profile of respondents reveals a predominantly female cohort, with over 80% identifying as women. Approximately 60% of participants were between the ages of 35 and 54, suggesting that the MOOC attracted mid-career professionals. The majority of learners resided in Greece, Turkey, and Spain, reflecting the outreach and relevance of the course within the project's key regions. Academically, nearly 60% of participants held qualifications beyond the Bachelor’s level, indicating a well-educated audience. In terms of professional status, around 79% were in-service educators with prior teaching experience. Despite this, many reported limited prior exposure to inclusive education or special needs pedagogy, underscoring the importance and

timeliness of the MOOC content. Figure 12 provides a visual overview of key participant demographics.

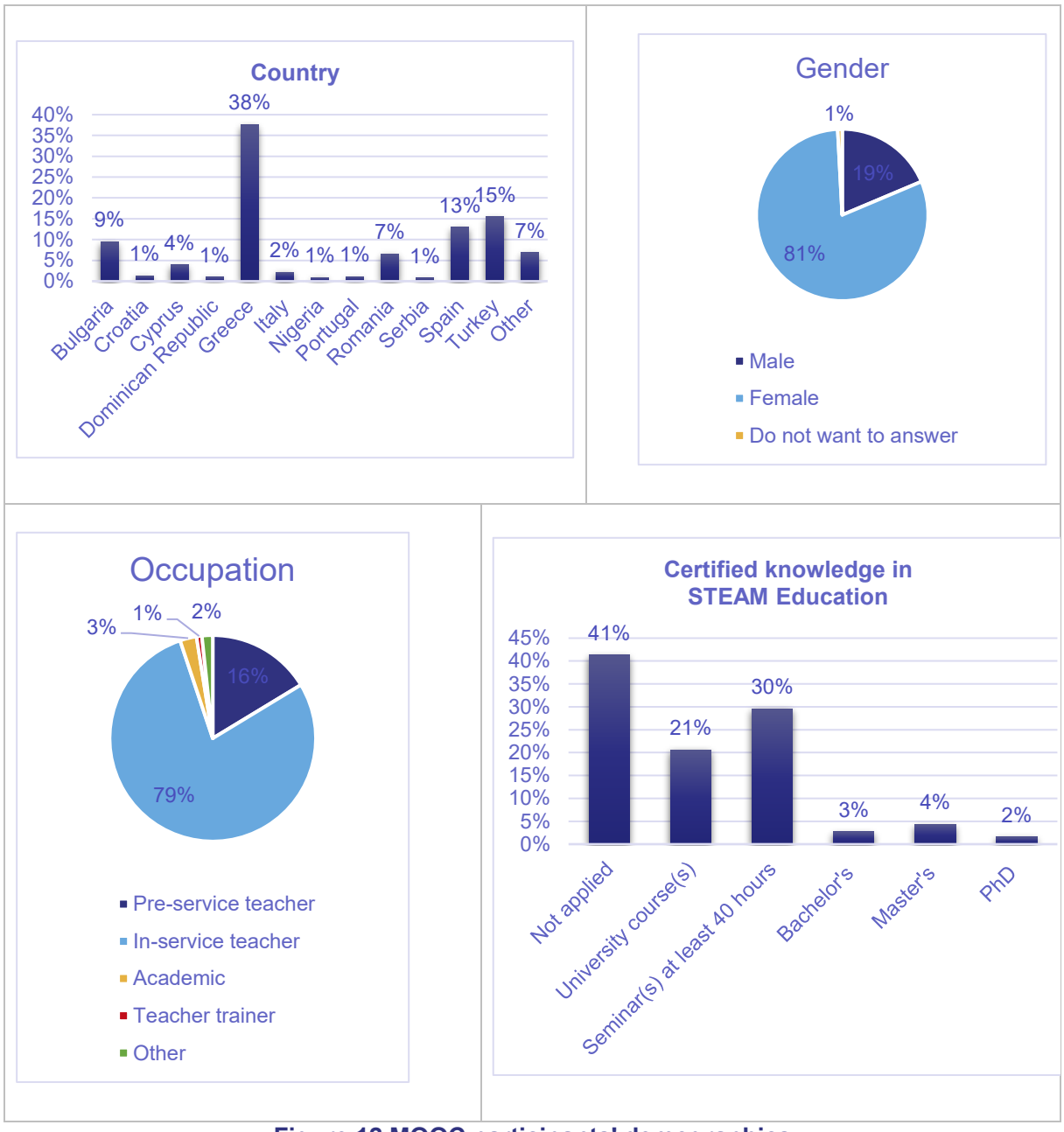

Figure 12 MOOC participants' demographics

Pre-course survey data revealed that participants' primary expectations from the MOOC were to gain new knowledge and skills and to access educational resources related to Inclusive STEAM Education. While certification and competitive advantage were less important to them initially, respondents placed high importance on applying the knowledge to their professional context, enhancing their current work, and fostering positive change in their institutions. These insights suggested that participants

approached the MOOC not merely as a credentialing opportunity, but as a vehicle for meaningful professional development.

Post-course responses were collected from participants who successfully completed the MOOC and received certification. These responses indicate that the course largely met participants' initial expectations. Between 85% and 90% of respondents reported that they had acquired valuable knowledge and skills, accessed high-quality educational resources, and benefited from the certification. Moreover, interactions with experts and opportunities for peer collaboration were also positively evaluated, with 77% and 73% of participants, respectively, highlighting these as key benefits.

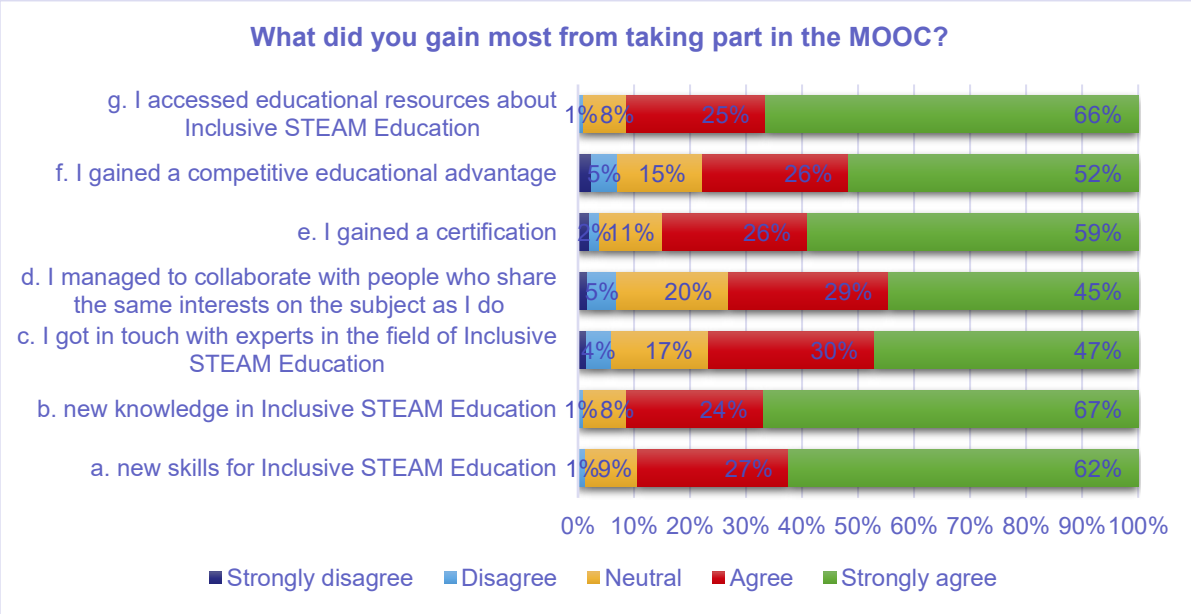

Figure 13 Benefits of the MOOC according to the post-MOOC survey

Although competitive advantage was not a primary motivation at the outset, approximately 78% of participants ultimately perceived the MOOC as enhancing their professional standing. Notably, 84% of respondents expressed confidence in their ability to apply the knowledge gained to their current professional roles. In addition, between 60% and 70% anticipated that the course would empower them to drive changes within their institutions and potentially influence regional or national educational policies.

Qualitative feedback further substantiated these findings. Many respondents expressed appreciation for the clarity, structure, and practical relevance of the course content. The thematic analysis of open-ended comments highlighted several recurring

themes: increased awareness of inclusive education principles, better understanding of how to integrate STEAM disciplines in an inclusive setting, and appreciation for the opportunity to collaborate and exchange with peers. Participants also noted that the MOOC helped reduce their sense of professional isolation and fostered a sense of belonging to a broader educational community.

Participants expressed strong satisfaction with the learning experience overall. Approximately 93% agreed or strongly agreed that the MOOC was well-designed; 89% positively rated the learning process; and 86% acknowledged the course's usefulness for their professional development. Preferred course features included quizzes (92%), interactive resources (91%), and self-reflection assignments (89%). Additionally, 80–83% of participants appreciated tutor support and peer interactions through the forums.

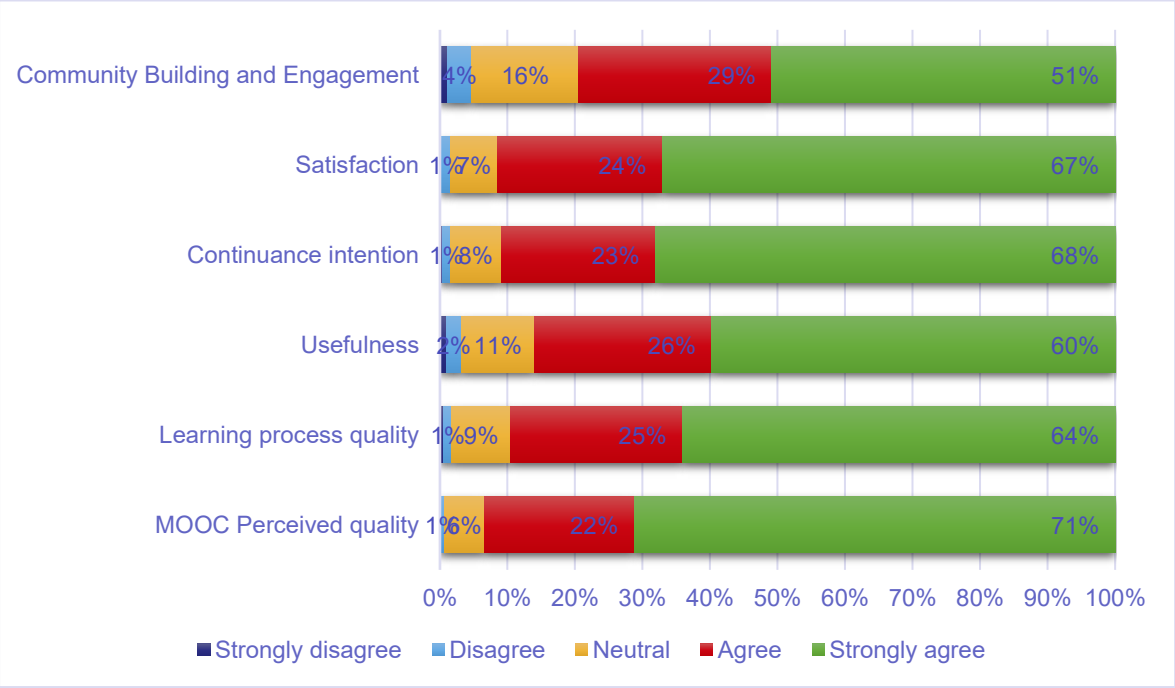

Figure 14 Evaluation of MOOC learning experience by the trainees

However, several challenges were noted, particularly around time management due to the intensive weekly workload, especially for in-service teachers. Some participants faced difficulties with the language of instruction, requesting more translations or native-language support. Technical issues and navigation challenges were also mentioned. Suggestions for improvement included increasing the interactivity of the course through live sessions, group activities, and case-based learning, and providing more practical, real-world examples of inclusive STEAM education. Many also called

for opportunities for community building through peer feedback, networking spaces, or follow-up webinars.

Overall, the high completion rate, positive evaluations, and strong learning impact suggest that the SpicE MOOC successfully met its pedagogical aims and offered a valuable model for large-scale professional development in Inclusive STEAM Education.

Evaluation of the SpicE blended training

The SpicE blended learning traiing on Inclusive STEAM Education was developed as a follow-up learning experience for participants who had successfully completed the MOOC and expressed interest in continuing their professional development. The course was structured into two parallel learning pathways, one for pre-service and one for in-service educators, each tailored to their specific needs and teaching contexts, while maintaining some interconnections.

At the start of the blended course, a voluntary questionnaire was distributed to participants. This initial survey received responses from 21 individuals in the pre-service group and 163 from the in-service group. A second voluntary questionnaire was administered at the end of the official course period, with 9 participants responding from the pre-service group and 98 from the in-service group.

Pre-service participants were predominantly female, aged 18–24, and came from the four countries involved in the SpicE project (Greece, Cyprus, Spain, and Bulgaria). Most were preparing for careers in special or primary education. In-service participants were mainly female, aged 35–54, and represented a wide range of teaching backgrounds and levels of experience.

Before the course, only 14% of pre-service participants reported prior practical experience with STEAM projects and most expressed low confidence in applying Inclusive STEAM approaches. In contrast, 77% of in-service participants had some experience in the field and reported moderate confidence levels. Both groups expressed strong motivation to deepen their knowledge, access inclusive education resources, and engage in peer and expert collaboration. Certification and enhanced employability were particularly important for pre-service participants, while in-service

educators aimed to improve practice and contribute to school-level or organisational change.

The course format combined synchronous sessions (live online meetings) and asynchronous activities carried out through a dedicated Virtual Learning Environment (VLE). This blended structure was highly appreciated for its balance between guided interaction and flexible, self-paced learning. Participants valued the clarity of the structure, the quality of materials, and the opportunities to collaborate and exchange ideas.

The evaluation revealed high levels of satisfaction: 100% of pre-service and 94% of in-service participants reported being satisfied or very satisfied with the course. Most felt that their expectations were fully or mostly met and that the content was well aligned with their professional goals. Participants reported acquiring new knowledge and skills, and many expressed increased confidence in applying inclusive STEAM methods. Several noted the course's potential to support changes in classroom practices and influence broader educational environments.

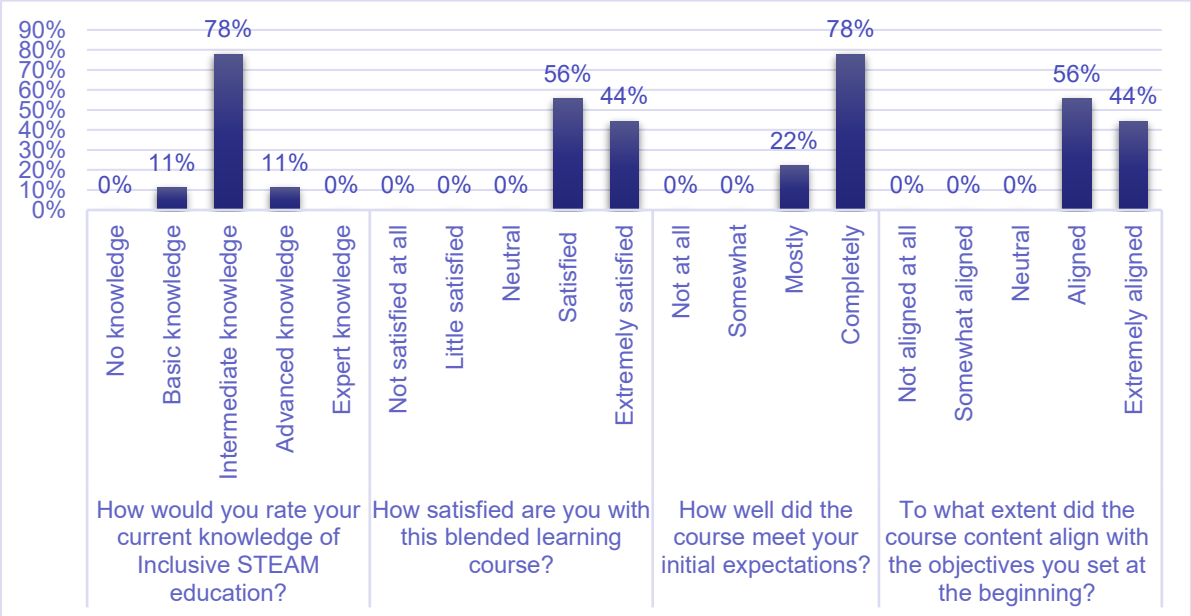

Figure 15 Level of satisfaction with the pre-service blended course

Despite these strengths, participants also identified several challenges. These included the limited duration of the course, a stronger focus on theory than practice, time constraints, particularly for in-service educators, and occasional issues with the scheduling and communication of course requirements. Some participants found certain digital tools complex and requested more step-by-step guidance.

Finally, interest in future participation was very strong: 100% of pre-service and 87% of in-service participants expressed a willingness to join similar training in the future, confirming the strong engagement and relevance of the blended course to Inclusive STEAM education.

Evaluation of the SpicE training mobilities

The third and final phase of the SpicE training pathway consisted of international exchange mobilities, where 48 selected participants traveled for two full weeks to participate in hands-on, practice-based activities. These mobilities provided a unique opportunity to apply the knowledge and competences gained during the previous MOOC and blended learning phases in real-world, collaborative environments. Two mobility programs were implemented, hosted in Alicante (Spain) and Nicosia (Cyprus), each combining structured training sessions, collaborative projects, and cultural exchange.

The vast majority of participants were in-service teachers (89%), with only 11% identifying as pre-service. Female educators represented the dominant group, 87% in Alicante and 85% in Nicosia. Most participants were aged between 35 and 54, with the largest age brackets being 35–44 years (38% in Alicante, 36% in Nicosia) and 45–54 years (30% and 32%, respectively). Participants came from the four participating countries of the SpicE project—Bulgaria, Cyprus, Greece, and Spain. Primary education was the most common teaching field (55% in Alicante, 53% in Nicosia), followed by special primary education and pre-school education.

Prior to the mobilities, participants rated various aspects of the upcoming experience. In both groups, over 80% considered the training content and opportunities for international collaboration as very important elements. The importance of facilities and logistical arrangements also received generally positive feedback. Cultural and social components of the mobilities were also recognized as valuable, with 64% of participants in both locations rating them as very important, acknowledging the role of informal exchange in supporting professional development.

Post-training evaluations reflected very positive experiences across both sites. A large majority rated the overall experience as excellent (82% in Alicante, 78% in Nicosia), and the training facilities also received favorable evaluations (82% and 58%, respectively). Sessions were considered highly effective in enhancing participants'

understanding and application of Inclusive STEAM Education, with 71% in Alicante and 68% in Nicosia rating this aspect as excellent.

Cultural and social activities were also appreciated (76% in Alicante, 65% in Nicosia), confirming the added value of intercultural exchange. Importantly, 93% of Alicante participants and 100% of Nicosia participants reported that the in-person nature of the mobilities significantly enhanced their ability to collaborate with peers from other countries, in comparison to the earlier virtual learning phases. All participants from both programs (100%) stated that they would recommend the mobility experience to others.

Based on the open-ended questions, the SpicE mobility experience was widely praised by participants as an inspiring, enriching, and transformative learning opportunity. Among the most frequently mentioned highlights were the opportunities to collaborate with educators from across Europe, exchange practices, and explore innovative approaches to inclusive STEAM education. Many valued the practical, hands-on nature of the activities, especially the egg drop challenge and STEAM labs with students, which brought theoretical knowledge to life. Participants highlighted the value of interdisciplinary teamwork, exposure to diverse educational systems, and the culturally immersive environment. The collaborative spirit, the warm hospitality of the hosts, and the chance to build professional networks and friendships were also cited as particularly memorable aspects. Sessions led by experts, especially those focusing on inclusion, universal design for learning, and practical classroom strategies, left a lasting impression.

Despite the overall positive evaluations, several challenges were also noted in this training phase. A common theme was the initial difficulty of working in diverse, international teams, particularly given differences in educational systems, language barriers, and unfamiliar group dynamics. Some participants felt that time constraints and the fast-paced schedule limited deeper reflection or more extensive engagement with some of the content. Others mentioned the challenge of expressing complex educational concepts in a second language or adapting to unfamiliar pedagogical approaches. Nevertheless, most participants saw these difficulties as opportunities for growth, with many reporting increased confidence, adaptability, and motivation to apply inclusive STEAM strategies in their own educational contexts. Some participants expressed the desire for more follow-up opportunities or platforms for continued collaboration beyond the mobility phase.

Conclusions

The SpicE professional development pathway for Inclusive STEAM Education was carefully structured into three complementary phases: MOOC, blended training, and international mobility, to provide a progressive and coherent learning journey for educators. This three-tiered approach effectively supported the transition from knowledge acquisition to practical application, offering increasing levels of interaction, contextualisation, and hands-on experience.

The **MOOC phase** served as the entry point, introducing foundational concepts, pedagogical frameworks, and inclusive practices in STEAM education through an accessible, scalable, and self-paced format. With over 1,400 participants from 57 countries and a high completion rate, the MOOC demonstrated both wide reach and strong engagement. Participants gained essential theoretical grounding and expressed confidence in applying their new knowledge in educational settings, although many noted the need for more opportunities to practice and collaborate in real-time. These findings align with broader research highlighting the importance of inclusive STEAM frameworks in supporting learners with specific learning disabilities (Sari et al., 2024; Tomar & Garg, 2021).

Building on this foundation, the **blended training** phase offered a more structured and collaborative learning experience. It was designed for those who had successfully completed the MOOC and wished to deepen their competences. With two tailored pathways, for pre-service and in-service educators, the course combined synchronous online sessions with self-paced activities via a virtual learning environment (VLE). Participants highly valued the interactivity, expert guidance, and peer collaboration, although challenges such as time limitations, theoretical emphasis, and workload management were noted. Despite these, both satisfaction and perceived impact remained very high, underscoring the added value of this phase in bridging knowledge and practice. The development of competence-based approaches, such as those proposed by Spyropoulou & Kameas (2024), was particularly evident in this phase, contributing to the broader pedagogical shift toward structured, needs-based training for educators.

The **final mobility phase** provided participants with a unique opportunity to engage in intensive, in-person training through two-week exchanges in Spain and Cyprus. These mobilities enabled educators to apply their learning in diverse, multicultural settings

through team-based, hands-on activities. Participants consistently reported that this phase enhanced their confidence, intercultural collaboration skills, and ability to implement inclusive STEAM strategies in real-life contexts. While some faced challenges related to group dynamics, language, or limited time for reflection, these were largely perceived as growth experiences. The success of this phase underscores the need for intentional planning and structured practice in inclusive STEAM environments (Wade et al., 2023), especially when applied across varied national contexts (Agaliotis & Kartasidou, 2023a).

Across all three phases, participants demonstrated increasing confidence, motivation, and professional growth. While each phase presented different challenges, ranging from time constraints to language barriers, the progression from knowledge to practice proved both necessary and effective. The integrated design of the SpicE learning pathway allowed educators to gradually build competences, reflect on their practices, and engage in meaningful collaboration at both national and international levels. Ultimately, the three-phase model of the SpicE project stands as a successful example of multi-level professional development in Inclusive STEAM Education, with strong potential for transferability and scale-up in other contexts.

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Part 3: Case studies of Inclusive STEAM applications

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Technology-assisted learning: a computer game to develop fine motor skills in students with autism

Ahmet ŞAHİN

Yüreğir Science and Art Center, Adana, TURKIYE

Introduction

Students beginning their education must achieve a certain level of physical and cognitive readiness, particularly in fine motor skills. These skills are essential for tasks such as holding a pencil or using scissors, which are critical for academic activities and improving quality of life. Recent studies indicate a significant rise in autism prevalence in the United States, from 1 in 250 in 2000 to 1 in 44 in 2021 (CDC, 2024). Students with autism often exhibit weak fine motor skills.

This study proposes a computer game that uses finger movements to develop fine motor skills. The game is designed with input from high-IQ students, fostering project-based learning. The adaptable learning scenario accommodates students with varying needs, combining finger exercises with educational objectives through a sensor-equipped glove.

Methods

Circuit setup

The project employs an Arduino Uno, flexible sensors, and other materials to create a wearable glove. The total cost of the circuit setup is $75.85. Alternatively, a DIY flex sensor can be constructed for $14 using materials such as flexible straws and copper foil tape.

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Table 15 Circuit materials and costs

Item No.	Material	Quantity	Cost (USD)
1	Arduino Uno	1	8.00
2	Breadboard (Medium)	1	2.00
3	Suitable for DIY 5x7 cm Circuit Boards	1	0.30
4	Short Flex Sensor (77 mm)	5	65.00
5	10K Ohm Resistor (0.25 Watt)	5	0.30
6	20cm Male-to-Male Wire Cable	1	0.25

Table 16 DIY Flex sensor materials and costs

Item No.	Material	Quantity	Cost (USD)
1	100-Pack Flexible Drinking Straws	1	6.00
2	Copper Foil Tape, Paper Circuits (6mm)	1	3.00
3	Old Network Cable	1	Free
4	40pin Male to Female, 40pin Male to Male, 40pin Female to Female	1	5.00

The circuit is established according to the circuit connection diagram in Figure 16.

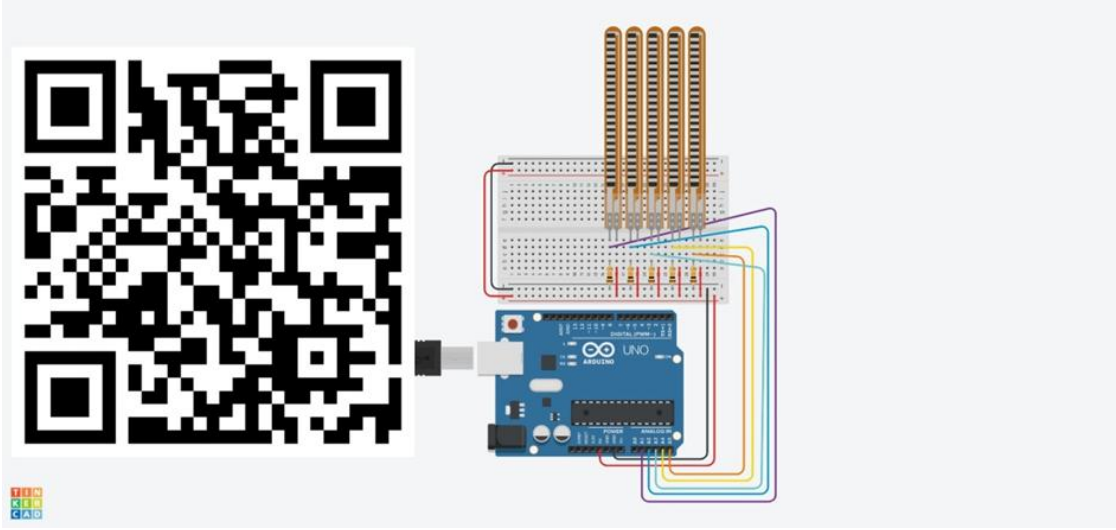

Figure 16 Circuit connection diagram

The game is designed according to the student's interest and skills. The teacher prepares the game with the Block-based coding program mBlock. For example, for a game for a student who is interested in music, playing different instruments with his fingers, the following draft is prepared in mBlock (Figure 17).

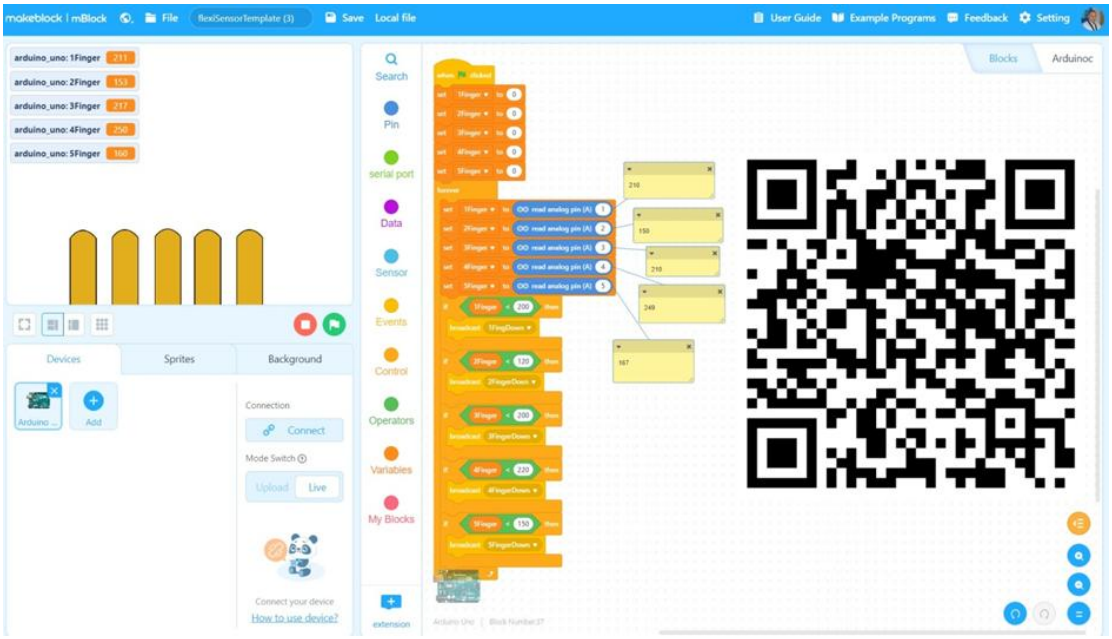

Figure 17 mBlock draft

Implementation for students with weak fine motor skills

Teachers create wearable sensor gloves using online resources (Robotic Emmi, 2025) and design games tailored to students' interests using block-based programming (mBlock). For example, a music-themed game requires students to bend fingers to play virtual instruments. Progress is tracked through daily scores over two weeks.

Implementation for mainstream students

Students work in groups to build flex sensors using materials like straws and copper tape. They experiment without guided examples, fostering creativity. Those with coding skills can design games using microcontrollers.

Implementation for high-IQ students

Teams identify individuals with motor skill challenges, design wearable tech, and create accompanying games. They present their projects, including wireless functionality, in a 10-minute presentation followed by Q&A.

Evaluation and feedback

Teachers assess progress using observation forms, score tracking, and student feedback. Adjustments are made based on outcomes and suggestions.

Conclusion

This project clearly demonstrates the effectiveness of technology-assisted learning in developing fine motor skills for students with autism. Furthermore, it highlights the significant benefits of involving high-IQ students in designing educational tools, which promotes inclusivity and innovation.

In this context, the story of Buğra Çankır serves as a particularly inspiring example of the long-term impact of such educational support. Diagnosed with autism at age 3, Buğra Çankır has become a successful individual pursuing a Ph.D. in music thanks to proper education and support (EYHMG, 2023). This case stands as living proof of how early interventions and technology-assisted learning approaches can unlock the potential of individuals with autism.

In conclusion, this study emphasizes both the transformative power of technology in

education and the importance of personalized learning approaches. Success stories like Buğra Çankır's remind us once again how crucial innovative educational methods are for individuals with autism.

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STEAM for All: A case study from Escola Montessori Rubí

Erica P. Köchig[1], Beatriz Lores-Gómez[2]

[1]*Universitat Rovira i Virgili, Tarragona, Spain*
[2]*Universitat Jaume I, Castellón, Spain*

Introduction

Integrating Science, Technology, Engineering, Arts, and Mathematics (STEAM) into Early Childhood Education (ECE) is central to global educational policy agendas aimed at fostering creativity, critical thinking, and social inclusion (UNESCO, 2024). STEAM not only responds to future labour market needs but also enables transformative educational experiences that support equity, gender sensitivity, and cultural diversity from an early age (Council of the European Union, 2021). This chapter presents a case study of Escola Montessori Rubí, a public preschool and primary school in Catalonia, Spain, that has embedded STEAM within its Montessori-inspired curriculum.

Context and background

Rubí is a mid-sized industrial city near Barcelona, with a population marked by cultural diversity and economic migration. According to Gencat (2024), 13.65% of its residents are migrants, predominantly from Morocco. Escola Montessori Rubí serves this population with a commitment to accessibility and inclusion, offering preschool and primary education in a working-class neighbourhood.

Since 2015, the school has participated in several regionally and nationally funded innovation projects focused on STEAM, digital education, and environmental awareness (Programa Magnet, Xarxa Coordinació Digital Centre, Xarxa Escoles

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Verdes). Each initiative involves professional development components that guide teachers in applying inclusive, student centred and innovative methodologies.

At every educational level, the school offers structured STEAM workshops over three days (introduction, work session, and wrap-up). Students complete a set of three worksheets aligned with each day's activity. Workshops are developed cooperatively (Borko et al., 2015), with teachers proposing and refining activity ideas collaboratively.

The school integrates the Montessori philosophy, emphasising autonomy, exploration, and sensorial learning, with Catalonia's commitment to active learning and equity. Since introducing its Educative Project in 2017, Escola Montessori Rubí has fostered an environment where digital tools, interdisciplinary collaboration, and gender equity are embedded in the pedagogical culture.

This study aimed to explore how STEAM materials and pedagogies are implemented within a Montessori-inspired public school. These insights support the development of an assessment tool designed to evaluate STEAM practices in ECE from a Montessori perspective.

Methodology

The research employed a qualitative methodology based on participant observation and informal interviews (Cohen et al., 2007; Swain & King, 2022). Fieldwork took place in October 2024, following an initial unstructured interview with the school principal. Observations were conducted across regular classes in ECE and in primary school, and interdisciplinary STEAM workshops involving mixed-age groups (Figure 18) were carried out, where each teacher implemented an activity for a group of 9-12 children.

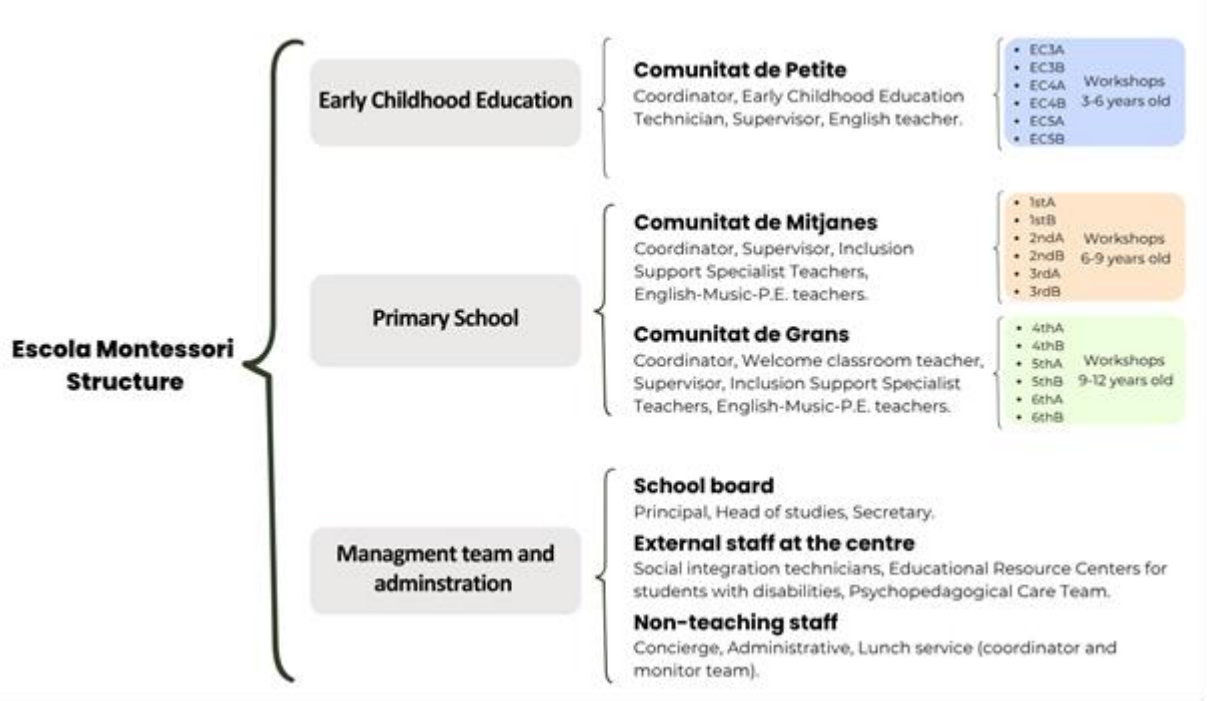

Figure 18 Escola Montessori's structure

Data were collected through field notes, logs, and reconstructed conversations (Table 17). The analysis followed a descriptive, theory-generating approach (Robson, 2002), triangulated with publicly available school documents and social media content.

Table 17 Summary of the observation by school level

Teaching level	Activities and workshops
Early Childhood	- *Los Submarinos*' coral activity (theory about ocean floor and artistic design), and activity in cooperation with the *Guardianes del mar*, a 2nd year primary school group (email writing to NGOs). - 4 activity offers to work in groups: facial traits (artistic portrait using mirrors), self-guided tablet activity (basic mathematics games), snakes and ladders game, and arithmetic and number writing practice. - Group *Fuego*, fire drill and security elements explanation and exploration (research about the school security materials and preparation for the annual fire drill with the local firefighters). - Basic arithmetic and geometry (individual games on tablets). - Basic geometrics (plastic figure set and individual tasks).
Primary School	- *Los aviones* group's observation and recording of the sky in the playground. - Self-awareness and family (activities about family composition and self-esteem). - Bio-plastic (material development) and art+plastic (3 activity offers with plastic as the main material). - 3D printing (planning a useful object for the community, digital design on Tinkercad, and printing). - Solar oven made of a pizza box (planning, design, and trial in the

Teaching level	Activities and workshops
	playground). - Catalan language acquisition (sayings selection and textile vinyl printing). - Catalan language development (3-4 children group tabletop games). - Gymnastics (rhythmic gymnastics with ribbon, vault, and balance beam). - Set of circuit crafts (Makey Makey self-guided material).

Results

Teachers employed a fluid approach to STEAM, as a transdisciplinary process integrating it for regular classroom planning (Fuego project, Los aviones project, Los Submarinos project), across disciplines and age groups (Los Submarinos and the Guardianes del mar), and for the 3-class workshop structure. In the case of the workshop activities, they were arranged based on student ideas (3D printing objects for the community, art & plastic expression), projects (solar oven, textile vinyl printing, family composition and self-esteem, gymnastics), ongoing global projects (3D printing gameboard missing elements, art &plastic on-going group design), and self-guided materials (set of circuit crafting, Catalan tabletop games).

In the case of digital tools, they were integrated thoughtfully across the school. In preschool, tablets supported mathematical development (basic mathematics activities), while interactive boards were used for collaborative storytelling (NGO activity) and visual learning (activity explanation). In primary education, the *Tinker Classroom* enabled children to experiment with digital design with Tinkercad software and 3D printing. Robotics and basic programming were introduced through material like Makey Makey, linking physical movement with computational logic.

Considering gender and intersectionality, a strong commitment to gender equity was evident in both language and practice. Teachers used inclusive vocabulary, deliberately showcased female scientists and artists, and avoided gender-stereotyped tasks (art & plastic artists, gymnastics celebrities). The multicultural makeup of the student body informed a pedagogy focused on empathy and respect (family composition and self-esteem). Students with mild disabilities were supported by a dedicated specialist team, ensuring participation in everyday classes and STEAM activities.

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Discussion and conclusions

This study underscores the potential of integrating STEAM into Montessori-inspired approaches from ECE, particularly when developed through the lenses of equity and inclusion (Council of the European Union, 2021). The case of Escola Montessori Rubí illustrates how to effectively implement inclusive STEAM in a public school by embedding interdisciplinary, project-based learning into daily classes and workshops (Borko et al., 2015), while teachers foster autonomy, creativity, emotional skills, and social responsibility in their students (UNESCO, 2024).

The school also demonstrates how educational innovation is sustainable when teachers receive continuous professional development, institutional autonomy, and structured peer collaboration (Köchig, 2025). As a result of this professionalisation process, STEAM activities and digital education are not isolated units but part of a systemic culture of experimentation and reflective practice (Redecker, 2017). Such practices reflect the EU's emphasis on levelling up STEAM education quality and access for teachers (European Commission, 2025).

In conclusion, the findings point to the need for national and EU-level policies that support STEAM integration while valuing pedagogical diversity and child-centred learning from the early years. Teacher training programs should prioritise STEAM education, digital competence, and intersectionality as core elements. Additionally, schools benefit from sustained involvement in professional networks and partnerships, which not only enhance content knowledge but also provide ongoing pedagogical and methodological support.

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The Role of art in the inclusion of students with Special Educational Needs in STEAM Education

Luis Mesquita da Fonseca[1]

[1]*Agrupamento de Escolas de Esmoriz Ovar Norte, Esmoriz, Portugal*

Introduction

STEAM education is an interdisciplinary approach that blends Science, Technology, Engineering, Arts, and Mathematics into an integrated learning model. This approach encourages creativity, innovation, critical thinking, and collaboration among students, which can help them develop essential skills for the modern world. While this pedagogical model has gained increasing relevance in 21st-century education, students with Special Educational Needs (SEN) still face significant barriers to full participation in standard educational settings. These barriers can be systemic or personal and often compromise the quality and equity of their learning experiences.

In Portugal, the Decreto-lei No. 54/2018 establishes the legal framework for inclusive education, recognizing that every student has the right to access and participate in quality learning opportunities. The law outlines three levels of support measures — Universal, Selective, and Additional— that aim to meet the diverse needs of students within regular school contexts.

Universal Measures are intended for all students and include strategies such as differentiated instruction, curricular flexibility, and varied assessment methods. These aim to promote learning and well-being in a preventive and proactive way, ensuring a baseline of inclusion for every learner.

Selective Measures are intended for students who show early signs of academic underachievement but do not have long-term or profound disabilities. These are temporary, targeted interventions designed to improve learning outcomes through

additional pedagogical support, small group activities, or targeted remediation. In this study, 70% of students with Selective Measures were diagnosed with Autism Spectrum Disorder (Level 1 – 30%) and Attention Deficit Hyperactivity Disorder (ADHD – 40%). The remaining 30% of this group presented with Specific Learning Disabilities (SLD), such as dyslexia and dysgraphia.

Additional Measures are intended to students with persistent and complex difficulties that severely impact their learning processes. These students typically require individualized curriculum modifications, assistive technologies, and ongoing support from multidisciplinary teams. In this study, 60% of the students receiving Additional Measures had Autism Spectrum Disorder (Levels 2 and 3) and benefited from personalized sensory regulation strategies, including preferred music, noise-canceling headphones, and sensory stimulation. The remaining 40% had severe cognitive deficits.

This study examines the role of art in promoting the inclusion of students with Additional and Selective Measures within the STEAM educational framework. It explores the implementation of an inclusive STEAM project at Agrupamento de Escolas de Esmoriz-Ovar Norte, a public school in Portugal, with a focus on the intersection between creative arts and inclusive education.

Students engaged in interdisciplinary artistic activities that led to the creation of two illustrated books—**An Adventure in the Rain** and **The Dream of a Star**—in which they developed narratives, characters, and artwork based on their ideas and emotions. These outputs reflected not only their learning but also their social participation and emotional expression.

The primary goal of this work is to understand how integrating art into STEAM activities can foster an inclusive environment that caters to students with diverse needs, ultimately contributing to their academic success and social integration.

Objectives

The primary aim of this study, conducted by a school psychologist, was to investigate how art-based STEAM activities can support the inclusion of students with Additional Measures and Selective Measures. More specifically, the study sought to explore how various forms of art —such as visual arts, music, and digital arts (including LED

environment design)— can enhance students' cognitive, emotional, and social development.

The integration of art into STEAM activities was seen as an opportunity to engage students in a non-verbal and more accessible manner, helping them to overcome barriers that may exist in more traditional subjects like mathematics or science. Additionally, the study aimed to assess how creative processes can support students with special disabilities, including those with intellectual disabilities and autism spectrum disorder (ASD), and to evaluate the potential of art to improve self-esteem, academic participation, and peer relationships.

To guide this investigation, the following objectives were established:

- To explore how artistic-pedagogical strategies within the STEAM framework can support the inclusion of students with Special Educational Needs (SEN), particularly those receiving Selective and Additional Support Measures.
- To analyze the effectiveness of integrating visual arts as a tool for self-regulation, engagement, and emotional expression among students with ASD, ADHD, SLD, and cognitive impairments.
- To evaluate the impact of the creation of illustrated storybooks — *An Adventure in the Rain* and *The Dream of a Star* — on the academic motivation, participation, self-regulation and self-esteem of students with Additional Measures.
- To document the inclusive pedagogical practices developed in a public Portuguese school (Agrupamento de Escolas de Esmoriz – Ovar Norte) and assess their relevance for promoting accessibility and success in STEAM education.
- To contribute to the development of inclusive and creative methodologies that align with 21st-century competencies and foster active participation, collaboration, and creativity in mixed-ability classrooms.

Methodology

The research was conducted during the first semester of the 2024-2025 academic year, from September 2024 to February 2025, at the Agrupamento de Escolas de Esmoriz-Ovar Norte, a public school in Portugal.

A mixed-methods design was employed, combining qualitative and quantitative approaches to provide a comprehensive understanding of the impact of art-based STEAM activities on students with Special Educational Needs (SEN).

The sample consisted of 47 students aged between 10 and 18 years, receiving different types of support according to Decreto-Lei n.º 54/2018:

- 60% of students receiving Additional Measures were diagnosed with Autism Spectrum Disorder (ASD) Levels 2 and 3. These students were autoregulated through personalized sensory strategies including preferred music, noise-canceling headphones, and sound mufflers. As part of the intervention, they created two illustrated books, *An Adventure in the Rain* and *The Dream of a Star*, developing stories, characters, and artistic sequences.
- The remaining 40% of Additional Measures students had moderate cognitive impairments.
- Among students receiving Selective Measures, 70% were diagnosed with ASD Level 1 (30%) or Attention Deficit Hyperactivity Disorder (ADHD) (40%), while the remaining 30% presented Specific Learning Disabilities (SLD) such as dyslexia and dysgraphia.

Data collection included direct observation, standardized assessments, and ongoing monitoring by the Multidisciplinary Support Team for Inclusive Education (EMAEI), which ensured adaptations of activities according to individual needs.

Observations were carried out during interdisciplinary STEAM activities integrating visual arts (drawing, painting, sculpture), music (rhythm exercises, sound composition), and digital arts (LED environment design). These activities encouraged creative problem-solving by combining scientific, technological, and artistic concepts.

Quantitative data from assessments and qualitative data from observations and interviews were analyzed to evaluate the effectiveness of art-based STEAM interventions in promoting inclusion, engagement, and well-being among students with SEN.

Results

Preliminary findings from this study indicate that the integration of art-based activities within the STEAM curriculum had a notably positive impact on students receiving Additional Measures and Selective Measures.

For students under Additional Measures, the personalized curriculum—designed to address their complex educational needs—was significantly enhanced by the inclusion of creative arts. Many of these students, especially those with severe Autism Spectrum Disorder (ASD), often face challenges in traditional verbal communication. The use of visual arts and hands-on activities, such as drawing and LED environment installations, provided effective avenues for self-expression and improved self-regulation. This multimodal approach allowed these students to demonstrate understanding of complex scientific concepts in a manner that conventional assessments may not capture.

Moreover, the art-based STEAM interventions contributed positively to the emotional and social development of students with special educational needs. Teachers and support staff observed improvements in social interactions, as collaborative art projects encouraged cooperation, peer communication, and a greater sense of belonging—areas typically challenging for students with Additional Measures.

Students benefiting from Selective Measures also showed increased engagement and motivation through art-based STEAM activities. The creative projects offered hands-on, enjoyable experiences that helped bridge abstract or difficult content, particularly in technology and science subjects. This engagement facilitated a deeper connection with the curriculum and bolstered their confidence in academic participation.

These results underscore the potential of integrating artistic practices into STEAM education to foster inclusivity and support the diverse needs of students with Additional and Selective Measures.

Conclusions

The study highlights the crucial role of art in fostering inclusive STEAM education for students with diverse special educational needs. Art integration enables students with Additional Measures, including those with severe ASD and cognitive impairments, to express themselves and engage meaningfully with academic content.

Similarly, students with Selective Measures benefit by increasing motivation and deeper curriculum engagement through creative projects.

These findings advocate for wider adoption of interdisciplinary STEAM programs that integrate art, to create inclusive, supportive, and motivating environments where every student can thrive.

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https://www.calameo.com/read/00793630328ae28c665ca
The Dream of the Star
https://www.calameo.com/read/0079363602f3e7497ef3d

What if…I think, act and observe

Elisa Ripamonti

[1]*State Comprehensive Institut Koinè, Italy*

Introduction

Schools reopened in 2021 following extensive COVID-19 pandemic restrictions, though strict social distancing rules remained in place. This immediately posed the problem of how to plan for in-person learning with disabled pupils while maintaining distance learning for others. In Italy, all children with disabilities attend mainstream classes, so the teacher must find ways to include and involve the other classmates, so they can understand the value of sharing and the necessity of working together for the common good.

The chapter details an inclusive educational project undertaken during the immediate post COVID-19 pandemic period for a pupil with low-level Down Syndrome, who struggled with speech, fine and gross motor skills, and concentration. The project focused on creating an interactive story, using Scratch, and employing adapting activities to meet the student's specific needs and foster her engagement. The project also aimed to develop problem-solving skills, empathy, and basic programming knowledge among her classmates. The emphasis was on the engineering problem design process, as a systematic and iterative methodology for addressing complex challenges and enhancing outcomes which underlines the importance of collaborative learning, embracing "mistakes" as opportunities for growth, in order to observe the complexity of reality and designing educational experiences that are both meaningful and accessible for all students.

Methodology

What was important from the very beginning was to **build strategies and teach methodologies that would be replicable over time; this helped** to address various inclusion situations and also to equip students with tools fostering **continuous**

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learning and life skills. The engineering problem design approach is a systematic and iterative method for solving complex challenges. It typically involves defining the problem, researching, brainstorming for solutions, developing and prototyping the best idea, and then rigorously testing and evaluating it. This cyclical process allows for continuous refinement and improvement, ensuring the final solution effectively addresses the initial need while adhering to constraints.

- **Problem Identification:** "Who has the problem? What is the problem? Why is it important to solve the problem?" The core problems identified was to provide the disabled student with the same opportunities with her classmates, to equip her with the ability to be able to read for leisure, and to help her imitate the classmates and feel well.
- **Solution Brainstorming:** The team noticed that she was able to scroll on a tablet, so they decided to create a digital story using Scratch, a visual programming language. The classmates wanted to involve her in the creation of sprites and stages, but she needed to learn how to slow-down and coordinate movements.
- **Collaborative Approach:** All the classmates were involved in the design process, recognizing their unique perspectives.
- **Interactive Design and Adaptation:**
    - Initially, the children proposed to use stamps for colouring characters, aiming for slow, sharp, and repetitive movements. However, this proved unsuitable.
    - They then observed their own pen-holding techniques and created cardboard frames to help the student control her strokes.
    - They used AAC (Augmentative Alternative Communication) with visual codes and simple instructions to help her identify and choose images and understand communication.
    - For the story background, they incorporated the student's passion for collecting by gathering natural objects from the garden, using AAC strings combined with simple oral sentences for comprehension.

- The disabled child couldn't speak but she could reproduce meaningful sounds; however, it was too difficult for her to understand when to "talk". To address the pupils' difficulty with conversational turn-taking and reproducing sounds, the classmates recorded her communicative sounds throughout the day and integrated them into Scratch in the desired order.

Figure 19 To facilitate the handgrip

Figure 20 To slow down the graphic mark

Figure 21 Stamps

Results and discussion

The results highlight the positive outcomes and impact of the project:

- **Achieved Goal for the Pupil with Disability**: The primary goal of providing the student with her own digital tale was achieved. We can imagine the pupil entertaining herself independently in the evenings: a real goal for her life!
- **Broadened Possibilities**: The project was just the beginning for creating a common digital library with varying complexity levels. This was the class's first major success in fostering an inclusive environment, underscoring that with the right strategies, even complex disabilities can be successfully included in the classroom. It demonstrated ways of how to give to every child their rightful place in the classroom and acknowledge their unique learning needs, which differ for each student.
- **Specific Objectives Met**:
  - *For the pupil with the disability*: She identified and chose images, understood verbal communication supported by AAC, refined gross-

motor skills, strengthened cause-and-effect understanding and learned to entertain herself.

- *For the classmates*: They activated problem-solving skills, recognized the needs of others, learned to compare and share opinions, sought and tested solutions, and learned simple programming commands in Scratch.

- **Inclusion of Other Pupils**: The project also successfully involved two other pupils with mild ADHD and dyslexia, who were undiagnosed at the time.
- **Development of "Coding" Mindset**: The experience fostered a "coding" way of thinking, emphasizing the need to extract useful information from complex realities, simplify it, and create achievable sequences.
- **Teacher and Student Growth**: Emphasis should be placed on the activity's usefulness, not only on an ethical and social level, but also in unconsciously encouraging children to think divergently, collaborate, and be forward-looking.
- **Embracing Mistakes**: Trying and not succeeding is not a failure; mistakes should be "starting points" for problem-solving, exchange, and debate, leading to new solutions, as is often the case in everyday life, which is full of challenges and chances to be resilient.

The Scratch storytelling and the respective code can be found in the following link: https://scratch.mit.edu/projects/1180394498

“If ants get together, they can move an elephant” says an African proverb. This is the teachers’ power: to not be alone to make the difference.

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The power of Inclusive STEAM Education in Nigerian tertiary education

Charity N. Egbo[1]

[1]*Department of Educational Administration and Planning, Faculty of Education, Abia State University, Uturu, Abia State, Nigeria*

Introduction

The Inclusion of Science, Technology, Engineering, Arts and Mathematics (STEAM) education has been transformative within education systems worldwide. However, STEAM education within Nigerian universities and colleges is predominantly exclusionary particularly for students with mild disabilities, whereby such students face immense barriers to access and full participation. Excluding them not only denies them career and professional prospects but also denies Nigeria's labour market potential sources of talent and ideas to drive innovations and development.

This chapter reports findings from a large two-year intervention study conducted at six Nigerian tertiary institutions and demonstrates inclusive STEAM education to be both possible and worthwhile when delivered through sustained multi-faceted interventions. This research aims to counter pervasive deficit discourses about disability within Nigerian tertiary education by demonstrating students' academic skills when such students are given proper access and support.

Methodology

Research design

In this study, a mixed-methods study involving quantitative and qualitative approaches to understanding Nigerian university students' inclusive STEAM education and assessing the efficacy of a multi-component intervention was applied. Baseline

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measurement was initiated to start this sequential explanatory study, leading to intervention and finally to extensive outcome measurement for 24 months.

Study setting and participants

The study was implemented in six Nigerian institutions located within six of the country's geopolitical zones, including two federal universities, two state universities, a federal polytechnic and a college of education. This ensured variation by type of institution, by size, by resourcing and by geographical location. There were three stakeholder groups involved in this study; Faculty were purposefully sampled for discipline, career stage and inclusive education experience, and quantitative questionnaires were returned by 187 faculty members (response rates of 68-89% per institution). Forty-three disability support staff were interviewed individually from coordinator to support specialist. Seventy-six students with a variety of disability types participated in focus group discussions, including visual impairment (29%), hearing impairment (24%), physical impairment (26%) and learning disability (21%) (Table 18).

Table 18 Study institutions and participant distribution

Geopolitical Zone	Institution Type	Faculty Survey Participants (n)	Response Rate (%)	Disability Support Staff Interviewed (n)	Students with Disabilities in Focus Groups (n)
North-West	**Federal University**	32	78%	8	13
North-East	**State University**	29	68%	6	12
North-Central	**Federal Polytechnic**	35	89%	9	14
South-West	**State University**	31	82%	7	11
South-East	**College of Education**	28	71%	6	13
South-South	**Federal University**	32	85%	7	13
Total	**6 Institutions**	187	79% (avg)	43	76

Data collection procedures

Data were collected in three phases lasting for 24 months. Institutional accessibility questionnaires with standardized instruments, faculty questionnaires on attitudes and knowledge towards inclusive STEAM education, semi-structured interviews with support staff for disabilities and focus group discussions among students with disabilities formed a baseline data collection activity for Phase 1 for months 1-6. Phase 2 (months 3-18) implemented an intensive multi-component intervention regimen including professional development workshops on Universal Design for Learning principles, development of adaptive instructional materials, and creation of peer mentoring networks. Phase 3 (months 19-24) replicated baseline data collection protocols to evaluate intervention effects.

Data analysis

IBM SPSS version 28.0 was used to explore quantitative data using descriptive statistics, paired-sample t-tests to compare pre-post values and multi-regression analyses. Qualitative data were also submitted to thematic analysis using standard procedures and inter-rater reliability was above 85% for major themes.

Results

Baseline findings

Institutional assessments of accessibility revealed widespread disparities in inclusive practices among institutions. Composite measures of accessibility ranged from 2.8 to 4.2 on a scale of 10, falling short of the adequate point of 6.0 (Table 19). Mathematics and engineering departments had lower accessibility scores of 2.3 and 2.8, respectively, signifying cumulative physical, technical and procedural impediments.

Table 19 Baseline institutional accessibility scores by domain

Domain	Mean Score	Standard Deviation	Range
Physical Accessibility	3.2	0.8	2.1-4.1
Technological Accessibility	2.9	0.9	1.8-3.9
Policy/Procedural Accessibility	3.6	0.7	2.9-4.3
STEAM-Specific Accessibility	2.8	0.6	2.3-3.4

Domain	Mean Score	Standard Deviation	Range
Overall Accessibility	3.1	0.5	2.8-4.2

Note: Threshold for adequate accessibility = 6.0/10

Faculty (n=187) reported alarming knowledge gaps, with 76% indicating lack or minimal knowledge of teaching practices for inclusion. Engineering and mathematics faculty reported the highest percentages of minimal knowledge, at 82% and 79%, respectively. While attitudes toward inclusion were positive (mean rating 6.7/10), faculty did not feel confident when providing accommodations (mean self-efficacy rating of 4.1/10).

Student focus groups revealed systematic exclusion barriers, particularly for laboratory classes. Visually impaired students faced significant barriers to access visual material for which no other format existed. Hearing-impaired students faced limitations to access lectures and group laboratory sessions, given that interpreter services were not available. Physically impaired students faced an inaccessible lab facility, and learning-disabled students pointed to a lack of accommodation for assessment.

Intervention implementation

There was high participation in the faculty professional development program, with 164 faculty (87.7%) completing 40 hours of training in four modules over the course of 12 months. There was a 91% average attendance at sessions, and 89% of participants marked the training "very helpful" or "extremely helpful." The peer mentoring program was also successful in matching 68 students with disabilities with trained peer mentors, and achieving 94% satisfaction rates for both mentees and mentors. Emphasis was placed on peer support and social relationships instead of tutoring.

Post-intervention results

Faculty ratings also showed significant improvements on all measures evaluated. Inclusive teaching practices knowledge improved from 3.9 to 8.7 ($d=4.2$, $p<0.001$), and accommodations efficacy improved from 4.1 to 8.5 ($d=3.8$, $p<0.001$). Percentage of faculty with "moderate" to "high" confidence to teach students with disabilities improved from 24% to 83% (an increase of 246%) (Figure 22).

Table 20 Pre-Post Intervention Faculty Outcomes

Measure	Pre-Intervention Mean (SD)	Post-Intervention Mean (SD)	Change	Effect Size (d)	p-value
Disability Awareness	5.8 (1.4)	8.2 (0.9)	+2.4	2.0	<0.001
Inclusive Teaching Knowledge	3.9 (1.2)	8.7 (1.1)	+4.8	4.2	<0.001
Accommodation Self-Efficacy	4.1 (1.3)	8.5 (1.0)	+4.4	3.8	<0.001
Attitudes Toward Inclusion	6.7 (1.1)	8.9 (0.8)	+2.2	2.3	<0.001
Perceived Institutional Support	4.3 (1.5)	7.8 (1.2)	+3.5	2.6	<0.001

Note: n=164 faculty members completed both pre and post assessments

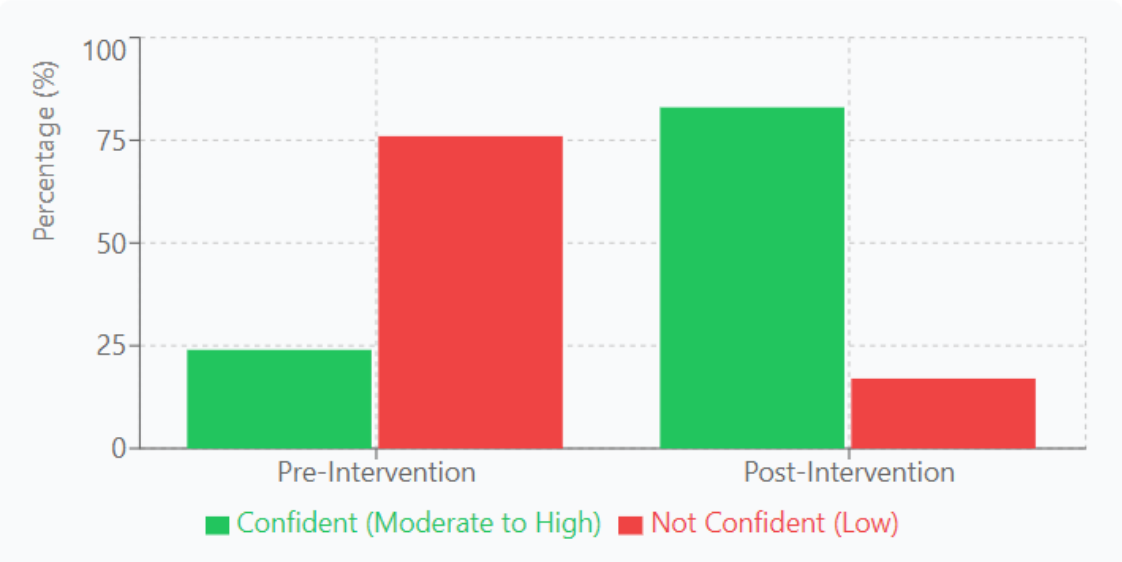

Figure 22 Faculty confidence in teaching students with disabilities

Note: 246% increase in faculty confidence (from 24% to 83%)

Institutional accessibility scores rose dramatically across all domains with the largest gain being for engineering from 2.3 to 6.8/10 and for computer science from 3.1 to 7.2/10. All fields were above the benchmark for sufficient accessibility of 6.0 following intervention. Students' academic achievement also showed substantial improvement. Both students with disabilities improved by a 0.87-point increase on their STEAM course GPAs (with a 41% improvement, $p<0.001$), from below average to average comparison, relative to students without disabilities. Registration for STEAM classes

improved by 43%, and withdrawal decreased by 37%. Class completion rates improved from 68.5% to 87.2%.

Qualitative success factors

Thematic analysis identified four main drivers to successful inclusive STEAM education implementation. Senior administrative leadership and policy development were most crucial, and those with senior administrative leadership made the most on implementation. Faculty empowerment with thorough professional development needed ongoing support through communities of practice after start-up training. Technology adoption needed cautious contextualization to local available resources, infrastructure, and maintenance capabilities. Intersectoral collaboration between disability services, faculties, and outside stakeholders provided necessary technical skills and career networking.

Discussion and implications

This paper demonstrates that inclusive STEAM education is no longer an aspiration but extremely feasible at Nigerian universities when implemented with systematic, evidence-informed interventions. The 24% to 83% faculty confidence change is an institution's capacity change. This shows that exclusion of students with disabilities from STEAM fields is rooted in knowledge deficits rather than attitudinal biases. The 0.87 GPA point gain places students with disabilities on par with the achievement of their non-disabled peers, directly challenging deficit conceptions of academic ability. Coupled with higher enrolment and lower withdrawal rates, these findings indicate that low achievement is less likely to result from internal shortcomings and more likely to result from lack of support.

Recommendations

Based on these findings, several recommendations for policy and practice emerge; Institutions must develop overarching accessibility policies within STEAM environments and redesign faculty reward systems to prioritize inclusive teaching. National initiatives must develop accessibility standards for higher education and incorporate inclusive education incentives within funding formulae. Professional development endeavours must be sustained through institutional teaching centres as opposed to isolated interventions. Pre-service teacher training must include components on inclusive education so that new faculty arrive with the requisite knowledge and skills.

Conclusions

There are clear improvements across institutional access, faculty knowledge and confidence, and student outcomes which indicate that barriers to disability inclusion in STEAM education can be addressed through intentional and strategic actions. The inquiry also reconsiders negative narratives around disability in Nigerian higher education, tracking the unrealised potential of students with disabilities. The finding that inclusive education benefits all students, not just those with disabilities provides a further rationale for resourcing inclusive approaches. As Nigeria expands its knowledge economy, economic inclusion of citizens with disabilities in STEAM areas represents both a moral and economic issue.

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Inclusion in the context of Interdisciplinary Learning

Kristina Fratrović[1], Snježana Marković-Zoraja[1]

[1]*Primary School Dubovac, Karlovac, Croatia*

Introduction

In teaching, we encounter students who have learning difficulties, and teaching needs mudy be adapted in such a way that abstract concepts and processes are taught using concrete examples from everyday life. This example shows an interdisciplinary approach to teaching mathematics and science subjects in extracurricular teaching with the aim of developing science and mathematical skills from an early age. The activities carried out with students have shown that students with learning difficulties (intellectual difficulties) achieve the desired outcomes by working on practical tasks in a group with their peers, thus achieving student inclusion. Depending on the type of student difficulty, tasks can be differentiated according to the student's abilities (e.g. visual support, shorter tasks, etc.). During the implementation of these activities, cooperation between students spontaneously develops. Teaching assistants can also be included in the teaching. During the nature lessons and by learning about nature and mathematics using concrete examples, students with disabilities showed greater motivation and engagement, successfully solving the assigned tasks, which is important for creating a positive self-image. Working in groups enabled students to develop social skills through collaborative learning, and encouraged empathy and acceptance of diversity among other students. An interdisciplinary approach was achieved in the teaching topics of Science and Biology, where students learn about cycles in nature and the circulation of substances in nature (lower primary school age) and about the role of autotrophic organisms in the carbon cycle and carbon storage (upper primary school age and high school), and by applying mathematics, they estimate and measure the size of trees, calculate the age of trees and stored carbon. In this way, they compare the roles of older and younger trees in cycles in nature. Before going to the field, the biology and mathematics teacher prepares worksheets for work and gives instructions to students on how to work. Classes can take place in

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any city park with the presence of biology and mathematics teachers who monitor the students' work. This type of class is conducted as a review and systematization of topics from Science and Biology (e.g. interrelationships in nature and the carbon cycle, life cycles, producers - key organisms, etc.)

Methodology

By performing simple practical work in nature, we teach preschool children to compare and estimate different sizes, the mutual relationships of living beings, and the role of trees for life on Earth. Children compare sizes with their palm prints or their height, e.g. the circumference or height of a tree, and then transfer the estimated sizes into another form, i.e. a drawing or sketch. Children with disabilities work successfully in all activities because the activities include the movement of students in nature when estimating sizes, and due to direct assessment and physical contact with natural objects, more sensory stimuli and learning with the activation of all senses are enabled, which ultimately leads to active learning. Namely, in addition to observing and comparing sizes, children can listen to sounds in nature, feel the smell of a tree, and touch a tree. Children work with work materials adapted to their age. For younger school age, activities include measuring the circumference of a tree using a measuring tape, calculating the age of a tree, and monitoring the life cycle of a tree (Natural Resources Wales, n.d.)

Students use mathematical methods (pencil, correspondence) and a measuring tape to measure the approximate height of trees, compare trees by height, circumference and age (Natural Resources Wales, n.d.) and conclude about the number of cycles and the importance of trees for life on Earth.

Figure 25 Estimating tree circumference using hand span

Figure 24 Comparing tree height to student height

Figure 23 Measuring tree circumference with a measuring tape

Using a pencil to measure tree height

Working in pairs, one child stays beside their tree while the other walks away from the tree but looks back at intervals. When they look back, the child holds a pencil at arms length vertically and lines it up with the tree. They keep walking until the bottom of the tree is level with the bottom of the pencil, and the top of the tree is level with the top of the pencil (Natural Resources Wales, n.d.). Staying in the same spot, the child turns the pencil to a horizontal position, with the end of the pencil still at the base of the tree. The child standing beside the tree now walks away from the tree, at a right angle until they reach the “point” of the pencil. The pencil holder will need to shout “stop” to their partner when they look like they are level with the point of their pencil. They then mark this spot. The distance between this mark and the base of the tree is the height of the tree. The distance can be measured roughly by pacing out or exactly by using a measuring tape or trundle wheel.

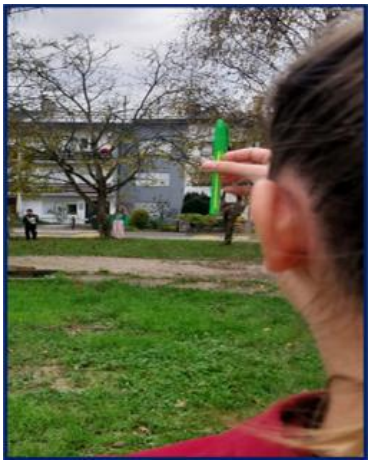

Figure 26 Measuring tree height using the pencil method

Figure 27 Measuring distance from student

Measurements and assessments are performed using practical and simple methods, and students with difficulties successfully solve such tasks. In older elementary school and high school, students will use measurements and mathematical knowledge and methods to recognize measurable characteristics of planar and spatial shapes in nature using mathematical methods - mirror, shadow, similarity, circle (Šikić et.al.,2023). They calculate the height, age of a tree and breast diameter in order to investigate the carbon cycle and the role of trees in the ecosystem.

Students also use applications for biological measurements and analyze differences in the measurement results obtained. High school students apply the acquired knowledge in mathematics and measure tree height using the tangent of the angle. The students calculate the tangent using a clinometer (Natural Resorces Wales, n.d.). They calculate the age of the tree and carbon storage (Natural Museum Wales, n.d.). They describe the carbon cycle, calculate aborbed CO_2 (Fransen, 2019) and conclude about the role of autotrophs.

Using a clinometer to measure tree height

Working in pairs, student 1 looks through the straw so that the treetop is visible and then walks backwards, away from the tree, keeping the top in sight. Student 2 follows and notes when the weighted string lines up with the 45° line. Both students stop when this happens and measure the distance from the tree. This distance is equal to the height of the tree minus your height to your eyes (Natural Resorces Wales, n.d.).

Figure 28 Measuring tree height using a mirror – triangle similarity

Figure 29 Measuring tree height using a clinometer

Figure 30 . Measuring tree height using an isosceles right triangle

Students with difficulties perform practical measurements with an adapted clinometer with the angle tangent already written. Activities with all ages take place in groups, and it is recommended that there are 4 to 5 students in a group per class of 20 to 25 students in total.

Results

In the presented example of working with students, it was shown that students with disabilities successfully complete tasks independently and in groups at all ages. Students who are integrated into the system as newcomers from another language area also successfully complete all tasks because all activities are carried out on concrete examples, which allows for easier understanding. All students easily use the application for determining plant species (Pl@ntNet) and the application for determining tree height (GLOBE Observer). In the activities carried out, all students learn to think critically, interpret observed phenomena and interrelationships based on the study of nature and simple research, and draw conclusions based on measurements taken, while developing natural science, mathematical and digital competences. In this form of teaching, it was shown that students with disabilities participate equally in group work and that they successfully achieve the given outcomes because understanding and connecting measurements of real sizes in space is facilitated, as is connecting size with the role of trees in the ecosystem. All measurements are made on specific examples in nature (trees), which allows understanding and connecting the scale with real, concrete examples from everyday life. Students use measuring tools (tape measure, triangle, etc.) to measure quantities, which benefits the development of psychomotor skills. The work also emphasizes the accuracy of reading measurements, so students with difficulties develop skills in which it is necessary to focus on the activity being performed. In addition, spending time in nature allows students to learn in pristine nature, in a healthy and green environment, which develops positive attitudes towards preserving nature, which is important for the personal well-being of each individual. The evaluation was carried out in a way that groups of students make posters on which they show the life cycles of plants and the role of plants in the ecosystem, the results of measurements, and draw conclusions. Younger students use worksheets for field work and use them to solve tasks related to cycles in nature. At the end of all activities, a self-evaluation of student work was conducted, where all students with difficulties stated that they actively participated in the group work, that they adopted the given outcomes, and that they found the lessons extremely interesting.

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Conclusion

An approach based on interdisciplinary, experiential learning and working in a natural environment encourages the development of scientific, mathematical and digital skills, but also provides a framework for the inclusion of students with difficulties and the integration of students from other language areas. This form of teaching shows that inclusion is not just a matter of adaptation, but of creating an environment in which every student can experience success and feel a valuable member of the community.

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Integrating Inclusive STE(A)M practices in primary education: The Fizzy Q application

Maria Barouta[1]

[1]*Kanalia Primary School, Corfu, Greece*

Introduction

In the beginning of the 21st century, a big challenge for the educational community globally was to create effective and innovative ways of teaching important skills for future citizens. In a rapidly evolving society some of these skills are critical thinking, creativity, problem solving, collaboration, communication skills, as well as, digital and scientific literacy. A useful approach that encourages educators to work in an interdisciplinary way and addresses 21st century skills is STE(A)M education. STE(A)M education improves teaching quality and effectiveness (Zhou & Liu, 2023) and triggers students' interest (Quigley, 2020).

Apart from the necessity of teaching important 21st century competences, another challenge that emerges in the current educational reality, is the management of multicultural classrooms in public schools. Migrant or refugee students with different cultural background struggle to follow the curriculum in a foreign country, since language constitutes a barrier in their school life. However, inclusive teaching and learning techniques can be incorporated within the STE(A)M framework. According to Wade et al. (2023), the promotion of equity and access for all children to learn is critical from a young age. Inclusive STE(A)M practices can be of great assistance for educators dealing with the challenges reported previously and are, also, interested in their personal and professional development.

The present work describes in detail a pilot educational project, implemented in primary education, using the Fizzy Q application. The project was implemented in collaboration with Scientix® and the representatives of the Fizzy Q app. Its main objective was to

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test the application in the primary school classroom and understand how to better use science digital tools in order to facilitate the learning procedure for migrant students.

Inclusion in STE(A)M Education

A multidisciplinary way of teaching and learning, which combines the disciplines of Science, Technology, Engineering, Arts and Mathematics, has been proven to be important for students from a young age, since it enhances their critical thinking, creativity, scientific literacy and connects knowledge with real world challenges. Moreover, another important factor for effective learning is an inclusive teaching environment which takes into consideration the students' needs, interests, difficulties and cultural background. According to Wade et al. (2023), STE(A)M education offers a fertile ground for all students to participate actively through multiple means of engagement and hands-on activities. Moreover, through STE(A)M education, educators can create a supportive environment for all students despite learning difficulties or linguistic barriers, since there is space for multi-disciplinarity and various activities (Milanovic et al., 2023).

The "Fizzy Q" application

The "Fizzy Q" application is a mobile application developed by the start-up Trapeze.digital in partnership with "La main à la Pâte" foundation and aims to turn a smartphone or a tablet into a portable digital laboratory. There are two versions of the application; "Fizzy Q Junior", which is for primary school students, from 7 to 12 years old, and "Fizzy Q" for high school students. Fizzy Q Junior functions as a digital science notebook which aims to facilitate the implementation of experimental activities in science and mathematics, based on Inquiry-Based Education and Pedagogy.

The app is free and allows students to access the tablet's or the smartphone's sensors in order to carry out experimental measurements and document their work. Apart from already existing educational activities, Fizzy Q provides the opportunity for teachers to create their own activities using the digital tools. Students can start an activity, create a new notebook, edit a notebook they have created and share their work with their teacher (Figure 31). The application offers more than 20 tools for measuring colour, sound, movement, position, light, size, etc. (Figure 32).

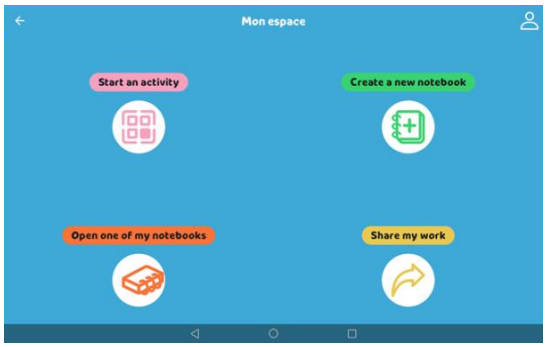

Figure 31 Main environment of the digital science notebook

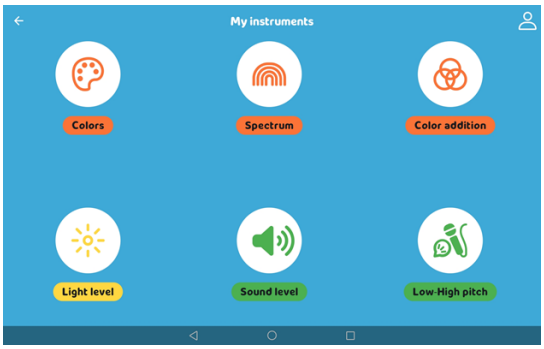

Figure 32 Digital instruments for measurements with Fizzy Q Junior

When students choose to create a new notebook for conducting an experiment, they have to complete all steps of a scientific experiment. In the first page they have to write their question, in the second page their hypothesis, then provide text or pictures with their measurements and, finally, write the results and their conclusions.

Fizzy Q and Fizzy Q Junior are free applications and do not require any personal data for registration. The official site of the app offers extra educational resources and a user guide in order to facilitate teachers and students.

School setting and methodology

The pilot project was implemented in a 6th-grade classroom of Kanalia Primary School of Corfu, Greece. Of the 14 students of the class, two were Ukrainian refugees and two were Albanian immigrants. There were, also, two students with mild learning difficulties, one student with autism and one with Attention Deficit Hyperactivity Disorder (ADHD). The students were divided in 4 groups and each group used one of the school's tablets.

The methodology of the implementation was based on the STE(A)M educational approach and included project-based learning, inquiry-based learning, collaborative-learning, mobile-learning and problem-solving. The activities were connected to the school's national curriculum, and more specifically, to the subject of science of the 6th grade.

Objectives

The main goal of the project was for all students to get familiar to the Fizzy Q Junior application, enhance their scientific literacy through science activities and engage actively in the learning procedure. More specifically, students were expected to:

- Navigate the Fizzy Q app, and learn how to use its different instruments.
- Understand the concept of sound intensity level.
- Conduct an experiment about sound measurements and create a science notebook with Fizzy Q Junior.
- Place different sounds from their daily lives on a sound scale.
- Enhance their digital literacy.
- Work collaboratively in groups.

Implementation

The project started with a preparatory lesson, in which students were introduced to the Fizzy Q Junior application. Each group of students got a tablet, installed the app, navigated in the various and different instruments and experimented with measurements (Figure 33). This introduction happened along with a slide presentation where the teacher explained each element and button of the app to the students.

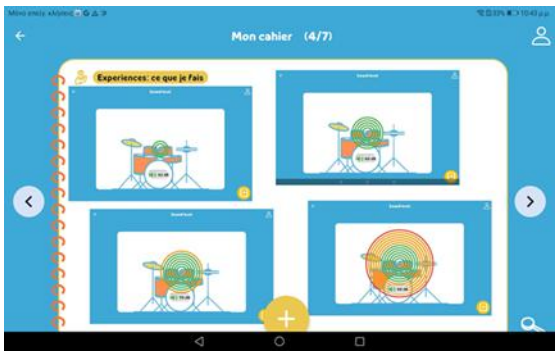

Figure 33 Measurements of various sounds

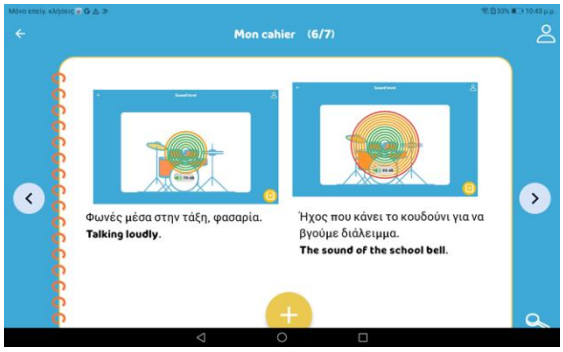

Figure 34: Results of the measurements

After that, students implemented an activity about sound. They used the appropriate instrument to measure the intensity of different sounds in and out of the classroom. They took screenshots and organized their measurements and results (Figure 34).

In the end, they created a sound scale and discussed about which sound level is annoying for our ears, what sound-pollution is and how we can protect our hearing from loud noises.

Results and conclusions

The results of the implementation were based on the teacher's notes and observations through the implementation of the project and on a short questionnaire given to students, concerning their experience and the difficulties they encountered in the end of all activities.

The results showed that the interface of the Fizzy Q app was easy to navigate and students did not have problems working with it. The activities were engaging and all students enjoyed teamwork. The level of English was not difficult for the 6th-grade students to understand, and the four migrant students of the classroom found it easy to handle and participated actively. The activities promoted inquiry-based learning and stimulated students' interest and curiosity. It helped students organize their experimental work and thoughts on their tablets and conduct experiments using a digital tool. Fizzy Q can benefit many migrant and non-migrant students towards science and digital literacy. It is, also, a handful tool for educators to organize their science teaching lessons and create their own activities within an inclusive and creative learning environment.

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Co-designing research directions for Inclusive STEAM Education in Europe

Sabrina Bresciani[1], Francesca Rizzo[1]

[1]*Politecnico di Milano, Milan, Italy*

Introduction

While STEM (Science, Technology, Engineering and Mathematics) education is considered a key driver for nations' competitiveness, scientific evidence on both inclusive education and STEAM (which is define as STEM through the use of artistic approaches, involving creative thinking and applied arts; Joint Research Centre, Mazzeo Ortolani, Pokropek et al., 2024) is still lacking. A recent report of Europe' Joint Research Center (2024) outlines that one key factor for improving STEM education and uptake is increasing the number of well-designed studies on the effectiveness of STEAM and STEM (pg. 5). They note that the vast majority of research on STEM education originates outside Europe and call for well-designed experimental and longitudinal studies on STEAM and STEM to support evidence-based policies. The EU STEM Education Strategic Plan, published in March 2025 outlines three key objectives, one of which is "build a stronger and more inclusive EU STEM talent pipeline (LEVEL up)" (pg. 6). Yet, the STEM Education Strategic Plan' inclusiveness actions are focused on gender participation, while other dimensions of inclusion are lacking. In particular, the document mentions only once "special education" and there is no mention of disability, autism, ADHD, anxiety, mental health, accessibility due to distance or physical/social ability. The scarcity and scattered research on inclusive STE(A)M education does not provide policy makers with the needed evidence for including inclusive STEAM practices in strategic actions. As EU's Framework Program 10 (FP10) will soon shape Europe's research until 2034, a stronger support on

assessing the economic and social benefits of STE(A)M inclusive education (more broadly defined) should be provided in order to identify the most effective inclusive STEAM practices.

The aim of this work is to identify research directions on inclusive STE(A)M education that are based on pragmatic societal needs in Europe, theoretically relevant and methodologically well designed. This research is conducted as part of the EU funded project Road-STEAMer, aimed at crafting a roadmap for STEAM education in EU funding schemes.

Methodology

To identify relevant research directions that can provide useful evidence to guide EU's research programs on inclusive STE(A)M education, recent EU policies and strategic documents are contrasted with scientific evidence, stakeholder needs and best practices. The first step has been the analysis of STEAM literature (Yeomans et al., 2025) to identify key evidence and theoretical approaches, as well as to analyse extant STEM literature reviews (JRC, 2024). Next, several roadmapping workshops are conducted applying the technology roadmapping technique (Phaal, Farrukh & Probert, 2004), adapted for the purpose of the project. Participants belonged to relevant categories of actors of the STEAM education ecosystem, including industry players, program managers of tertiary education, students with autism spectrum disorder, special education teachers, administrators in public schools, digital education specialists, university students, school heads in and outside of Europe for a cross-cultural. The work of projects funded under the same call, SENSE and SEER, was mapped and two workshops were conducted with additional EU funded projects on STEAM including SpicE. All input was collectively organized into the roadmap (for further details see: Bresciani et al., 2025).

Results

The insights gained with this participatory approach are aggregated in the roadmap in a list of actions categorized in priority areas, that can provide guidance on research needed for supporting policy making in inclusive STEAM education. Some actions are aligned with the EU' STEM Education Strategic Plan, providing actionable research

ideas, while others provide novel ideas compared to the strategic plan. The complete list of actions can be found in the STEAM roadmap interactive version (Figure 35; Bresciani et al. 2025), while in the following sections, we discuss only actions related to inclusive STEAM. Overall, the roadmap suggests to the European Commission to establish a "*Mission Education* to achieve as systemic change of the educational system and assessment through coordinating STEM/STEAM education research actions for enhancing EU competitiveness through skills development, a harnessing AI and digital technologies for a transdisciplinary inclusive approach to learning" (Bresciani et al., 2025). Such Mission Education, shaped as the current EU Missions (Mazzucato, 2021), should coordinate a series of research actions that investigate and assess projects and experimental policies, informing the EU for evidence-based policy making through longitudinal in-depth studies and randomized control trials (Banerjee & Duflo, 2009).

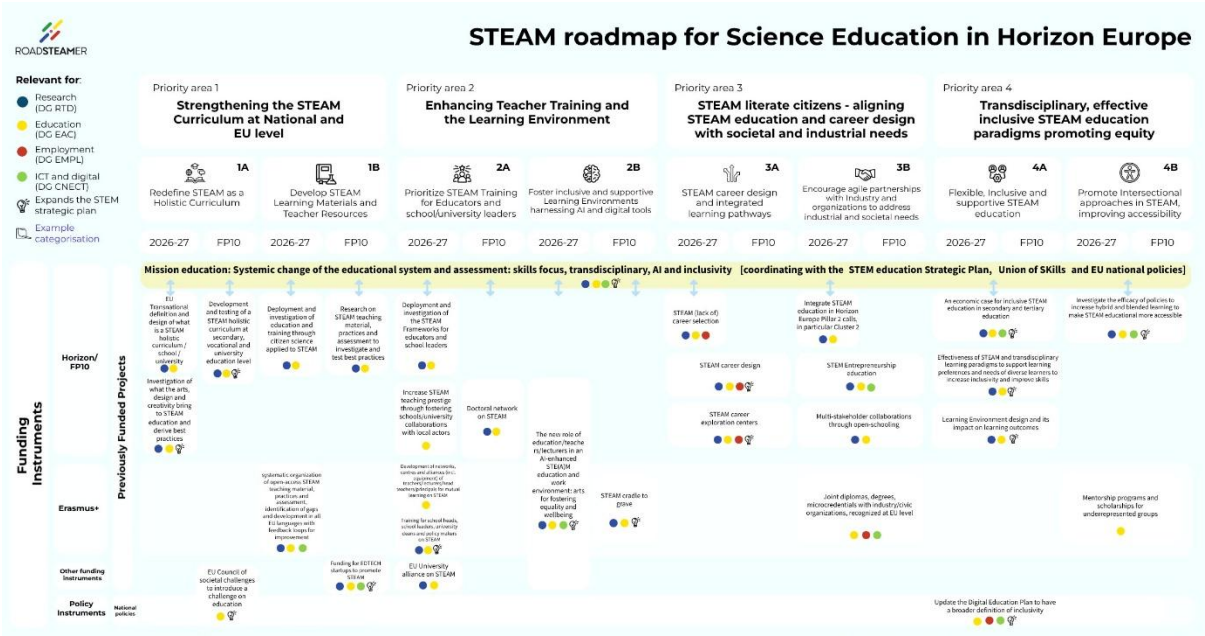

Figure 35 The interactive STEAM roadmap for science education in EU funding schemes (source: https://www.road-steamer.eu/steam-edu-roadmap/)

Specifically for inclusivity in STEAM, the roadmap suggests four key research topics.

Research topic: An economic case for inclusive STEAM Education.

Longitudinal studies and control trials (Banerjee & Duflo, 2009) should be developed to calculate the economic case for developing learning paths and environment that are

inclusive for underrepresented groups, including women and all genders, people with disabilities, autism, ADHD, sensory sensitivity, low socio-economic status, migration background, etc., in partnership with industry players and other organizations. Existing examples of companies and programs with inclusive culture and programs include Auticon, Microsoft's Neurodiversity Hiring Program, SAP's Autism at work, IBM's Neurodiversity Advancement Initiative, Google Autism Career Program in collaboration with the Stanford Neurodiversity project, Specialisterne

Research topic: Effectiveness of STEAM and transdisciplinary learning paradigms to support learning preferences and needs of diverse learners to increase inclusivity and improve skills.

Future research should test multiple STEAM and transdisciplinary (existing or new) learning approaches and evaluate (Quigley, Herro & Baker, 2019) which approach is most effective for which type of learner, including learners with disabilities or belonging to vulnerable groups (incl. intersectionality); such programmes could include Universal Design for Learning to be applied to STEAM education (Thoma, Farassopoulos & Lousta, 2023), or the International Baccalaureate with STEM.

Research topic: Investigate the efficacy of policies to increase hybrid and blended learning to make STEAM educational more accessible.

Future research should investigate how hybrid and blended learning formats can address barriers, which can be physical or digital, to make STEAM curriculum, educational resources, tools, and facilities equally available to all students, in particular for learners with difficulty to physically access secondary and tertiary education or language barriers (Dziuban, 2018; European Commission, 2022; Ahuja, et al. 2023; European Commission, 2023)

Research topic: Learning environment design and its impact on learning outcomes.

Research is needed on the impact of the physical environment ion educational outcomes for a variety of students' needs and abilities (including disabilities) to design STEAM spaces that consider the overall quality of the learning experience alongside functionality, and promote participatory, reflective design strategies that create spaces reflecting the views and feelings of all participants.

Conclusion

In terms of implications for theory, this work provides suggestions for research avenues that are based on a co-designed list of actions for STEAM education in EU's funding schemes based on two and a half years of research in the project RoadSTEAMer and related projects. Results point toward the need to support and investigate a systemic change in that provides a range of learning options rather than a one-size fits all approach typical of national curricula. Similarly to the EU funded Missions, a systemic change in education would require bold and orchestrated actions. Studying the systemic change of education is both a theoretically relevant and pragmatically crucial need to make Europe competitive as well as supportive of diverse needs that can increase the uptake of STEAM careers.

Key words: research policies, inclusive education, STEAM, autism

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Overall conclusions

This book set out with two clear aims: first, to showcase the benefits of STEAM education for addressing the unique needs of students with mild disabilities; second, to provide guidance on the skills and competencies primary education teachers need to manage inclusive STEAM classrooms, as well as on the training needed to achieve that.

Drawing on the findings generated from SpicE research and its implementation of a comprehensive teacher training programme on Inclusive STEAM Education, the book begins to fill an important gap in current literature, who often disregarded the potential of STEAM Education for addressing inclusion in the classroom. Finally, by showcasing inclusive practices from the field, this book offers not only evidence and reflection on the essential elements of Inclusive STEAM programmes, but also inspiration for future experimentation, and for defining new educational research trajectories, at the intersection between STEAM and inclusive education.

To support this future endeavour, the project dedicated its last efforts before closing formally to the creation of a community of educators, policymakers, teacher trainers, researchers and industry actors, all united by a shared commitment to advancing Inclusive STEAM education across all levels. We warmly invite you to join the https://steamalliance.eu/.

As the SpicE project comes to an end, this publication represents not a conclusion, but a starting point: a stepping stone for future research, practice sharing, and community building. Together, we can ensure that STEAM education delivers on its promise, giving all students the means to unlock their potential.

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