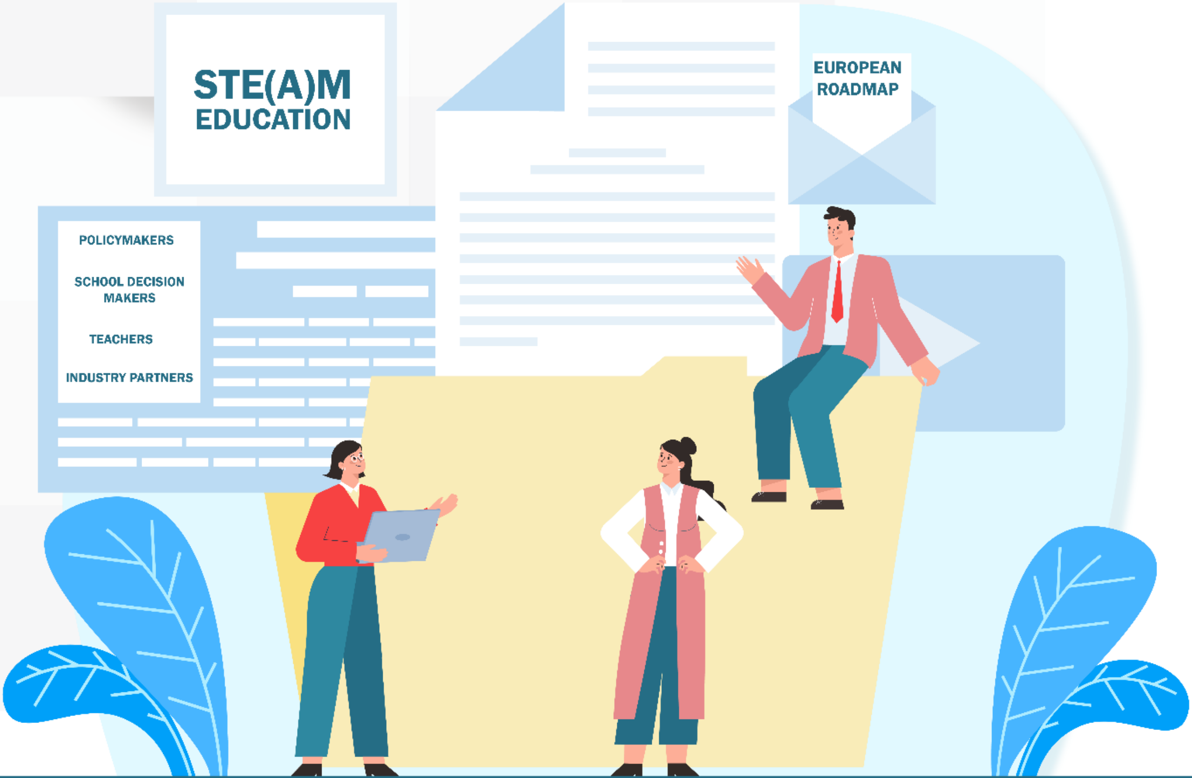
The SEER

STE(A)M EDUCATION EUROPEAN ROADMAP



Mapping of STE(A)M Education practices and policies: Current Trends

THE STE(A)M EDUCATION EUROPEAN ROADMAP

Funded by the European Union

The SEER receives funding from the European Union's Horizon Europe programme project The SEER (Grant agreement: 101058569) coordinated by European Schoolnet. The European Commission's support for the production of the SEER publications does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Project NO	101058569
DATE	30/8/2023
TITLE	**This document corresponds to *Deliverable 1.1 Mapping of STEM Education Practices and Policies V1* as per the SEER project .**
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WORK PACKAGE	WP1
CONFIDENTIALITY LEVEL[1]	Public

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[1] Confidentiality level:
Public = Public
Sensitive = Limited under the conditions of the Grand Agreement
EU Classified = Classified

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1. Introduction

Science, Technology, Engineering, and Mathematics (STEM) education is a key factor in promoting economic growth, innovation, and global competitiveness. It is crucial for addressing some of the major challenges facing Europe and the world, such as climate change, healthcare, and sustainable development. With the rapid advancement of technology and automation, there is a greater demand for workers with advanced STEM skills, which makes it imperative for Europe to prepare its' future workforce accordingly. At present, however, Europe faces several challenges in STEM education. The lack of qualified teachers, inadequate resources, and insufficient focus on practical applications of STEM subjects are just a few examples. These challenges have contributed to a growing skills gap, where employers struggle to find the skilled workers they need, while students lack the necessary knowledge and skills to pursue STEM careers. Integrating STEM subjects in education and showing pupils the interconnectedness of Science, Technology, Engineering, and Mathematics highlighting and especially its' relevance for the society, would help students to develop a holistic understanding of how these fields relate to each other and to the world around them. Teaching STEM in an integrated is assumed to break down the silos that often exist between different subjects, promoting collaboration and creativity and so scientific innovation and progress.

1.1 The STE(A)M Education European Roadmap Project (SEER)

To achieve mainstreaming of STE(A)M education in Europe, the SEER project will provide a set of roadmaps that will pave the way for the policy and institutional changes necessary for the large-scale implementation and offer guidance to teachers to help them navigate EU-funded STE(A)M education resources and projects.

As shown in Figure 1, the SEER will achieve the following by:

- Collecting and analysing current STE(A)M Education initiatives and policies and state of the art education practices in that field,
- Fostering exchange and dialogue among all STE(A)M education stakeholders to deepen the analysis of the misalignment between the practice and the core European objectives and identify strategies for a successful future for STE(A)M education, and
- Providing guidance for future actions and incentives for key education stakeholders (Ministries of Education, schools, parents, teachers) to adopt STE(A)M education.

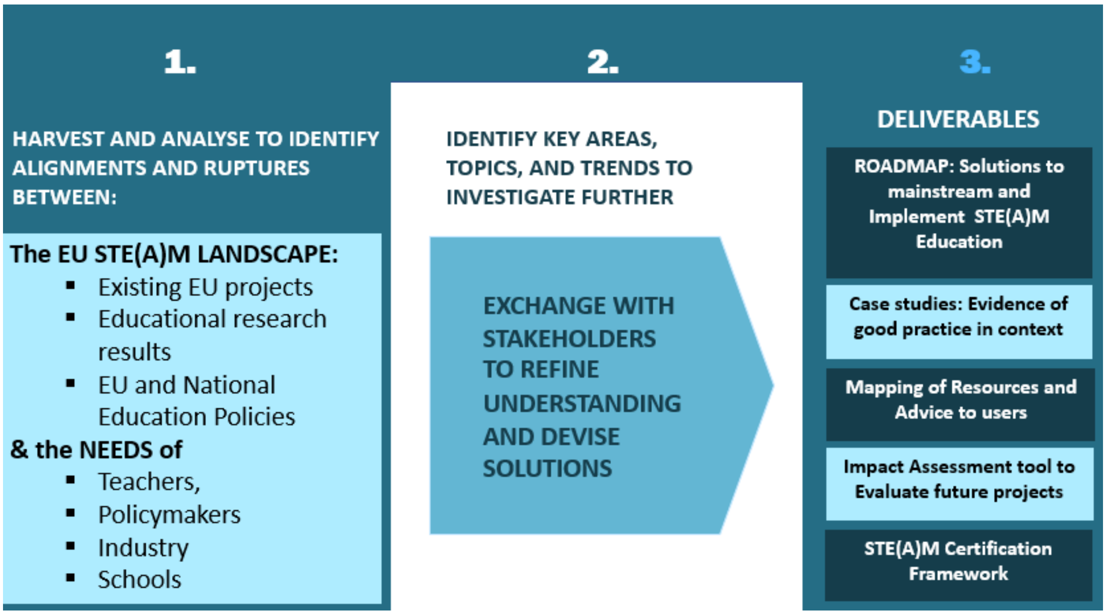


Figure 1: The SEER structure

1.2 Aims of the Report "Current Trends in STEM Education"

This report will provide deep analysis of EU policies and related practices, seeking to best understand what the ideal conditions for mainstreaming of STE(A)M education are, and how to implement them. The researching areas that will create a basis for the report include a literature review of trends in STE(A)M-educational research, a qualitative analysis of all European funded STEM Projects listed in Scientix project repository and the evaluation of national policies and measures in STEM education in the SEER Consortium countries.

Produced during the first year of the project, this report covers the investigation of current trends and gaps in STEM education. In order to gain insight into the effectiveness of STEM education initiatives in Europe, we conducted a qualitative analysis of the EU-funded projects listed on the Scientix web platform. Using the constant comparison method, we systematically reviewed the project descriptions and outcomes, identifying key themes and patterns in the data. This method allowed us to compare and contrast different projects, and to identify similarities and differences in their approaches and outcomes. Through this analysis, we were able to gain a deeper understanding of the strengths and weaknesses of these initiatives, and to identify areas for improvement in STEM education in Europe. By using a qualitative approach, we were able to capture the nuances and complexities of these projects, and to generate insights that would not have been possible with a purely quantitative analysis. Overall, this harvesting process provides valuable information for policymakers, educators, and researchers interested in promoting STEM education in Europe, and demonstrates the importance of qualitative methods in educational research.

2. History of STE(A)M-Education

2.2 What is STEM Education?

In the introduction we already highlighted the significance of STEM education and its role in science and society. An increasing interest in STEM-Education started in 2005 (Copeland et al., 2018) and has seen a notable increase in the funding since then, reflecting a predominantly positive outlook on STEM education as an educational framework, notwithstanding some criticism (McComas & Burgin, 2020).

Despite the consensus on its importance, what precisely constitutes STEM education remains a contentious issue within the academic community. Perceptions range from traditional, subject-oriented education to more integrated, inter-, or transdisciplinary approaches (Breiner et al., 2012). These diverse approaches are often combined with methodological concepts such as Inquiry-Based Learning (IBL), Project- or Problem-Based Learning (PBL), Design-Based Learning (DBL), and the use of real-life contexts, thus broadening the scope of understanding around STEM education and its main goals (Bybee, 2013; Ortiz-Revilla et al., 2022).

Delving into the history of STEM education offers further insights. The criticality of scientific literacy and technological advancement emerged predominantly in the aftermath of World War II. The foundations of STEM education can be traced back to the era of Dwight Eisenhower, following the establishment of institutions like NASA and the National Science Foundation (NSF) in the United States. The term 'STEM' itself was coined relatively recently. It is generally attributed to Judith A. Ramely, the former assistant director of the Education and Human Resources Directorate of the NSF, in the early 2000s. She modified, the original acronym 'SMET' used since the 1980's to the now universally recognized 'STEM' (Michael K Daugherty, 2013).

The NSF's definition of STEM fields is particularly inclusive and extensive. It goes beyond the traditional confines of mathematics, natural sciences, engineering, and computer and information sciences to incorporate social and behavioural sciences. This broad categorization includes disciplines like psychology, economics, sociology, and political science (Breiner et al., 2012). Therefore, understanding the varied interpretations and historical evolution of STEM education is essential to engage constructively with its multifaceted nature and impact.

Given these varying interpretations of what constitutes STEM education, it is indeed intriguing to ponder why these specific four disciplines - Science, Technology, Engineering, and Mathematics - have been merged under this umbrella term. What is the rationale behind this particular grouping, and why, for instance, was Mathematics chosen over Geography? The answer is that the different STEM-disciplines are intrinsically linked due to their shared skills and competencies, and is believed to have critical impact to technological innovation and economic growth (Bacovic et al., 2022). A common thread that weaves these fields together is the emphasis on real-word problems and problem-solving (Sanders), . STEM education fosters critical thinking, a skill that involves the analysis and evaluation of issues and ideas and is indispensable in all STEM fields (Marrero, M. E., Gunning, A. M., & Germain-Williams, 2014). These fields are often at the cutting edge of innovation and technology, constantly pushing the boundaries of knowledge and its practical applications. Quantitative reasoning is another key characteristic of STEM subjects, often requiring a solid understanding of mathematics and the ability to interpret data in different contexts (Doig, B., Williams J. et al., 2019). The spirit of research and experimentation is a key competence in all STEM fields also including mathematics (Leuders & Philipp, 2014).

2.3 Variations of STEM Education

To resolve the issue of different STEM-education aspects highlighted in the last chapter the comprehension of STEM education has been broadened in various ways. In this report, our primary focus is on the different forms of Integrated STEM and STE(A)M Education. Integrated STEM Education emphasizes the combination of diverse STEM subjects, while STE(A)M and its variants promote the integration of STEM with non-STEM fields and creativity.

2.3.1 Integrated STEM-Education

Integrated STEM education, often abbreviated as ISTEM, represents a comprehensive approach to teaching and learning in these disciplines. As the term suggests, it involves a multi-, inter-, or transdisciplinary strategy to "integrate" more than on STEM or non-STEM subject into a joint learning experience. Although as for STEM itself, there is no universally accepted definition of Integrated STEM, it is possible to delineate its various interpretations since most definitions have a similar setup. For example, Kelly and Knowles (2016) define"integrated STEM education as the approach to teaching the STEM content of two or more STEM domains, bound by STEM practices within an authentic context for the purpose of connecting these subjects to enhance student learning" (Kelley & Knowles, 2016, S. 3)

The core of this definition agrees with the most classical and modern interpretations, see for example (Bybee, 2013). Several overviews illustrate the differences and common aspects of different concept of integrated stem education (Razi & Zhou, 2022; Thibaut et al., 2018).

To examine key themes and methodologies of recent STE(A)M initiatives, we opted to review various (integrated) STEM and STE(A)M frameworks to identify commonalities and differences, thereby defining core and optional elements of their respective definitions. As part of this endeavour, we investigated 11 distinct integrated STEM frameworks.

Integrated STEM education usually emphasizes the integration of methodological advice and the inclusion of 21st-century skills in its teaching approaches. A framework for Integrated STEM typically combines three core elements: the number and type of subjects involved in an inter- or transdisciplinary manner, methodological aspects such as Inquiry-Based Learning (IBL), Project or Problem-Based Learning (PBL), and Design-Based Learning (DBL), and skills, which are usually subsets of 21st-century skills as creativity, communication etc.

The explicit definition of Integrated STEM within a framework often includes optional components. For instance, integrated learning may combine one, two, or three STEM subjects, and potentially non-STEM subjects, based on a shared or joint learning scenario. This scenario may optionally be set within a real-life or authentic context. Other optional components include 21st-century skills, and various learning methodologies like Inquiry-based learning (IBL), design-based learning (DBL), problem or project-based learning (unfortunately both are abbreviated with PBL). In summary by comparing the different integrated STEM-frameworks the various definitions of Integrated STEM can by systematically categorized as follows:

Typical structure: Integrated STEM definitions contain following optional components:

"*Integrated learning combines* n *(*$n \in \{1,2,3,\ldots\}$*) or more STEM subjects possibly (optional: also with non-STEM) based on a shared/joint learning scenario, together with optional elements as …*"

- 21 Century skills (as for example creativity, collaboration)
- Authentic context, real-life context etc.
- IBL, DBL, PBL etc.

As we will discuss later in the analysis of the Scientix Project-repository, the specific number of subjects or other chosen options does not significantly impact practical applications, hence it seems the simplest and mostly applicable definition suits best. So, for the purposes of our study, we define Integrated STEM Education as follows:

*“Integrated STEM learning combines the subject matter two or more subjects into a joint learning experience (*with at least one of these subjects belonging to STEM*)”*

2.3.2 STE(A)M Education

STE(A)M education, another notable variant of STEM education, originally referred to the integration of arts into STEM teaching. This approach emerged from the perceived lack of creativity among recent college graduates (Razi & Zhou, 2022). STE(A)M, or similar acronyms, now have various interpretations (Aguilera & Ortiz-Revilla, 2021), albeit similar, primarily aimed at shifting the focus of STEM education towards topics that appeal to underrepresented groups in STEM fields. However, much like STEM education itself, there is no universally accepted definition or purpose of STE(A)M education (Aguilera & Ortiz-Revilla, 2021).

Unlike Integrated STEM, there are fewer conceptualized definitions of STE(A)M education. However, the common thread seems to be the enhancement of creativity in the form of "expressiveness, evoking emotion, generating empathic understanding, stimulating imagination that disrupts habits of mind and creates open-mindedness, and eliciting emotional awareness" (Eisner, 2008). Hence, supported by empirical evidence as (Brown & McGrath, 2005) the primary objective of STE(A)M education is to bolster 21st-century skills such as problem-solving, creativity, and collaboration, by integrating non-STEM disciplines as arts, and thereby motivating students to explore novel ideas and approaches in order to address the challenges prevalent in the 21st century (Liao, 2016).

Henceforth, we will use STE(A)M education to refer to all the aforementioned variants. It is important to note that these distinctions have minimal practical implications, as almost all European initiatives use the term STE(A)M or similar acronyms without any specific definition.

The "A" in STE(A)M, originally standing for "Arts," now has various interpretations. These range from the original "Art," to skills such as engagement, creativity, innovation (Perignat & Katz-Buonincontro, 2019), to a broader "A" for "All," which meaning varies from includes arts, design, humanities (Ge et al., 2015) to all in a literal sense, usually without committing to forcing a connection to non-STEM subjects. So, the interpretation of STE(A)M also varies among authors. Some view it as an extension of the STEM acronym, simply allowing for the combination of art or other subjects with STEM subjects. Others see it as a restrictive approach, permitting only teaching methods that combine STEM subjects with art or any other non-STEM subject.

2.3.3 Some remarks on Integrated STEM and STE(A)M education

While the concept of Integrated STEM education can be defined with relative precision, there are subtle nuances in the various interpretations of this educational approach. Integrated STEM was introduced, at least in part, because real-world applications typically do not confine themselves to specific subjects, thus providing students with a more realistic understanding of the world. However, the requirement for authentic contexts, as suggested by Kelley et al. (2016), also depends on students' personal interests and attitudes. This makes it somewhat challenging to determine what qualifies as Integrated STEM and what not. The distinction between Integrated STEM and STE(A)M education largely depends on one's interpretation of STE(A)M education. For practical reasons related to the platform analysis, we will not specify any interpretation of STE(A)M education. Instead, we view it as a broad concept and leave it to the project leaders to determine whether their project qualifies as a STE(A)M project. This determination is made by simply looking for any form of STE(A)M in the project description.

2.3.4 Modern aspects of STEM education

Modern STEM education features several prominent topics, and as is characteristic of educational theories, the same concept can have as many definitions as there are authors discussing it. The goal is not to delineate these subjects with the utmost scientific precision, but rather to provide a broad overview of their implications.

Methodological aspects, such as Inquiry-Based Learning (IBL), Design-Based Learning (DBL), and Problem or Project-Based Learning (PBL), share cyclical aspects, centralizing on the identification of a solution and reflecting upon specific facets. Contexts in science education, particularly real-life or authentic learning experiences enhance the comprehensibility of the STE(A)M framework. In the evolving pedagogical landscape, diversity and inclusion have risen to prominence. Whereas diversity delves into understanding distinctions based on gender, culture, and other factors, inclusion aims to bridge these divides. Environmental issues, especially climate change and the decline in wildlife diversity, stand as pivotal challenges of the 21st century and hold significant relevance in STE(A)M education. This is in juxtaposition to sustainability education, which zeroes in on transitioning to eco-friendlier lifestyles.

Concepts from the world of work and entrepreneurship are integrated into STE(A)M education. This not only offers a realistic insight into career life but also accentuates the significance of STE(A)M across both STEM and non-STEM related fields.

The digital transformation of our society profoundly influences STE(A)M education. On one side, digital tools—ranging from videos and learning apps to widely accessible digital teaching resources—reshape the contemporary learning landscape. Conversely, the acquisition of digital competencies is essential for nurturing responsible citizens, thus emphasizing their critical role within STE(A)M education.

Numerous psychological factors hold significant weight in STE(A)M educational research. Constructs like self-efficacy, self-concept, and self-esteem are foundational to student development and play a decisive role in their choice to pursue a STEM career.

2.4 Trends in STEM-educational research

This section summarizes and presents the insights derived from several meta-analyses, all of which are aimed at identifying prevailing trends within the realm of STEM educational research. The primary objective of this synthesis is to spotlight the prominent topics and significant trends that have emerged in recent years within the field of STEM education. The meta-analyses varied in their objectives and conceptual frameworks, leading to subtly different conclusions. Nonetheless, each meta-analysis focused its research on a distinct set of STEM journals across varying timeframes.

The field of STEM education research has witnessed a substantial increase in interest, evidenced by an upward trend in the number of STEM-related research publications (Hsu et al., 2023; Li et al., 2019). This growing interest is further corroborated by an increase in the annual number of article accesses (Li et al., 2019). Nearly half of all such published articles have incorporated the acronym 'STEM' within their titles, underscoring the prominence of this field in contemporary educational research (Irwanto et al., 2022).

In recent years, there has been a noticeable shift in the methodologies employed in STEM education research. Earlier in the decade, around 2010, qualitative analyses were more prevalent. However, contemporary trends indicate a slight dominance of quantitative analyses (Irwanto et al., 2022; Li et al., 2020). Within the quantitative research area, surveys have emerged as the predominant method.

Conversely, in the qualitative domain, case studies have been the method of choice d (Bozkurt et al., 2019).

Numerous prominent topics have been examined across these meta-analyses (Bozkurt et al., 2019) and bibliometric analyses (Tas & Bolat, 2022; Zhan et al., 2022), and while they occasionally yield disparate results, several key themes in STEM educational research consistently emerge. For the sake of clarity, we present these topics without any hierarchical ranking and without asserting their comprehensiveness.

- Specific topics
- Skills
- Methodologies as inquiry-based education
- Gender, diversity, and inclusion
- Psychological factors as motivation and self-efficacy.

Research within the areas of integrated STEM, STE(A)M or similar variants is still rare This scarcity is particularly evident in the field of impact research, although preliminary findings suggest promising effects (Todd Richard Kelley et al., 2021). Nevertheless, the increase of existing frameworks, such as those developed by (Kelley & Knowles, 2016) for integrated STEM and (Spyropoulou & Kameas, 2020) for STE(A)M, lays a robust foundation for the expansion of impact research in these areas.

3. Outlook: Developments in National Policies

To get a clear idea of what exists and what still needs to be done to progress to the desired direction we are harvesting also national policies and initiatives in STE(A)M. First, we took a close look at the previous reports that were published in 2011, 2015 and 2018 and gave information about the current efforts to increase student’s interest in pursuing science, technology, engineering and mathematics studies and careers and STEM education.

3.2 National STEM Policies 2011 – 2018

In 2011 the questions inquired information about current national STEM strategies, modernizing pedagogical methods, measures for strengthening teacher training and professional development in STEM, promoting partnerships between schools, universities, and industry, increasing women participation in STEM, guiding pupils towards STEM careers and the role of technology in STEM agenda. Comparing the initiatives two main actions proved to be common: development of effective and attractive STEM curricula, teaching methods, and educators’ professional development. Because of low PISA results, most of the ministries and private sector had invested either in improvement of teaching in mathematics or all STEM subjects. Another common approach was to build connections between the different actors in STEM education and build networks of cooperation between schools, universities, industry, teachers, and teacher trainers. Already in 2011 there were a lot of initiatives that tried to ensure equal opportunities for boys and girls across the education system and targeted special career guidance initiatives, as well as inviting industry representatives to schools to talk about their careers or taking pupils to STEM workplaces.

In 2015 77% of all surveyed countries agreed that they follow overarching strategies in national education where the role of STEM education is highlighted. Around 70% of countries were prioritizing initiatives that promote use of ICT in STEM and 60% were focusing on the development of new or revised STEM teaching and/or learning resources. In some of the countries emphasis on teacher collaboration and peer learning was set which is very beneficial for fostering STE(A)M. Almost all surveyed countries planned or had already implemented online professional development courses for teachers. Surprisingly, 15 out of 16 STEM teacher competence areas were considered not to be adequately covered in initial teacher education. Only content knowledge was covered sufficiently in opinion of the surveyed countries.

The report in 2018 states that on European level there is no common understanding of what STEM refers to. In most surveys STEM appears to be interchangeable with "science teaching", a term used to refer to "all of physical sciences, life sciences, computer" (Report 2018 on national STEM measures). It is already stated out in this report, that mathematics plays a crucial role in teaching STEM subjects in an integrated way as most of the subjects require deep consideration of mathematics. There are various new methodologies and software applied in the STEM teaching (e.g., Kahoot, GeoGebra, etc.). Besides specific STEM courses there are also several initiatives being organized across Europe by different stakeholders, such as nonprofit organisations, companies, teachers' professional organisations, etc., yet they are not part of curricula or specific program.

Even though STE(A)M is not a term that would be used across Europe, we can observe a number of aspects that have been promoted in national policies throughout the years or at certain times that were promoting integrated STEM teaching. We will bring the developments in certain STE(A)M relevant aspects in a timeline as we analyse the survey that we have conceptualized specifically about STEM and STE(A)M education.

3.3 National STEM Policies 2023

To get an up-to-date information about the current state on national policies and initiatives, after careful analysis of the literature and past EU projects, we have developed a questionnaire on national STE(A)M policies that can be answered by national education experts in the fields of interest. This questionnaire, designed to uncover trends and detect gaps in STEM education across European countries, will feature both quantitative items, assessed through a Likert scale, and qualitative items. The quantitative items will be analysed using the programming language R. The qualitative items, on the other hand, will be analysed using an inductive coding system, with responses cross-validated by two independent researchers to ensure consistency and accuracy. This planned dual approach, amalgamating both qualitative and quantitative analyses, is anticipated to yield a comprehensive understanding of the future trajectory of STEM education in Europe.

The questionnaire is divided into 4 sections (A-D):

Section A: <u>STE(A)M education in the country</u>. This section aims to understand to what extent STE(A)M education is currently practised on national level.

Section B: <u>National STE(A)M policies and initiatives</u>. We have identified different areas that are enabling STE(A)M education and try to collect information on any ongoing or planned education strategies, policies, campaigns, initiatives, projects etc. that are promoting these aspects.

Section C: <u>Initial teacher education</u>. This section aims to collect information about current state of initial teacher educating programs and to what extent STE(A)M relevant skills are provided.

Section D: <u>Professional development courses for educators.</u> This section aims to collect up to date information about the possibilities to attend courses that improve STE(A)M teaching.

The surveys will be filled out in Autumn 2023 and the results will be presented in the next WP1 deliverable 1.2. in chapter 3.2. National STE(A)M policies 2023.

4. The Scientix Platform

As previously stated, the objective of this analysis is to comprehend the goals and objectives of all European STE(A)M initiatives listed on the Scientix Platform since 2000, with a particular emphasis on Integrated STEM and STE(A)M education and to put it in historical context. To specify further, we aim to discern the primary themes of these initiatives, their intended outcomes, their main target groups, and how these projects contribute to the overall development of STEM education. This comprehensive understanding will provide valuable insights into the current landscape and future development of STEM education in Europe.

4.2 Methodology

The focus of this research is to establish a comprehensive overview of European STE(A)M initiatives. To achieve this, we aim to answer several key questions. We seek to identify the prominent trends in European STE(A)M initiatives in recent years. Also, we aim to assess regional variations in these trends across Europe, such as differences between Eastern and Western Europe. Additionally, we plan to analyse the evolution of these trends over time. Lastly, we intend to examine the influence of target group perspectives, including learners, teachers, policymakers, and researchers, on these trends, with a particular emphasis on integrated STEM education. To summarize it we have three major research questions.

Q1: What are the most prominent trends in European STE(A)M initiatives in the last twenty years?
Q2: How have the trends in European STE(A)M initiatives evolved over the past twenty years?
Q3: Are there visible patterns or shifts in the focus of STE(A)M initiatives in Europe over time, and do these patterns depend on the target groups (learners, teachers, policymakers, researchers, …)?

In addition to these primary questions, we also aim to answer several secondary questions. These include investigating correlations between our results and historical developments, exploring connections with European education policies, and examining the alignment of these initiatives with EU funding programs such as FPx, Horizon, and Erasmus. These questions will provide a more nuanced understanding of the landscape of European STE(A)M initiatives and their alignment with broader educational and policy trends.

To gain insight into trends of STEM education initiatives in Europe, we conducted a systematic content analysis of the EU-funded projects in Europe. The analysis was conducted on the EU-funded STEM education projects listed on the Scientix platform (https://www.scientix.eu/projects) between 2000 and 2022 (n=784) during September 2022 and April 2023. The platform provides project descriptions, offering additional information for to researchers and educators. It also includes a list of all participating project partners, intended target groups, aimed educational level and other fundamental details. In certain instances, the outputs of these projects are, if the project team makes use of this function, directly accessible via the Scientix platform. The project descriptions on the platform, as well as project webpages and any available materials as teaching or learning materials, learning apps, were examined to identify key themes and major developments in STEM-Education across Europe. The categories were first derived from different STEM frameworks (see section 2) and then inductively extended using the constant comparative method (Glaser, 1965) generating a set of codes that captured the relevant information.

The foundation for this analysis is a coding manual developed for D1.1. that includes all categories and codes, along with examples for each case and clear instruction how to code. This manual serves as an extensive guide, ensuring consistency and accuracy in the coding process, which is crucial for the reliability and validity of our analysis. Two independent scientists coded the data using a combination of deductive and inductive approaches, generating a set of codes that captured the relevant information. The coders then compared their codes and resolved any discrepancies through discussion and consensus. To ensure scientific rigor and reliability, the intercoder reliability was checked using Cohen's Kappa after both coders adhered to coding manual mentioned before. By using independent coders and establishing intercoder reliability, we were able to enhance the credibility and trustworthiness of our findings, and to minimize the potential for bias and error in our analysis. However, in some cases both the scientists were unable to extract any valuable information from the available data.

We chose to bypass the target group, output type, and educational level descriptions provided on the Scientix repository. Instead, we derived this information from other available resources. This decision was made to ensure a more comprehensive and accurate understanding of these aspects, based on a wider range of data sources.

Following the initial analysis, all consortium partners of the SEER project conducted a review of the existing categories and codes. Based on this review, additional categories were identified and included. Subsequently, all projects underwent a second round of analysis, incorporating these new categories in the same manner as the initial round.

We also carried out a quantitative keyword analysis of all projects listed on the Scientix platform. However, due to technical constraints, our analysis was confined to the project descriptions available on the platform.

The objective of this analysis was to gather information on various aspects of the projects, including their intentions, primary themes, main target groups (such as teachers and students), principal outputs (like summer schools and teaching materials), types of stakeholders, and any other information pertinent to contemporary STEM education. With these considerations in mind, we developed the following categorization system, which we separated into multiple parts.

The first part of the analysis (Table 1) focused on purely formal aspects of the STEM-initiatives that can be derived directly from the project description.

Table 1: STEM education categories – Formal aspects of STEM-initiatives

Category	*Code(s)*
Coordinating Country	Country Name
Other Countries	Country Name(s)
Start Year/ End Year *Project Duration*	Integers
Stakeholder	Students Pre-Service Teachers In-service Teachers Policy Makers Teacher-Educators Industry Parents Other

Accessibility	Webpage not available Outputs not available Outputs behind wall

In the second part of the content analysis (Table 2), the focus is on identifying the main goals of STE(A)M initiatives, seeking information about the subjects or topics covered, the level of education targeted, the type of outputs produced, and the specific target groups involved.

Table 2: STEM education categories – main goals, outputs and target groups

Subject(s)	Science Technology Engineering Mathematics
Level of Education	Kindergarten Primary Lower Secondary Upper Secondary Vocational School Higher Education Special Needs Other
Outputs	Policy Brief (or recommendation) Teaching Material Learning Material Student activity Teacher activity Science Communication Other
Target Group	Students Pre-Service Teachers In-service Teachers Policy Makers Teacher-Educators Industry Parents Other

In the second part of the content analysis (Table 3), we conducted a detailed examination, specifically focusing on four key aspects: topics, methodology, skills, and expected impact on motivational aspects.

Table 3: STEM education categories: Topics, methodology, skills and impact

Category	**Codes**
Topics	Digitalisation Sustainability Environmental Issues Real-life Problems Diversity

	Inclusion Health STE(A)M Careers Other
Methodology	Inquiry based learning. Project based learning. Design based learning. Other
Skills	Creativity Collaboration Communication (Teachers) Communication (Learners) Problem Solving Other
Motivational Aspects	Self-Efficacy (teacher/learner) Self-concept (teacher/learner) Self-esteem (teacher/learner) Confidence (teacher/learner) Other

To analyse the different perceptions of STEM, particularly integrated STEM and/or STE(A)M, we initially focused on identifying projects that would qualify for integrated STEM education and how many subjects have been involved. If multi- or transdisciplinary approaches have been explicitly mentioned or at least been described this has been coded separately (Table 4).

Table 4: STEM education categories – Approach towards integrated STEM

Number of Subjects	Integer
STEM approach	Multidisciplinary Interdisciplinary Transdisciplinary
Integrated STEM (implicitly)	2 STEM Subjects and more 1 STEM Subject and at least one other subject
Integrated STEM (explicitly)	2 STEM Subjects and more 1 STEM Subject and at least one other subject
STE(A)M	Coded only if explicitly mentioned

In the process of our analysis, we found that Digitalisation, STEM Career and 'Diversity' emerged as particularly broad codes. Given their expansive nature, we made the decision to elevate these codes to the status of categories (Table 5).

Table 5: STEM education categories – Popular STEM themes

Digitalisation	Digital Competence development Digital content
Digital Content	Web application Videos Learning Apps Other
Diversity	Girls

	Gender Cultural diversity Performance diversity
STEM Career	Career Entrepreneur Word of Work

4.3 Limitations

This analysis is subject to several limitations. Firstly, the scope of the analysis is confined to the projects listed on the Scientix repository, which may not be representative of all STE(A)M initiatives in Europe during this time. Secondly, the quality, completeness, and accuracy of the project or research descriptions provided on the Scientix repository, and the project webpages may vary, and in some cases, may not be entirely accurate. Thirdly, there are instances where the information on the webpage or the project outputs contradicts the project description. Additionally, some webpages or project outputs are no longer accessible, and, in some cases, both the scientists were unable to extract any valuable information from the available data limiting the comprehensiveness of our analysis Furthermore, we did not conduct a quality assessment of the project outputs, which could potentially affect the interpretation of the results. Lastly, qualitative analysis inherently involves subjective interpretation of texts, which can introduce potential biases. However, by implementing intercoder reliability measures, utilizing a coding manual, and cross-checking interpretations among two coders, these biases should have been reduced to a minimum.

5. Analysis

The importance of STEM education in general and the need for improvement have been highlighted before. The European Union has offered longstanding support to STEM education initiatives within its flagship programs, Horizon Europe and Erasmus Europe as well as their predecessors, allocating substantial funding towards this cause. Beyond assessing the impact of these initiatives, it is crucial to understand their objectives and targets. These goals not only reflect the needs and aspirations of the European educational sector, but they also serve as an indicator for the direction and priorities of STEM education. The general aim of this chapter is to understand the core elements and basic aims of STE(A)M initiatives in Europe and how they contribute to the development of STEM education in general.

5.2 Formal Aspects

Our focus for the present analysis (see Table 6) was primarily on formal aspects. We examined a total of 778 projects. The time required for the analysis of each project ranged from 25 to 90 minutes. In 15 instances, we were unable to extract any information due to the inaccessibility of Scientix and/or project webpage, or the project description failing to provide any valid information. Our coding scheme comprised 69 categories, and we applied a total of 14,632 codes. This extensive analysis underscores the breadth and depth of our investigation into these STEM education projects.

Table 6: Number of projects analysed

Projects in Total	Projects Analysed	Categories	Used Codes
777	763	69	14632

The number of projects registered on the Scientix platform increases usually every two weeks, and the timing of registration does not consistently align with the project's lifecycle. Projects are often registered to Scientix after their initiation, and in some instances, even after their conclusion. Consequently, conducting a real-time analysis using the Scientix repository is not feasible. This temporal inconsistency in project registration necessitates a retrospective approach to analysing the data available in the Scientix repository (Figure 2).

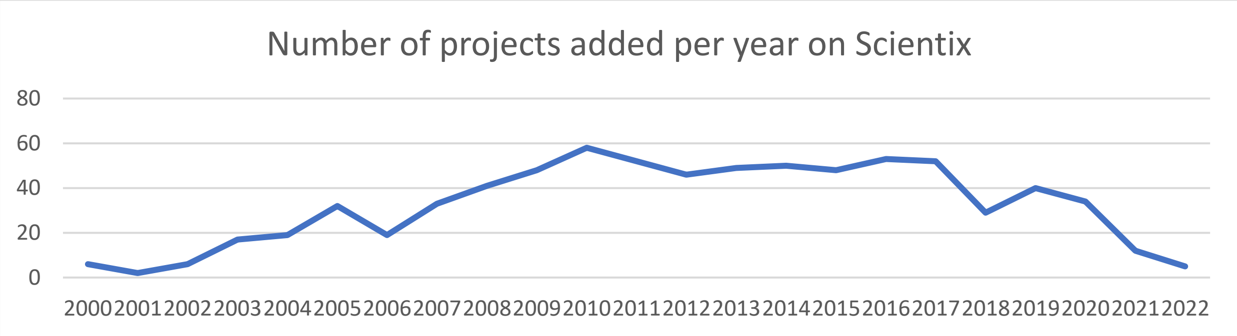


Figure 2: Number of projects added, per year, on Scientix between 2000-2022

The duration of the projects typically spans between two and three years, with an average duration of approximately 2.53 years and a median duration of 2 years. The countries most frequently coordinating these projects include Spain (9%), Germany (7.8%), Belgium (7.6%), Italy (7.4%), the United Kingdom (6.8%), and Greece (5.1%).

The accessibility of project pages and their associated outputs is a critical factor (Table 7), as it directly impacts the availability of all project outputs and, consequently, the overall sustainability of the project. To systematically categorize the accessibility of a project, we introduced a hierarchical coding system. This system comprises three distinct codes that deviate from the standard norm. Our hierarchical coding system for project accessibility is as follows: **Materials Behind a Wall** describes projects that are accessible upon registration. While these materials are not openly accessible, they can be reached once the registration process is completed. The next level of accessibility pertains to projects where **outputs are no longer available**, at least partially. This indicates that while some aspects of the project may be accessible, others have been removed or are otherwise inaccessible. The highest level of inaccessibility is assigned to **projects where the entire webpage**, including all included outcomes and information, **is no longer accessible**. This represents a complete loss of access to the project and its associated materials.

Table 7: Accessibility of project pages

Materials behind a wall	Outputs not available	Webpage inaccessible
14 1,83%	298 39,06%	222 29,10%

The data reveals that in the case of projects that have been added to Scientix in the last 4-5 years (Figure 3), it is uncommon to encounter missing or broken links, rendering the information unavailable. Furthermore, for project sites that have concluded three years or more ago, a substantial proportion is completely inaccessible. Cumulatively, there are now over 220 from 778 webpages of projects thar are now inaccessible and their outputs are no longer directly accessible. This situation could be attributed, at least in part, to evolving regulations, such as data protection rules, which have impacted the availability of these resources.

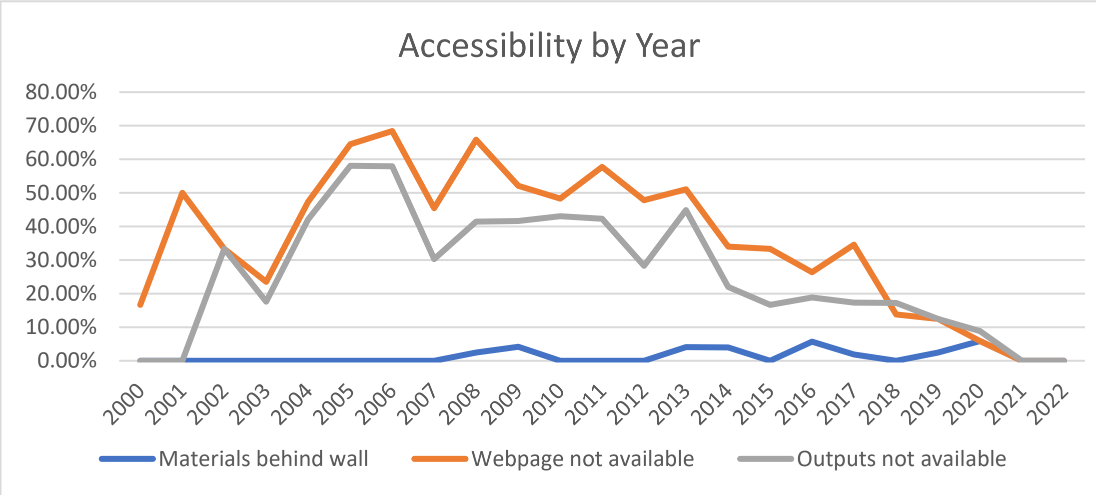


Figure 3: Accessibility of projects over the years 2000-2022

5.3 Target Groups and outcomes

As indicated, we extracted the main target groups directly from the project descriptions and by reviewing the project outputs (Table 8). In-service teachers and students emerge as the primary target groups for STE(A)M initiatives, significantly outnumbering other groups. Other notable target groups include the public and researchers. It is evident that teachers and students are the primary focus of these initiatives, reflecting their central role in the educational process. The industry sector is less frequently targeted by STE(A)M initiatives, despite its significant stake in the outcomes of STEM education.

The data presented in the subsequent graph (Figure 4) suggests a relative stability in the trends over the recent years. This implies that there has been no significant shift or transformation in the observed patterns during this period.

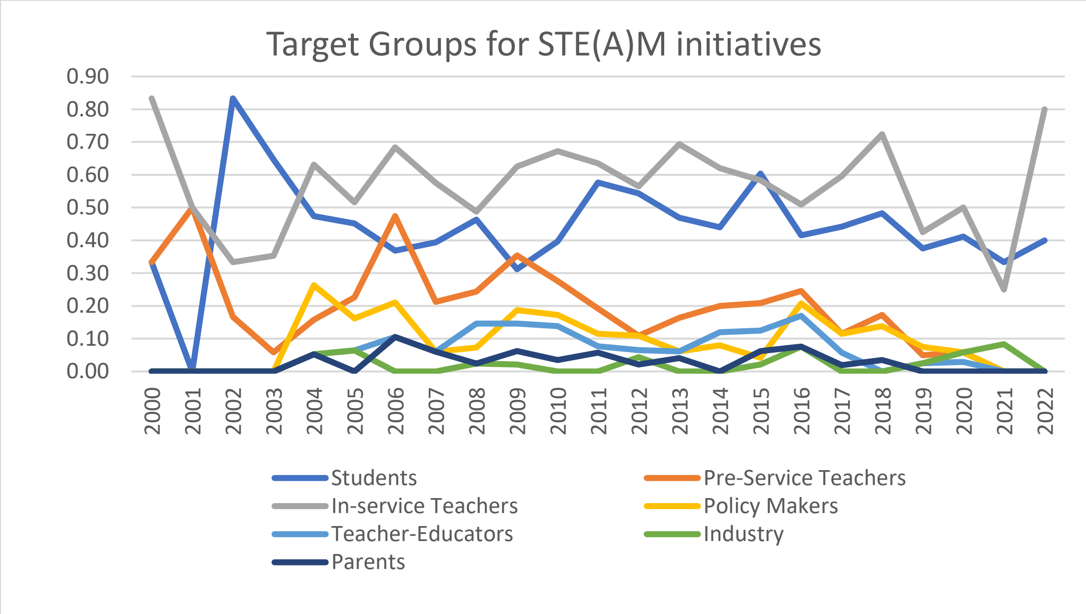
Students	Pre-Service Teachers	In-service Teachers	Policy Makers	Teacher-Educators	Industry	Parents %
341	145	435	84	64	16	26
44,69%	19,00%	57,01%	11,01%	8,39%	2,10%	3,41%

Table 8: Target groups for STE(A)M initiatives

Figure 4: Target groups for STE(A)M initiatives between 2000-2022

The main target group for STEM education initiatives are teachers and students in secondary education (Table 9). There has been no substantial change in this in the recent years.

Table 9: STEM education initiatives target groups across school levels



Kindergarten	Primary	Lower Secondary	Upper Secondary	Vocational School	Higher Education	Special Needs
41	337	525	510	125	96	11
5,37%	44,17%	68,81%	66,84%	16,38%	12,58%	1,44%

In terms of subject areas within STE(A)M initiatives (Table 10), science emerges as the most prominently featured, while engineering is the least represented. On average, projects cover 2.24 subjects (sd = 1.1), with science being counted as a single subject. The distribution of subjects has remained relatively stable over the years.

Table 10: Representation of subject areas within STE(A)M initiatives

S	T	E	M
621	462	253	310
81,39%	60,55%	33,16%	40,63%

Most projects produce learning or teaching materials, even though these terminologies are often used interchangeably. This suggests a strong emphasis on the creation of practical resources that can directly support the teaching and learning process in STEM education. Conversely, policy recommendations appear to be less common in the output of these projects (Table 11).

Table 11: Outputs of STE(A)M initiatives

Teaching materials	Learning materials	Learning material or teaching material	Student Activity	Teacher Activity	Policy recommendation	Science Communication
375	237	418	259	272	77	119
49,15%	31,06%	54,78%	33,94%	35,65%	10,09%	31,06%

For teachers and students, the activities typically encompass workshops, professional development courses, summer schools, and similar educational events. These activities are designed to provide hands-on learning experiences, enhance professional skills, and foster a deeper understanding of STEM subjects.

5.4 Topics

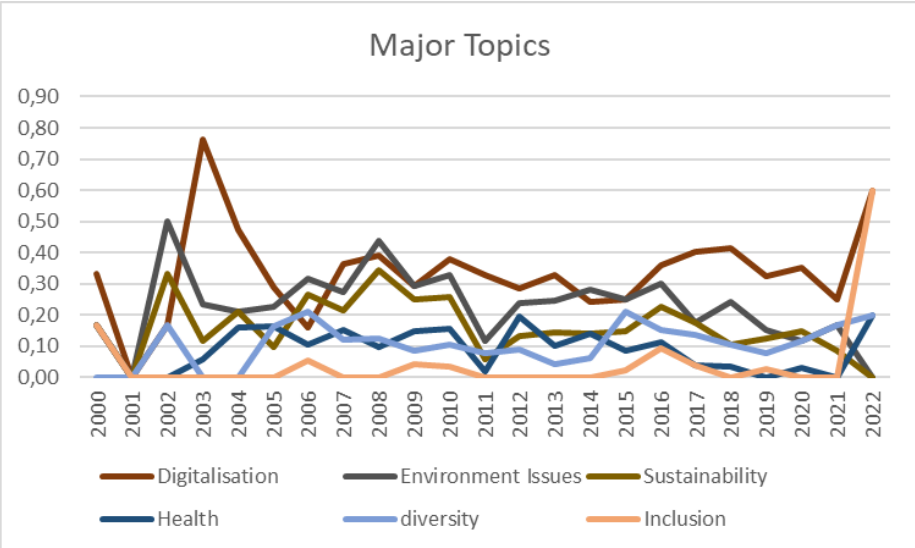
One of the main goals of this study was to gain insights into the activities and trends of European STE(A)M initiatives in recent years. A significant proportion of these projects revolve around STEM-themed topics, which can be classified into various categories (Table 12). Conversely, other projects concentrate on the development of educational concepts and frameworks, without a specific focus on any topic.

Table 12: Categories of themes and topics covered in STE(A)M initiatives

Careers	Digitalisation	Environment Issues	Sustainability	Health	Diversity	Inclusion
175	L273	196	140	77	88	15
22,94%	35,78%	25,69%	18,35%	10,09%	11,53%	1,97%

Digitalisation appears as the most prevalent theme, featuring in 35.78% of the projects (Figure 5). **Environmental issues and careers** are also significant themes, addressed in 25.69% and 22.94% of the projects respectively. **Sustainability** is incorporated in 18.35% of the projects, reflecting its relevance to contemporary societal issues. **Health and diversity** are addressed in 10.09% and 11.53% of the projects respectively. Inclusion (1.97%) is rarely recognized with small pikes in 2016 and 2022.

Figure 5: Major topics covered in STE(A)M initiatives through the years



As previously noted, the concept of digitalisation within STE(A)M initiatives can be separated into two distinct aspects. The first involves the provision of digital tools as learning materials, equipping learners, or teacher with practical digital resources. The second aspect pertains to the development of digital skills (Vuorkari et al., 2022). However, the explicit focus on the development of digital competencies or skills is comparatively rare. Less than 5% of all projects specifically focus on these skills (Table 13). This is even though such competencies are inherently developed in projects that concentrate on areas like coding, robotics, 3D printing, and so forth.

Table 13: Classification of digital tools and development of digital skills

		Answers	
		N	%
Digital Skills	All digital Skills	101	13,24%
	Robotics	58	7,60%
	Programming	65	8,52%
Total		763	100,0%

21st century skills play a dominant role in European STE(A)M initiatives (Table 14). Problem-solving emerges as the most frequently addressed skill, featuring in 60.55% of the projects, reflecting its central role in all STEM subjects, as pointed out earlier. Communication and collaboration skills, both for teachers (17.56%) and students (25.82%), are also targeted, albeit less frequently. Creativity and critical thinking are incorporated in 18.61% and 20.97% of the projects respectively.

Table 14: 21st century skills in STE(A)M initiatives

Problem Solving	Communication & Collaboration (Teachers)	Communication & Collaboration (Students)	Creativity	Critical Thinking
462	134	197	142	160
60,55%	17,56%	25,82%	18,61%	20,97%

A substantial number of projects within the analysed set place a focus on specific learning methodologies (Table 15), with Inquiry-Based Learning (IBL) emerging as the most frequently employed (20,58%) approach. However, it's important to note that methodologies such as IBL and Project-Based Learning (PBL) encompass a broad spectrum of interpretations and implementations. As such, the extent to which these methodologies have been utilized in their various forms within these projects is not immediately clear.

Table 15: Learning methodologies employed in STE(A)M initiatives

		Answers	
		N	%
Methodologies	Inquiry Based Learning	157	20,58%
	Project-based learning	39	5,11%
	Problem-based learning	26	3,41%
	Design-based learning	4	0,52%
Total		763	100,0%

When examining the target groups and topics covered (Table 16), there are not many significant differences observed. However, one notable distinction is that the theme of diversity is less frequently addressed for teachers and students, and more so for policymakers. Conversely, environmental issues are more commonly addressed in the context of teachers and students, and less so for policymakers.

Table 16: Topics addressed among target groups

		Policy Makers	In-service Teachers	Students
Topics	Real-life Problems	44,44%	51,54%	59,38%
	Digitalisation	31,94%	45,13%	43,08%
	Environmental Issues	18,06%	30,00%	33,23%
	Health	16,67%	10,77%	12,31%
	Diversity	27,78%	12,05%	12,31%
	Inclusion	4,17%	3,08%	2,15%
	STEM Careers	33,33%	25,64%	31,08%
	Total	100%	100%	325

The validation of impact within these STEM education initiatives is infrequently observable. Despite many projects providing descriptions in the research section of the Scientix repository, scientific publications detailing the success and impact of these initiatives are seldom mentioned on the Scientix repository or the project webpage. When considering psychological and motivational factors, by definition, almost all initiatives (especially those involving teacher or student activities) could potentially impact performance, motivation, or self-efficacy. Among these, the increase in motivation is the most frequently cited outcome (14.8%), followed by performance (7%), and finally self-efficacy or related terms (2.8%). However, it's important to note that the absence of explicit mention of these outcomes does not necessarily imply that they have not been enhanced or validated. It simply means that such improvements are not readily visible or explicitly reported within the available project descriptions or outputs.

5.5 STE(A)M and integrated STEM

As mentioned previously, diverse methods of incorporating subject-related approaches are prevalent in contemporary STEM education. From a theoretical point of view integrated STEM approaches can be classified systematically while STE(A)M approaches may rely on more subjective interpretations. The goal is to discern the prevailing concepts in European STE(A)M education. At the heart of both integrated STEM and STE(A)M education are concepts that connect subjects. While these two approaches are closely related, they are distinct and require equitable consideration.

The table below (Table 17) provides an overview of the number of projects that can be classified as STE(A)M or integrated STEM projects. The term 'integrated STEM' implicitly refers to interdisciplinary projects that, based on their description and/or main topic, combine at least one STEM subject with at least one other subject, which may or may not fall within the STEM category. It is extremely rare to find integrated STEM projects that connect only one STEM subject to at least one non-STEM subject (n=3). In all other instances, more than one STEM subject relates to a potential non-STEM subject.

The terminology of 'integrated STEM' and 'STE(A)M' and its variants is not frequently used. However, the use of 'STE(A)M' or equivalent terms has seen a significant increase in prominence since 2018 (more than 40 of 52 STE(A)M projects started 2018 or later).

Table 17: Usage of Integrated STEM/STE(A)M terminologies

Integrated STEM (explicitly)	Integrated STEM (implicitly)	STE(A)M
20	310	52
2,6%	40,63%	6,8%

The table also indicates that most initiatives have multidisciplinary topics, but scientific terminology is rarely used. Moreover, non-STEM subjects as arts or humanities explicitly mentioned in 40 initiatives, 9 of them use the terminology STE(A)M or something equivalent. This underscores the imperative for a more standardized nomenclature. Moreover, only 10% of all projects explicitly mention the use of interdisciplinary methods, suggesting that while multiple disciplines may be represented, they are not necessarily integrated or interconnected in these projects. Furthermore, transdisciplinary approaches are almost never mentioned.

6. Findings

6.2 General Findings

In our analysis, we noted that the majority of the main target groups for these initiatives are teachers or students. This highlights the emphasis placed on these demographics in STEM education. However, there are **notable discrepancies between the project descriptions and the information provided on their respective webpages**. This inconsistency can potentially lead to confusion or misinterpretation of the project's intent and outcomes. In particular we found that the descriptions of project outputs and target groups often lacked precision. A common oversight was classifying indirect target groups as direct ones, leading to **unsuccessful engagement with the intended audience**. Consequently, the process of determining the objectives of the projects and finding accessible outputs can be quite time-consuming and may not be possible at all. In general, it can be challenging for users to find relevant projects and resources without first knowing project titles or acronyms. furthermore, we observed that over 25% of the **project outputs are no longer available** through their original webpage/website or on any other platform (in part due to the webpage no longer being online) This reduces the discoverability for all possible interested groups as researchers, teachers, policymakers effectively significantly impacting the projects relevance at all.

The lack of clarity in project outputs and descriptions will certainly have a negative impact on the understanding and success of the projects, possibly preventing them from achieving their objectives. Therefore, there is a clear need for more accurate and detailed descriptions of project outputs tailored to different target groups as teachers, researchers, policymaker etc. This will ensure a better understanding of these initiatives and their contributions to STEM education. This observation also suggests that the development of more streamlined, target-group(s)-oriented and user-friendly concept for a project presentation including all outcomes that could increase the accessibility in general. A concise project description may improve the visibility of projects outcomes effects on STEM education and so increase the efficiency of research and analysis in this field.

6.3 Teaching and learning outputs.

As pointed out before over 50% of the outputs, teaching or learning materials, are designed mainly for **secondary education**. Again, the lack of precise target-group oriented projects descriptions, for example mixing the term learning and teaching materials, effectively reduces the discoverability and usability for aimed target groups. Together with the fact that more than 25% of all project pages are not available anymore there is a clear room to sustain project outcomes and results.

6.4 Trending Topics in STEM Education

Several key themes emerged as popular topics in both STEM educational research and European STEM-initiatives, including **sustainability, digitalization, gender diversity, integrated STEM, and STEM careers**. However, it's noteworthy that certain subjects, such as diversity (excluding gender diversity), inclusion and special education, which are prominent in STEM educational research, did not feature as prominently in European STEM-initiatives. This discrepancy suggests that while these areas are recognized as significant in the broader field of STEM education research, they may not yet be receiving equivalent attention in practical initiatives at the European level, indicating potential areas for future focus and development.

Self-efficacy emerges as a prominent topic in educational research in general, believed to significantly influence STEM career choices (Blotnicky et al., 2018) and play a crucial role in addressing gender-sensitive issues (Rittmayer, M.A. & Beier, M.E., 2008). However, despite its potential relevance, it is rarely explicitly mentioned in project descriptions. Furthermore, when claims of improved self-efficacy are made, they often lack supporting scientific evidence. This highlights a potential gap between educational research and practical implementation, suggesting the need for more rigorous scientific backing in project descriptions and a greater focus on self-efficacy in STE(A)M initiatives supported by accompanying research within the EU-projects.

Sustainability and environmental issues have risen to prominence in recent STEM education, reflecting the growing global emphasis on these concerns. However, there is a clear practical distinction between sustainability and environmental issues, each requiring unique approaches and solutions. This distinction is clearly reflected within European STEM-initiatives.

Common outputs in these areas include teaching materials, learning materials, out-of-school learning opportunities, and challenges. The emphasis is primarily on integrated STEM education, underscoring the importance of a holistic approach to these complex issues. While these projects have the potential to increase self-efficacy, this aspect is often overlooked or lacks empirical support, suggesting a need for further research and focus in this area.

Digitalization has emerged as the most prominent topic in STEM education, a trend that is partially reflected in STEM educational research. Digitalization impacts various aspects of STEM education, enhancing accessibility to teaching and learning resources. This includes the utilization of digital tools such as coding for sustainability, 3D printing, and robotics, which contribute to the development of competencies in using these tools.

Digitalization can be categorized into two main areas: the production of digital resources, such as web apps, learning videos, and digital tools, which is the case in most projects; and competence in using digital tools (Vuorkari et al., 2022), which is implicitly included in approximately 10% of all projects through coding, 3D printing, and robotics, but is as a competence rarely explicitly mentioned. Interestingly, we observed a clear spike in projects focusing on digitalisation in 2020, which is likely correlated with the shift to online learning due to the SARS-CoV-2 crisis. This underscores the pivotal role of digitalization in ensuring the continuity and accessibility of STEM education in challenging times.

Diversity, particularly gender diversity, is a common topic in STEM educational initiatives, with a slight increase in focus in recent years. Prominent content areas include gender-sensitive education and role models. However, other types of diversity do not play a less significant role, a finding that contrasts with modern STEM educational research, which often emphasizes the importance of diverse representation (*Education and Training Monitor 2021*, 2021). Inclusion does not play a significant role either, although there were small peaks in 2016 and 2022, likely corresponding to the European refugee crisis and the Ukraine-Russia conflict, respectively. These peaks suggest that global events and crises can influence the focus of STEM education initiatives.

In terms of stakeholders, most projects have a diverse consortium with partners from different countries and different stakeholder groups, even though partners from industry are rare. This is particularly surprising given the current shortage of STEM workers. This observation suggests a potential area for improvement, as industry partnerships can provide valuable real-world insights and opportunities for students.

6.5 Interdisciplinary approaches in STEM Education

One of the objectives of this analysis was to gauge the degree to which there is a shift from traditional subject-focused education towards a more integrated approach in STEM education.

Our analysis reveals a clear upward trend in an integrated STEM education, with most recent projects aligning with this approach in particular at secondary education level. However, **the terminology used in this field, if any, is not uniform**. Terms such as Integrated STEM, STE(A)M, and Inter/transdisciplinary STEM education are rarely used and if, then often used interchangeably, but their interpretations may vary. Especially in the case of STE(A)M education and its variants it is rarely mentioned what this term means.

Despite terminological issues most recent STEM-initiatives cover interdisciplinary topics. There is generally no scientific evidence as to what extend an interdisciplinary approach is implemented successfully in the projects' outputs.

It is important to note that the extent to which a project is inter- or multi- disciplinary cannot be directly observed or measured and just relied on the project or output description. Even though almost all projects cover multi-disciplinary topics, and many projects imply interdisciplinary approaches, it is not commonly explicitly mentioned. With that in mind, most projects address topics that are suited for an integrated STEM respectively STE(A)M-approach. However, it is rarely explicitly stated whether they truly adopt such an approach.

Integrated STEM and STE(A)M projects are almost always linked to real-life problems but the methodological aspects of inter- or multidisciplinary approaches cannot be observed directly and had to be extracted from the project description. Projects that focus on Inquiry-Based Learning (IBL), Design-Based Learning (DBL), Problem-Based Learning or Project-Based Learning (PBL) are in the most cases projects that qualify as integrated STEM or STE(A)M projects.

Despite the existence of various definitions of Integrated STEM education, the terminology is rarely used and the distinctions between them hold no practical relevance. The number of STEM-subjects involved, as well as the incorporation of non-STEM subjects, exerts minimal influence on whether a project qualifies for categorization as integrated STEM. Fundamentally, they convey the same interdisciplinary core concept, albeit under different terminologies. This observation underscores the importance of focusing on the underlying principles of these initiatives rather than the specific terms used to describe them. With that in mind we again emphasize a simple and clear as possible definition, understandable for all different target groups and focusing on the interdisciplinary character avoiding any further methodological requirements:

STE(A)M teaching and learning combines the subject matter of one or more STEM subjects with that of a non-STEM subject into a joint learning experience (which topic is not necessarily in STEM)

The term STE(A)M and its variants have significantly risen in popularity over recent years, surpassing the usage of 'integrated STEM,' albeit the explicit integration of arts, design, and humanities is rarely the case, regardless of whether the STE(A)M concept is employed. The emphasis on creativity alone does not sufficiently distinguish STE(A)M from STEM or integrated STEM. While the term STE(A)M may sound more appealing than 'integrated STEM,' there remains a need for a more explicit and actionable definition, explicitly addressing the role of arts and humanities within these projects.

7. Recommendations and areas of improvement for the SEER-Roadmap.

Throughout Europe, a diverse assortment of stakeholder groups has introduced STE(A)M initiatives that address a broad spectrum of topics. These predominantly multidisciplinary initiatives focus specifically on the challenges of the 21st century. While they indeed mirror societal needs, they produce a vast array of project outcomes, primarily in the form of teaching and learning materials. Such resources have the potential to significantly shape the STE(A)M educational landscape in Europe.

However, a challenge emerges when attempting to navigate this expansive educational terrain. Locating materials for particular topics or subjects is cumbersome without specific knowledge of project titles or acronyms. **The visibility of European educational projects at the national level remains uncertain, especially given that most project outputs are not translated into every European language, understandably due to high translation costs**.

Improving this situation requires target group-oriented project outcome descriptions that are both effective and time-efficient to search. Additionally, **the language used in these materials is not always oriented towards the intended audience**. For instance, terms that are prominent in research, like "self-efficacy," may rarely appear in STE(A)M initiatives. Varying terminologies across different target groups also necessitate diverse descriptions tailored to each group, be it teachers, researchers, or policymakers.

One notable observation is the emphasis on multidisciplinary topics in most projects. While these themes undeniably echo societal needs and are aimed at addressing 21st-century challenges, their practical integration into classrooms remains ambiguous. European secondary school teachers, who typically specialize in one or two subjects, face challenges in delivering interdisciplinary lessons. The intricate nuances between even closely related subjects, such as theoretical physics and mathematics, further complicate this. **High-quality Integrated STEM education mandates teachers to have proficiency in multiple subjects or to adopt collaborative teaching methods.** Moreover, employing methodologies like Inquiry-Based Learning (IBL), Design-Based Learning (DBL), and Problem-Based Learning (PBL) can be resource-intensive. These realities highlight the intricacies of implementing

STE(A)M or Integrated STEM and raise questions about its feasibility for all but the most specialized educators. This underlines the need not just for new teaching materials, but also for enhancing teachers' competencies. This also has implications for policymakers shaping STE(A)M curricula.

A significant concern is evaluating the impact and efficacy of STE(A)M initiatives. Although we don't doubt the general quality of these projects, their suitability for specific target groups remains inconclusive. Given the apparent lack of research and evaluation in European STEM initiatives, discerning which outcomes are effective under various conditions is challenging. There exists a **pressing need for evidence-backed outcomes**, failing which initiatives might face funding challenges or stricter requirements. Identifying best practice projects and enabling target groups to provide transparent feedback could help pinpoint effective teaching and learning innovations.

In conclusion, **a roadmap is essential for structuring the European STE(A)M initiative landscape**. This roadmap should encompass a target-group oriented overview of central aims and outcomes. A detailed delineation of prevailing trends, combined with the identification of best practices, can amplify the visibility and perceived importance of STEM initiatives. Platforms like Scientix should provide project presentations that address the core content with respect to the targeted stakeholder group, thereby offering supplementary projects in addition to best practices.

A subtle yet vital factor to consider is the interconnection among diverse initiatives. Although distinct on the surface, various projects can collaborate to create a more holistic perspective. This synergy may materialize through the integration of components such as professional development, instructional resources, and digital content, such as videos, from various STE(A)M initiatives. Identifying and emphasizing these 'collaborative intersections' within the SEER roadmap could provide a more comprehensive grasp of the STE(A)M educational landscape.

Furthermore, although platforms like Scientix have initiated central calendars for events such as professional development courses for teachers, conferences for scientists, and summer schools for students, broader implementation can further boost engagement and awareness.

A more concise synopsis of these recommendations is provided on the frame below. This synopsis will be taken onboard within the SEER project and contribute to the development of the Roadmap idea, while it will also shape the project’s future research but also outreach activities and initiatives.

RECOMMENDATIONS

1. Improve access to STE(A)M resources: One of the primary recommendations is to enhance access to STE(A)M resources in Europe. Given the diversity of initiatives across the continent, it's crucial to make these materials easily discoverable. To achieve this:

- Develop target group-oriented project outcome descriptions that are efficient for searching.
- Address language barriers by providing translations of project outputs into various European languages, prioritizing high-impact resources.

2. Provide tailored communication for diverse audiences: Recognizing the varied stakeholders involved in STE(A)M education, it's essential to tailor communication to meet their specific needs:

- Customize project descriptions and terminology to suit teachers, researchers, policymakers, and other stakeholders.
- Ensure that the language used in materials is accessible and relevant to the intended audience.

3. Teacher competency enhancement: To enable the effective implementation of multidisciplinary STE(A)M initiatives in classrooms:

- Support the professional development of secondary school teachers in multiple subjects or collaborative teaching methods.
- Encourage the adoption of resource-intensive teaching methodologies like Inquiry-Based Learning (IBL), Design-Based Learning (DBL), and Problem-Based Learning (PBL) with necessary support.

4. Evidence-backed impact evaluation: To ensure the efficacy of STE(A)M initiatives and secure continued funding:

- Promote research and evaluation efforts to assess the suitability of projects for specific target groups.
- Identify and highlight best practices within the STE(A)M education landscape.
- Encourage transparency and feedback mechanisms from target groups to refine teaching and learning innovations.

5. Collaborative integration: Recognize the potential for synergy among diverse STE(A)M initiatives:

- Emphasize the interconnections between projects and encourage collaboration.
- Facilitate the integration of various components, such as professional development, instructional resources, and digital content, to provide a holistic perspective of STE(A)M education.

6. Amplify engagement and awareness: To increase engagement and awareness of STE(A)M initiatives:

- Expand platforms like Scientix to provide central calendars for professional development courses, conferences, and summer schools.
- Encourage broader participation in these events to foster a sense of community and shared knowledge in STE(A)M education.

8. Concluding Remarks

Upon comparing the findings from Integrated STEM framework summaries, STEM education research trends, and our analysis of trends in European STE(A)M initiatives, we propose the following actions:

1. Standardizing frameworks, objectives, and opportunities for Integrated STEM and STE(A)M teaching can promote consistency and effectiveness in education.
2. Further investigation to validate the effectiveness of Integrated STEM and STE(A)M in improving STEM education.
3. More dissemination of the Integrated STEM and STE(A)M teaching concept. This suggests that there is still considerable room for expansion and further integration of this approach in educational settings. It underscores the need for continued efforts to promote and implement Integrated STEM education to fully leverage its benefits.

A principal constraint of this study is the extent to which project descriptions accurately represent the content of the project outcomes and results. While we have for example analysed all accessible policy recommendations using an assessment grid collecting basic information, we did not gather information about the intrinsic quality of the project outcomes. Moreover, considering that a substantial portion of project results comprise teaching or learning materials and policy recommendations aimed at disseminating project outcomes with the overarching objective of enhancing STEM education, an evaluation of these projects by the target communities, such as teachers, students, researchers, and policymakers, may lead to the identification of best practices. Such an approach could potentially steer an evidence-based shift in STEM education.

Without this evaluative mechanism, EU-STE(A)M initiatives, although rich in ideas and potential innovation, are subject to ambiguity regarding their efficacy and accessibility. This creates uncertainty about the sustainability of EU projects.

We were unable to conclusively determine whether research plays a pivotal role in European STE(A)M initiatives. Most of the projects reviewed provide limited information about the value of the project's outputs for research purposes and seldom reference scientific publications. Conducting a scientific literature search for each EU initiative (n=784) is a considerable task, requiring not only the identification of relevant scientific publications for each project and verification of which project components have been researched, but also an assessment of the reliability of the publishing journal. Hence, the relationship between research efforts and these initiatives remains an open question.

Thus, further empirical validation of these projects' effectiveness and impact is recommended to ensure their long-term viability and meaningful contribution to STEM education.

9. Literature

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10. Internet Resources

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https://preventioncentre.org.au/resources/writing-a-policy-brief/

https://www.researchtoaction.org/2013/07/how-to-write-actionable-policy-recommendations/

https://www.linkedin.com/pulse/how-write-policy-recommendations-influence-government-eddie-copeland/

https://www.sciencedirect.com/science/article/pii/S0277953606002309?casa_token=Weiju6hTWVMAAAAA:yc5dTBttwFOnDQk50OTVrFC5TfTeh1r9GSgW5ttueE7wo7NlQHnE1yWfQz7SSMyHks3iTPU6800