STE(A)M IT

AN INTERDISCIPLINARY STEM APPROACH

THE STE(A)M IT FRAMEWORK

EUROPEAN INTEGRATED STEM TEACHING FRAMEWORK

(Deliverable D2.3)

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

The STE(A)M IT project has received funding from the European Union's ERASMUS+ programme project STE(A)M IT (Grant agreement 612845-EPP-1-2019-BE-EPPKA3-PI-FORWARD) coordinated by European Schoolnet (EUN). The content of the document is the sole responsibility of the organizer and it does not represent the opinion of the European Commission (EC), and the EC is not responsible for any use that might be made of the information contained.

European Schoolnet | INDIRE Istituto Nazionale Documentazione Innovazione Ricerca Educativa | Ministarstvo znanosti i obrazovanja | República Portuguesa Educação | Direção-Geral da Educação | University of Cyprus | IUL

The STE(A)M IT project (1) created and tested a conceptual framework of reference for integrated STEM education; (2) developed a capacity building programme for primary school teachers and secondary STEM teachers, based on this framework, with a particular focus on the contextualisation of STEM teaching, in particular through industry-education cooperation, and (3) further ensured the contextualisation of integrated STEM teaching by establishing a network of guidance counsellors/career advisers in schools promoting the attractiveness of STEM jobs to their classes (http://steamit.eun.org).

Publisher European Schoolnet (EUN Partnership AIBSL), Rue de Trèves, 61, 1040 Brussels, Belgium.

Please cite this publication as: Tasiopoulou et al. (2022). European Integrated STEM Teaching Framework. October 2022, European Schoolnet, Brussels.

Keywords: Science, technology, engineering, and mathematics (STEM); integrated STEM education; STE(A)M education; primary education; secondary education; careers.

Authors: Evita Tasiopoulou, Jessica Niewint Gori, Eddy Grand-Meyer, Eleni Myrtsioti, Nikoletta Xenofontos, Anastasios Chovardas, Letizia Cinganotto, Patricia Garista, Ivana Jakić, Lidija Kralj, Darija Dasović, Katarina Grgec, Magdalena Apa, Anamarija Ljubek, Nikola Krikovic, Silvia Castro, Catarina Ramos, Eugenia Cândido, Amanda Francone, Ana Louro, Barbara Mandusic, Carmelita Cipollone, Cristina Cesio, Edyta Węgrzyn, Isabela Elena Ciurea, Ivana Gugić, Mara Sesar, Maria Chatzimichael Pouliaou, Marzia Lunardi, Nikolas Nikolaou, Nikolina Bubica, Paraskevi Sophocleous, Preeti Gahlawat, Raluca Olteanu, Simona Ungureanu, Sonia Maria Gomes Cerqueira, Zoe Kofina Michael & Agueda Gras-Velazquez.

Design: Rocío Benito Cólliga

ISBN: 9789464595079

Contributors: Achilles Kameas, Adriana Ressiore Campodonio, Albert Forn, Andrea Benassi, Andrius Busilas, Anikó Pázmándi, Annette Condon, Ariana-Stanca Vacaretu, Bogdan Cristescu, Cecilie La Monica Grus, Christodoulos Santziakki, Ciro Minichini, Cristina Rotaru, Efi Dariou, Elena Vender, Elisa Ripamonti, Enrico Balli, Filimon Diamantidis, Frauke Kesting, Gabriela Streinu-Cercel, Georgia Kouti, Giedrius Vaidelis, Giovanni Nulli, Ildikó Csordás, Ilia Mestvirishvili, Imbi Henno , Itziar Garcia Blazquez, James Serra, Jeanette Axisa, John Justyna, Julien No Mura, Kamil Melih Akay, Laura La Scala, Limor Ben shitrit Haimi, Lorenzo Guasti, Magdalena Traczuk-Rąpała, Marcos Noriega, Maria del Mar

Aleman Prados, Maria Guida, Maria Messaritou, Mario Muscat, Martha Hoebens, Maryna Manchenko, Mette Malmqvist, Milana Gujinović, Nial Pickering, Niki Kalyfommatou, Noel Harmsworth, Panagiotis Angelopoulos, Raluca Ionela Maxim, Rubén Durán, Sara Bezvodová, Sara Mori, Stacia Jackson, Tunç Erdal Akdur, Vasiliki Kotsikopoulou, Vasiliki Psarisou, Veronica Duskova, Vladimíra Kyselková, Yvoni Pavlou, Irene Pizzo, Massimiliano Naldini, Stephan Griebel, Amelia Chaves, Andreia Santos, Anna Brink, Augusto Jorge Carvalho Fernandes, Cristina Cesio, Ewelina Słowńska, Floria Valanidou, Georgios Parisinos, Isabel Maria Barbosa Oliveira, Jelena Solak Vodopija, Junior Ndiaye, Karolina Kasperska, Massimiliano Dirodi, Paraskevi Sophocleous, Raluca Olteanu, Simona Ungureanu, Spyros Onisilou, Tiziana Pezzella.

Published in 2022. The views expressed in this publication are those of the authors and not necessarily those of, EUN Partnership AISBL, the European Commission or the projects and organisations that supported the publication.

This publication corresponds to Deliverable D2.2 - First European integrated STE(A)M framework. The work presented in this document is supported by the European Commission's Erasmus + programme – project STE(A)M IT (Grant agreement 612845-EPP-1-2019-1- BE-EPPKA3-PI-FORWARD), coordinated by European Schoolnet (EUN). The content of the document is the sole responsibility of the STE(A)M IT consortium, and it does not represent the opinion of the European Commission (EC), and the EC is not responsible for any use that might be made of information.

TABLE OF CONTENTS

PREAMBLE: WHO IS THE FRAMEWORK FOR AND HOW TO USE IT?

Welcome to the first integrated STEM teaching framework! In the next few pages, you will discover what STE(A)M is about, why integrated teaching brings value for the future of STEM (science, technology, engineering, and mathematics) education, and how it can be implemented in the classroom, deepened through research, and supported in European decision making.

STE(A)M teaching is integrated STEM teaching where we have added (A) for 'all' because STEM doesn't work in isolation from the real world and other subjects, and because working as a team is key for meaningful integration.

But first, let's find out if the framework is for you (hint: it probably is!).

Who can use the framework?

The STE(A)M IT framework has been developed for a variety of educational stakeholders:

- Teachers and education staff in formal and non-formal education and in teacher training institutions who wish to introduce a holistic and integrated dimension to their lessons and activities.
- Pre-service and in-service teachers who are interested in innovative education and the ways and conditions that can facilitate introducing it into their daily practice.
- Heads of school who wish to understand the value of integrated STEM teaching for teachers and students and how they can support and facilitate its implementation in their schools.
- Researchers with a specific interest in the impact of teaching methods on teacher and student engagement, motivation, and performance, who wish to contribute and expand the understanding of integrated STEM teaching and learning, and further investigate its application and impact with their own research.
- Policymakers looking for the evidence-based theoretical background needed to design and plan policy and pedagogical interventions to pave the way for the introduction of integrated teaching and learning in their national context.
- EdTech professionals and STEM experts who wish to understand the needs of education professionals and want to nurture the STEM workforce of the future.

STE(A)M IT Project: Index of resources

Knowledge/ academic resources

	State of Play	Academic publication
Link	https://steamit.eun.org/integrated-stem-teaching-state-of-play/	
Teachers	Learn about the status of STE(A)M education in Europe to understand where to start when deciding to implementing STE(A)M	Explore academic literature on the value of integrated STEM education and view peers' feedback to the MOOC.
Researchers	Explore the state of play as a starting point to developing your own research.	Find evidence of value of integrated STEM teaching and the analysis of teachers' feedback to professional development resources. This resource provides sound academic background to explore the needs of teachers at different teaching level and how you can help them in the future.
Policymakers	Explore the state of play to better understand how policy can help teachers implement integrated STEM teaching and contribute to overcoming STE(A)M implementation barriers.	
EdTech / STEM Industry	Learn about STE(A)M education to understand the teachers' and students' need and discover how industry can better support them.	

Teaching resources

	Master Learning Scenario	Repository of integrated learning scenarios
Link	https://bit.ly/STEAMIT_MasterLS	https://steamit.eun.org/category/integrated-stem-learning-scenarios/
Teachers	Use to draft your own integrated STEM teaching with step by step guidance	Use the learning scenarios in your class and with colleagues, they can also be adapted to fit your and your student's needs
Researchers	Use it as guide to explore how integrated STEM teaching happens in the classroom, and how you can contribute to the respective steps and to improving teachers' skills	Have a look at some examples of co-created and peer reviewed examples
Policymakers		
EdTech / STEM Industry		

Teaching resources

	Guideline to overcome barriers to STE(A)M integration	STE(A)M IT Framework: Executive Summary
Link	https://bit.ly/STEAMIT_Guidelines-Barriers	https://bit.ly/STEAMIT_Executive-Summary
Teachers	Use the guidelines to overcome the obstacles that you can expect to encounter when implementing your own integrated resources	A quick overview of the Framework if you are short for time. Use it to get started with STE(A)M Education!
Researchers	Academics have designed those guidelines based on feedback from teachers, learn about the challenges and start researching how you can improve teacher trainings, resources, conditions and even infrastructure to further support them	
Policymakers		
EdTech / STEM Industry		

Career based resources

<table>
<tr><th></th><th>Repository of STEM jobs profiles</th><th>Guidelines on how to introduce STEM jobs in the classroom (Full)</th></tr>
<tr><td>Link</td><td>http://steamit.eun.org/category/stem-careers/</td><td>http://steamit.eun.org/guide-lines-on-how-to-present-stem-jobs-in-classrooms/</td></tr>
<tr><td>Teachers</td><td>A range of career profiles that you can use to inspire students to pursue a career in STEM</td><td>Learn how to use the career profiles in class</td></tr>
<tr><td>Researchers</td><td rowspan="2">Discover how STEM professionals can help students get excited about a career in STEM</td><td rowspan="2">Learn how teachers can introduce STEM professionals to their students, and how you can make it easier for them!</td></tr>
<tr><td>Policymakers</td></tr>
<tr><td>EdTech / STEM Industry</td><td>See the existing database and get in touch to introduce your own career profiles!</td><td>An exhaustive list on how to introduce STEM professionals to students, use it to see how you organise events with teachers</td></tr>
</table>

Career based resources

	JOBS PROFILES REPOSITORY: How to present STEM jobs in class (Short)	STEM Alliance: Advice from Industry
Link	https://bit.ly/STEAMIT_STEM-jobs-class	http://files.eun.org/scientix/STE(A)M-IT-SA-CAN-Advice-from-Industry.pdf
Teachers	An abridged version of the guidelines to go straight to the point about introducing STEM jobs to your students!	Learn how to connect with industry partners and STEM professionals
Researchers		Learn how teachers can initiate contact and connect with industry partners and STEM professionals and find opportunities to nurture the relationships
Policymakers		
EdTech / STEM Industry		Learn how teachers can connect with industry partners and STEM professionals and add your own advice or make the first step!

Career based resources

<table>
<tr><th></th><th>Career Advisers Network</th><th>Handbook for Career Advisers</th></tr>
<tr><td>Link</td><td>https://steamit.eun.org/career-advisers-network/</td><td>https://bit.ly/STEAMIT_Handbook-CAs</td></tr>
<tr><td>Teachers</td><td>Join the career advisers Network, talk with other teachers, and attend training to improve your guidance skills and nurture the STEM workforce of tomorrow!</td><td>A full guide on how to guide students towards STEM careers, and why you should!</td></tr>
<tr><td>Researchers</td><td rowspan="2">Learn about the Network and find opportunities to discuss with teachers about connecting with Industry</td><td rowspan="3">A handy resource to discover the value of careers in integrated STEM teaching. Use it to learn how you can help develop the relationship and improve best practice!</td></tr>
<tr><td>Policymakers</td></tr>
<tr><td>EdTech / STEM Industry</td><td>Join career advisers’ events and discover how you can contribute to meaningful collaboration between education and STEM industry!</td></tr>
</table>

Community of practice resources

	Stories of Implementation (STEM DISCOVERY CAMAPIGN Blog)	Massive Open Online Course: Integrated STEM teaching (Primary)	Massive Open Online Course: Integrated STEM teaching (Secondary)
Link	https://sdw-blog.eun.org/	https://bit.ly/STEAM-IT_MOOC_Primary	https://bit.ly/STEAM-IT_MOOC_Secondary
Teachers	Witness first hand the experience of other teachers who have implemented the STE(A)M IT learning scenarios and created their own	Take the course to understand integrated STEM teaching and learn tips from the experts!	Take the course to understand integrated STEM teaching and learn tips from the experts!
Researchers		Discover an example of online course designed for primary teachers to help them implement integrated STEM teaching in the classroom, background information, policy data and STEM career are included	Discover an example of online course designed for primary teachers to help them implement integrated STEM teaching in the classroom, background information, policy data and STEM career are included
Policymakers			
EdTech / STEM Industry			

How to navigate the framework?

The following section provides direction and guidance for key stakeholders to explore the framework and its resources. Of course, these are indicative, and stakeholders are encouraged to explore each section and category of resources on their own terms to meaningfully benefit from the STE(A)M IT framework.

Teachers can:

- Use the background section to understand the theory of STEM integration and its benefits for their students,
- Explore the resources, learning scenarios (LSs), and examples of integrated practice from European teachers and implement them as they are, adapt them, or create their own,
- Discover the STE(A)M IT opportunities for continuous professional development and complete one of the massive open online courses (MOOCs) to develop their career and improve their teaching practices,
- Follow the recommendations to improve their practice and find new innovative ways to teach STEM subjects in an integrated way.

Heads of school can:

- Review the framework methodology and evidence base for integrated STEM teaching,
- Explore the rationale and theory behind integrated STEM teaching and learn how to support their teachers in implementing it,
- Explore the resources, LSs, and examples of integrated practices from European teachers and how to support implementing them in their school,
- Follow the recommendations to support STEM integration in their school and engage their teachers in innovative collaboration.

Researchers can:

- Dive into the literature review and background to support and develop their research in STEM integration in European education,
- Explore the quality control of the teaching and learning materials and view the benefits for teachers and students, their feedback, and challenges first-hand,
- Follow recommendations for future research and understand the limitations of the current framework to build their own research projects and contribute to the advancement of STEM integrated teaching and learning.

Policymakers can:

- Review the framework methodology and evidence base for integrated STEM teaching,
- Explore the rationale and theory behind integrated STEM teaching and discover how to support teachers and schools in implementing it,
- Understand students' and teachers' needs through stories of implementation and feedback from students and teachers on STE(A)M IT teaching resources,
- Follow the recommendations to support policy improvements and engage in meaningful conversations with stakeholders at various levels.

EdTech and STEM professionals can:

- Explore the rationale and theory behind integrated STEM teaching, its value, and how it relates to the industry's needs,

- Discover how their know-how and technology, combined with their insight on STEM-related careers and skills, can improve integrated STEM practices,
- Dive into the research to understand the key value of career role models in nurturing an interest in STEM, thus securing a knowledgeable and dynamic workforce for the future.

Methodology

Before exploring integrated STEM teaching, read some explanations on how the framework was constructed below.

During the two academic years, 2019-2020 and 2020-2021, a series of actions, ranging from theoretical analysis and a literature review to working with teachers and carrying out a capacity building programme, have gradually led to the development of this framework.

In more detail:

Step 1: Desk research and SWOT analysis

To better understand the status and academic knowledge of integrated STEM teaching, we conducted an adapted SWOT analysis (strengths, weaknesses, opportunities, and threats) of scientific articles, reviews, and commentaries published in English between 2010 and 2019, retrieved using two different databases, ERIC and SCOPUS, and of grey literature published in English between 2010 and 2019, retrieved through a Google search.

The research supported the publication of ***STE(A)M IT integrated STEM teaching state of play***[1] and its findings are reflected in the *'Why the STE(A)M IT Framework?'* section.

Step 2: Working with pilot teachers

Pilot teachers were recruited to support the research process and draft an initial set of STE(A)M IT integrated teaching learning scenarios, implement them, and test them in their classrooms to verify their usefulness and adaptability. Following this process, pilot teachers peer-reviewed the learning scenarios to improve them.

Step 3: Co-creation and validation workshops

All the integrated STEM learning scenarios available in the framework were produced and validated through a methodology that involved co-creation, testing, implementation, and peer-review processes.

Three co-creation workshops were organised to present project updates, validate previous work, and determine the upcoming actions. Two targeted teachers, and one was for ministries of education and industry partners.

The first workshop introduced the project and its stakeholders, the second focused on reviewing and monitoring the first STE(A)M IT learning scenarios, and the third included the review of the outcomes of the testing phase. Although the COVID-19 pandemic created initial challenges in coordinating the creation and testing of the material, it also cemented the value of **integrated STEM teaching and highlighted the practical value of blended-learning modes of teaching and fully remote lesson implementation.**

As an Erasmus project, STE(A)M IT is one of many integrated STEM education projects and therefore can be read in conjunction with other projects exploring the same topic. Some of these are presented in more detail later in the

1 The document is available here : http://steamit.eun.org/integrated-stem-teaching-state-of-play/

framework.
As an additional way to validate the content and the framework and their usefulness for stakeholders, two validation workshops, one with teachers and one with researchers, were organised. These served the purpose of confirming the validity of the content of the framework and its accessibility to various interested parties and helped refine the delivery mode.

The workshops provided useful insights and different perspectives, which have been incorporated into this final version of the framework.

Partner projects

SCIENTIX

Scientix is the community for science education in Europe (http://www.scientix.eu/home) and promotes and supports a Europe-wide collaboration among STEM teachers, education researchers, policymakers, and other STEM education professionals. Scientix has been running since 2010, organising teacher training activities, dissemination conferences and events, and supporting the exchange of knowledge and experiences in STEM education via its portal, publications, and events.[2] The Scientix resource repository includes thousands of resources for teachers and other education stakeholders and hosts the STE(A)M IT resources ensuring that the resources remain available after the STE(A)M IT project has concluded.

2 Scientix receives funding from the European Union's H2020 research and innovation programme.

STEM Alliance

The STEM Alliance[3] is an international initiative coordinated by European Schoolnet (the network of 34 European ministries of education), that brings together industries, education stakeholders, and ministries of education to promote STEM education and careers to young Europeans and address anticipated future skills gaps within the European Union.

The STEM Alliance shares common goals and visions with STE(A)M IT in their objective of promoting STEM careers to young people and developing the skills needed for a future dynamic STEM workforce. The two projects therefore collaborate closely and support each other in creating resources and bringing industry expertise and information on future STEM careers to STE(A)M IT career advisers, teachers, and students.

3 https://www.stemalliance.eu/

SCIENTIX
The community for science education in Europe

STEM Alliance
inGenious education & industry

PREAMBLE: WHO IS THE FRAMEWORK FOR AND HOW TO USE IT?

WHY THE STE(A)M IT FRAMEWORK?

What is STEM integration?

STEM integration implies the concurrent teaching of a combination of STEM academic subjects by a teacher or group of teachers who specialise in different subjects. STE(A)M teaching, therefore, has a wider scope and involves the incorporation of a non-STEM subject in the same learning scenario, such as arts, literature, a foreign language, sports, etc.

STE(A)M curriculum models can contain STEM content learning goals that are primarily focused on one subject but contextualised in other STE(A)M subjects. In other words, STE(A)M education can be defined as teaching the content of two or more STEM domains, bound by STEM practices within a more relatable context, thus better connecting these subjects to enhance students' learning experience.

Sanders (2009) described STE(A)M education as *'approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects'* (p. 21). In doing so, Sanders suggests that outcomes for learning at least one of the other STEM subjects should be purposely designed in a course—such as a maths or science learning outcome in a technology or engineering class. Moore et al. (2014) go even further, defining STE(A)M education as *'an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems'* (p. 38). This then, implies that ALL subjects should be connected into a single lesson plan, and given real-world context to be valuable.

Given the above, attempting to define STE(A)M teaching calls for reflection on what integrated teaching and learning mean in educational theories where connectedness, flexibility, cooperation/relationship, and meaningfulness are considered key concepts for positive and successful education (Dewey, 1966; Gardner, 1994; Morin, 2012, as cited in Demirel, 2019). Consequently, integration from a pedagogical perspective supports a holistic and systemic approach to education, aiming to make the process of learning more harmonious.

If the value of teaching multiple subjects in an integrated way cannot be challenged, it remains that this cannot be an easy endeavour. Indeed, philosophers such as Edgar Morin (2012, as cited in Demirel, 2019) emphasise the complexity of education and the need for flexibility to cope with uncertainty. Additionally, integration requires overcoming traditional teaching methods, teacher-centred practices, and lessons that are exclusively content-based, in addition to the fragmented learning practices outlined above.

To overcome these difficulties, STE(A)M teaching embraces innovative methods that are capable of integrating different basic and transversal skills, distinctive content, and several ways of approaching learning. More specifically, integration also means integrating subjects, teaching activities, and different learning styles and dimensions.

An integrated curriculum is structured in such a way that it crosses the various disciplinary content, tying together various elements of knowledge with meaningful associations. Its vision is holistic in considering learning and teaching as processes that must reflect the real world, showing their dynamism, ecology, and continuous evolution. This vision of the world and skills cannot be developed in fragmented sectors but must unite knowledge, learning styles, relationships among teachers, learners, education stakeholders, and between the learning setting and the real world.

This perspective rests on the premise that learning occurs through a series of connections. This principle is valid for all topics but becomes even more crucial in disciplines that find more resistance and difficulty in involving students, such as STEM.

Why is STE(A)M teaching needed?

The acronym STEM is used in very different ways in education. In the last few years, the acronym STEM has been expanded to include A, highlighting the importance of creativity and 'arts' in STEM education, but also as a reference to 'all', i.e., highlighting the importance of connecting STEM to all other disciplines. While the organisation of primary education around Europe, with one educator teaching all subjects to a class, can easily support STE(A)M teaching and learning, in secondary education, STEM disciplines continue to be taught in isolation. There are no integrated STEM or STE(A)M classes but there are S classes, T classes, E classes, and M classes. Add to that the fragmented character of science education, where the 'S' itself is divided into physics classes, chemistry classes, biology classes, etc.

For students to see the interest of STEM degrees and careers, and even more importantly, to showcase the key role that STEM plays in improving our lives and our future, we need STEM to be taught in an integrated way. All STEM components need to work together but also collaborate with the A, for all subjects.

The need for deeper, more conceptually rooted knowledge, which students can relate to and apply to real-world problems, is well documented in STEM education (Braund & Reiss, 2006; Bulte, Westbroek, de Jong, & Pilot, 2006; Gilbert, 2006; NRC, 2012). However, didactic classroom pedagogies do not tend to foster schematic, applicable knowledge for most students (Greeno, Collins, & Resnick, 1996). They often instead result in the development of what Whitehead in 1929 called 'inert knowledge', i.e., factual knowledge that is decontextualised from the real world and fails to engage students with STEM topics.

The STE(A)M IT framework seeks to facilitate, support, and advance the introduction of **STE(A)M teaching and learning to primary and secondary education in European classrooms.** To do so, it offers a set of pathways for a range of key stakeholders: teachers, educational researchers, EdTech and STEM professionals, and policymakers. These pathways are composed of blocks of information that can be navigated differently depending on the stakeholder's individual needs, interests, and focus.

In addition to the pathways, the framework aspires to become a point of reference in STE(A)M learning and teaching. Its structure allows the framework to be expanded and developed with additional components, while the active contribution of various stakeholders (teachers, researchers, ministries of education, industry partners etc.) to its development offers precious insights and information on the latest trends and developments.

On the practical side, the framework provides teachers and heads of school with guidance on how to bring STE(A)M teaching into their daily practice through examples of topics that facilitate integration and lesson plans created and tested by teachers, along with tested strategies and guidance on integrating STEM careers into STE(A)M learning scenarios. Finally, assessment methodologies are provided. Policymakers, on the other hand, are offered insights on the benefits of integration and the practices observed internationally, the impact of this approach on teachers and students, and the challenges for implementing it within the current school organisation norms and existing curricula.

Why use the STE(A)M IT framework?

It contextualises STEM through real-world challenges

How do real-world challenges connect and promote integrated teaching?

The use of real-world challenges within the educational context adds unique elements of authenticity to the students' experience. Incorporating relatable and relevant issues encourages students to work together to solve a problem that is of high priority to them and their community, and in doing so, supports long-term thinking and sustainable knowledge.

The term 'real world' is not meant to differentiate learning within or outside the school, but rather to emphasise the essence of student ownership of the problem, solution, and learning, and connection with the larger community (Nagel, 1996).

Via STE(A)M teaching, students have access to the most recent and up-to-date knowledge (i.e., exchanges with experts, visits to specific establishments or locations), connect to the real-world (i.e., local community, their city or province), and develop a variety of skills and competences (critical thinking, problem-solving, communication etc.).

Criteria for selecting real-world challenges

While approaching and trying to select a real-world challenge, teachers are invited to consider the following criteria:

- The challenge must be real. It must involve an authentic challenge directly related to societal, economic, and environmental issues that affect students' lives and communities. Mythical insects, space aliens, and theoretical life forms, although interesting and popular, are not real-world challenges—at least not yet.

- Students must care about the challenge. If students do not care about the challenge, their motivation to solve it will be limited. It might be a problem in their own life or community, or a critical issue that is prominent in the news (such as climate or environmental issues). If the issue is useful for the purpose of the lesson but isn't quite so prominent in students' social context, teachers can help build that context to help them connect with it using videos, speakers, or trips.

- The challenge should be 'realistically achievable'. For a STE(A)M challenge to be of value, students should have access to the resources, knowledge, and skills they need to solve the problem—and the scope of the problem should be manageable (e.g., solving climate change isn't realistic, but engineering solutions for clean energy or figuring out how to reduce heat at the school ground level is).

- The challenge must allow for multiple acceptable approaches and solutions. Teachers should avoid issues with a single, predetermined approach and forgo the 'right' or 'wrong' evaluation. In their STE(A)M class, each team of students should be able choose a different approach for solving the challenge and several different solutions should be available.

- Students should use an engineering design process—drawing on science, mathematics, and technology skills and concepts—to solve the challenge. All the challenges should require students to use an engineering design process (figuring out a series of steps to solve the problem) that requires the use of multiple topics, even if each subject does not need to be used to the same extent (for example, some solutions may rely more heavily on science and others on mathematics).

- The problem should align with grade-level standards for science and mathematics. In a busy school day, neither teachers nor students have time for too much 'extra' curriculum content. Students will be more committed to the STE(A)M activity and the challenge at hand if they get to use skills they are learning anyway. That's the point of real-world challenges!

- Students need to have an active role in choosing the challenge. Although teachers will need to come up with examples and suggestions to help students understand the nature of these problems, the final choice should be left to students. Their active involvement paves the way for their engagement and active participation to the learning process.

Examples of real-world challenges

To define a common education agenda and create a more inclusive world by 2030, the United Nations adopted the Sustainable Development Goals Agenda in 2015 (SDGs)[4]. The SDGs provide a myriad of relatable challenges that can be used in the classroom; we have collected some examples below (and added a few extras too):

- Eradication of poverty and hunger,
- Clean water and sanitation,
- Affordable and clean energy,
- Industry, innovation, and infrastructure,
- Sustainable cities and communities,
- Responsible consumption and production,
- Life below water,
- Life on land,
- Peace, justice, and strong institutions,
- The coexistence of animals and humans,
- Good health and well-being,
- Access to scientific and technological breakthroughs.

A word about STEM careers to contextualise STEM in the real world:

A simple and effective way to assist students in understanding the interconnections of STEM disciplines, and in turn help them apply that understanding outside of school, is by providing them with examples of STEM jobs and careers, their value to society, the economy, and the progress of human knowledge, and of course by presenting role models in the form of STEM professionals. Consequently, all lesson plans produced in the STE(A)M IT framework integrate information on STEM careers and STEM job profiles that are relevant to the lesson objectives and the activities offered. The skills and knowledge needed for STEM professionals to succeed in their role are also explained in inspiring detail.

4 Read more about the SDGs here: [THE 17 GOALS | Sustainable Development (un.org)](https://sdgs.un.org/goals)

It nurtures 21st-century skills

The 21st century is characterised by the rapid and continuous multiplication of technologies, which in turn requires a range of specific skills to be an active citizen in this age, skills that STE(A)M teaching can help develop in students.

These skills are needed to face the broader world challenges we all face, and they equip learners with the capacity to negotiate the inherent complexities in today's global and knowledge-driven economy (Organisation for Economic Cooperation and Development, 2019). This new 'global' society requires a workforce that is knowledgeable, geographically mobile, and collaborative in nature (Dunning, 2000), and current and future jobs require analytical thinking, digital skills, and sophisticated communication skills (Levy & Murnane, 2012), all of which can be nurtured through STE(A)M teaching.

The 21st-century skills are 'not new, just newly important' (Silva, 2009, p. 631) and comprise three main knowledge domains: (1) innovative thinking; (2) digital literacy skills (information, media, and ICT, information, communication, and technology) (Black & Wiliam, 2009); and (3) life and career skills (Trilling & Fadel, 2009).

While '21st-century skills' may be defined, categorised, and determined differently from person to person, place to place, or school to school, the term does reflect a general—if loose and shifting—consensus. The following list provides a brief illustrative overview of the knowledge, skills, work habits, and characteristics commonly associated with 21st-century skills:

- Critical thinking, problem solving, reasoning, analysis, interpretation, synthesising information.
- Research skills and practices, interrogative questioning, and an inquiry mindset.
- Creativity, artistry, curiosity, imagination, innovation, personal expression.
- Perseverance, self-direction, planning, self-discipline, adaptability, initiative.
- Oral and written communication, public speaking and presenting, active listening.
- Leadership, teamwork, collaboration, cooperation, capability in using virtual workspaces.
- Information and communication technology (ICT) literacy, media and internet literacy, data interpretation and analysis, computer programming.
- Civic, ethical, and social-justice literacy.
- Economic and financial literacy, entrepreneurialism.
- Global awareness, multicultural literacy, humanitarianism.
- Scientific literacy and reasoning, the scientific method.
- Environmental and conservation literacy, ecosystems understanding.
- Health and wellness literacy, including nutrition, diet, exercise, and public health and safety.

Practical reasons to choose STE(A)M integration

In addition to the broad benefits that STE(A)M teaching offers from the pedagogical perspective outlined above, there are also more pragmatic reasons for teachers to choose STE(A)M teaching.

Given teachers' learning objectives and their constraints (such as number of students, level of experiences and area of expertise), integration will result in better understanding of isolated STEM subjects, better contextualisation of the principles of science, and a deeper understanding of the everyday value of STEM subjects. Students will benefit from STE(A)M teaching as the activities and assignments have been designed to encourage critical thinking and collaboration while their assessment is project oriented. In addition, STE(A)M teaching helps maintain students' interest for all subjects while nurturing individual competencies and students' inclinations. This has been observed in the testing phase of the STE(A)M IT learning resources as students reported overcoming their fear and doubt about individual STEM subjects they had previously perceived as 'too difficult' (e.g., mathematics).

A perhaps less desirable, but nevertheless advantageous, quality is the ability of STE(A)M education to provide useful learning settings in 'emergency education'. Indeed, during the COVID-19 pandemic, the implementation of the integrated STEM learning scenarios continued in various levels and contexts. This involved several subject combinations and activities that ranged from sports complementing physics, to the use of virtual labs and architecture software to build models in a learning scenario that tackled social issues and focused on sustainability.

The examples outlined above indicate that even in the face of uncertainty, less than ideal remote teaching, and lack of resources, STE(A)M teaching and learning was successful and a clear advantage for teachers and students alike. Reactions and feedback to the testing phase further verified that STE(A)M teaching provides the flexibility to be tried out in different teaching modes: online and remote, inside the classroom, or as a combination of both (mixed implementation).

Finally, integrated STEM teaching nurtures collaboration between teachers inside their school and with teachers from other schools (as demonstrated by the successful co-creation of the material between teachers from multiple countries), all while contributing to expanding the activities at school level and moving towards the full inclusion of the integrated methodology in the curriculum (outcome following the focus group discussion with the team from Sweden).

What are the pedagogical approaches that promote STE(A)M integration?

Certain pedagogical approaches are best suited to facilitating STE(A)M integration. The main approaches are outlined below, along with their impact on student learning.

Project-based learning

Project-based learning (PBL) is a student-centred model that organises learning around projects and includes complex tasks based on challenging questions anchored in real-world problems.

While there isn't a single universally accepted definition of PBL, the Buck Institute for Education (BIE) gives a concise definition that incorporates the key elements of project-based learning, PBL is 'a systematic teaching method that engages students in learning knowledge and skills through an extended inquiry process structured around complex, authentic questions and carefully designed products and tasks' (Markham, Larmer, & Ravitz, 2003 p. 4). The essential features of PBL therefore include 1) a central project; 2) a constructivist focus on important knowledge and skills; 3) a driving activity in the form of a complex question, problem, or challenge; 4) a learner-driven investigation guided by the teacher; and 5) a real-world project that is authentic to the learner (Barron & Darling-Hammond, 2008; Thomas, 2000).

In summary, PBL lets students access and construct knowledge for themselves based on their autonomous experiences and discoveries to avoid the curriculum being an orderly arrangement of pre-determined knowledge.

Today, a variety of practices are included under the umbrella of PBL, but the most prominent include challenge-based learning, place-based learning, activity-based learning, and design-based learning.

Scholars generally agree in identifying the following characteristics of PBL projects:

- PBL projects are central, not peripheral to the curriculum.
- PBL projects are focused on questions or problems that 'drive' students to encounter important concepts and principles at the intersection of two or more disciplines.
- PBL projects involve students in a constructive investigation.
- PBL projects are student-driven to a significant degree.
- PBL projects are realistic.

Furthermore, unlike in more traditional teaching practices, in PBL the teacher becomes a facilitator rather than an instructor, and educational goals are made explicit, (Moursund, 1999).

In practice, PBL is a teaching method where the starting point of the learning process is an 'authentic' problem with different workable solutions and diverse ways of reaching these solutions. Students are assigned specific tasks to (a) create an exact statement of the problem, (b) identify the information needed to understand the problem, (c) identify resources to be used to gather information, and (d) generate possible solutions and evaluate them.

In current educational paradigms, students commonly work alone on simple tasks, memorising short definitions. They only write for the teacher and occasionally create presentations. In contrast, PBL projects aim to develop critical thinking, collaboration, and communication skills by involving students in design, problem-solving, decision making, and investigative activities while working in small groups and creating realistic products or presentations (Jones, Rasmussen, & Moffitt, 1997; Thomas, Mergendoller, & Michaelson, 1999).

PBL leads to better learning results and student skills development

Field research has demonstrated that students draw significant benefits from this approach, including increased critical thinking skills, improved retention of knowledge over time, cross-disciplinary knowledge, increased motivation, ability to interact with others, and increased ability to seek information, communicate in groups, and deal with problems. (Thomas, 2000).

Furthermore, by assigning roles to students while they work in groups, PBL is a more effective means of adapting to students' various learning styles.

How can PBL be used to develop an integrated STE(A)M learning scenario?

Krajcik and Blumenfeld (2006) list five key features of PBL that can be helpful for teachers to design a project for their students, in the perspective of a STE(A)M learning scenario.

The key features are:

1. Driving question: a PBL project should start by identifying a unique challenge or problem, an open-ended question related to a real-world topic that will engage the students by being authentic and relevant to their needs (Laur & Ackers, 2017). A good question is feasible, worthwhile, contextualised, meaningful, and ethical.

2. Situated inquiry: designing a plan for the project while having in mind which learning outcomes will be addressed is key in PBL projects by integrating as many subjects as possible and considering what materials and resources will be accessible to the students to assist them.

3. Collaboration and technological tools to support learning: scheduling the activities with appropriate benchmarks and giving students direction for managing their own time and allowing enough time for collaboration (with the use of tech tools) is essential. However, the teacher's role is crucial in allowing students to explore the ideas, challenging them through collaborative activities, providing resources and guidance, facilitating the process of group learning, and monitoring their progress.

4. Learning outcomes: the teacher's evaluation and constructive feedback is essential for the learners to help them evaluate their learning outcomes and improve. The teacher should evaluate the outcomes and enable students' peer evaluation and self-evaluation.

Inquiry-based science education

Inquiry-based science education (IBSE) adopts John Dewey's principle that education begins with curiosity (Savery, 2006) and allows students to experience all the steps of the scientific method: ask a question and develop a hypothesis that could answer it, plan the testing of this hypothesis, collect data, and analyse the results before finally sharing it with their peers (Pedaste et al. 2015). IBSE is ideal for STEM education because it makes teaching hands-on and is perfect for learning how scientific research works since students learn how to formulate questions that can be answered through experimentation.

In IBSE, the teacher has both a facilitator and an instructor role and the approach can be gradually made student-directed. Students can start an IBSE project with a question provided by the teacher, and then be prompted to produce their own questions, thus solidifying what they learned for deeper learning.

IBSE taps into creativity, problem-solving, and critical and analytical thinking and helps students learn about data collection and interpretation while helping them explore concepts such as ethics and reliability in scientific inquiry. All these are skills of the 21st century, where data is abundantly present in every part of life.
Research has demonstrated that IBSE results in greater interest in science and motivation for STEM careers. Additionally, the benefits of IBSE are long-term and maintained, in contrast to the short-term acquisitions of traditional pedagogies that result in lower inclusion of both genders, and less interest in STEM.

What does IBSE stand for?

Inquiry is the intentional process of searching for information, formulating problems, running guided experiments, planning investigations, constructing models, debating with peers, and using evidence and/or representations for support. (Linn, Davis, & Bell 2004).

Therefore, IBSE encourages students to explore 'hands-on', experiment, ask questions and to develop responses based on reasoning (Rocard et al., 2007), and is grounded in a constructivist approach where inquiry and problem solving is at the heart of learning, thinking, and development. Through the active processes of IBSE, students construct their own understanding as they engage in questioning, problem solving, and reflecting on the consequences of their actions.

While there isn't a universally accepted definition of inquiry-based education, common core elements can be identified. Inquiry-based education engages students in (NRC, 2012, p. 41):

- asking themselves meaningful questions,
- obtaining supporting evidence to develop and evaluate ideas,
- explaining the evidence collected,
- associating information with the knowledge gained from investigations or evidence to formulate scientific questions or theories,
- communicating, justifying, and evaluating explanations (also in light of alternative explanations).

IBSE and student skills – How can IBSE lead to better learning results compared to individual learning? What student skills can be developed?

IBSE is a rich pedagogical approach that can help teachers nurture numerous skills in their students. Because it involves practices such as experimenting, arguing, and modelling, inquiry is a powerful tool for developing scientific literacy, along with critical thinking skills (Haury, 1993), practical scientific skills (Bybee, 2011), and an understanding of scientific concepts and phenomena (Schroeder et. al, 2007). In addition, by relying on different investigative methods and different sources of evidence, IBSE also helps students develop their awareness of how science operates and positive attitudes towards science. Furthermore, when explored in a collaborative setting, inquiry fosters arguing, negotiation, and communication with others (for example through discussions or writing presentations) (Linn, Davis, & Bell 2004).

Finally, the process of modelling fosters evidence-based reasoning in supporting or developing scientific theories and constructing scientific explanations (Wilensky & Resnick, 1999; NRC, 2012). All these skills are important in modern society, for example to understand environmental, medical, and economic issues that rely heavily on technological and scientific advances of increasing complexity (Rocard et al., 2007).

IBSE and the new role of teacher – How can IBSE be used for developing a STE(A)M learning scenario?

The inquiry approach shifts the teacher's role from 'dispenser of knowledge' to facilitator or even 'learning coach'. The teacher prompts their students to investigate questions that are meaningful to them, thus aiming to develop knowledge and understanding of the phenomena of interest (Mayer, 2002; Wood &Barrow, 2006).

Additionally, questioning and collaborative methodologies can be combined with formative assessment methods to encourage students to focus on experimental data and facts. The role of formative assessment within inquiry-based teaching is to support students in understanding the learning goals and monitoring their progress towards them.

Some good examples of formative assessment include asking the students to:

- draw a concept map in class to represent their understanding of a topic,
- write one or two sentences identifying the main point of a lecture,
- submit a research proposal for early feedback,
- do peer evaluations or a pass and fail evaluation of their work,
- prepare public presentations or displays.

How can IBSE be applied in STE(A)M learning?

Teachers need to design and implement activities where the starting point is an open-ended question or problem, and students should then be asked to find a potential solution using their knowledge or skill set.

Below are some examples of such questions that will prompt students to take a broad approach to problem solving:

- How can we describe the lifecycle of a plant?
- What do you think you need to make a bulb light up?
- Do you think you could live without using plastic?

This open-ended and empowering approach to learning relies on students' choice and voice, which promotes confidence, engagement, and self-esteem. It is also possible to ask students to observe their local environment for possible problems or needs of others to address.

Before engaging in IBSE activities with students, it is essential for the teacher to answer to the following questions:

- What phenomena and basic science concepts will the unit focus on?
- What prior ideas and experiences might the students have?
- What level of understanding of the selected concepts do we expect the students to achieve?
- What kind of formative assessment questions and tasks may be integrated and what outcomes would we anticipate?
- What science inquiry and/or technology design skills will be emphasised?
- What attitudes about science should be identified?

For the overall learning experience, it is also important to:

- Clarify the goals and objectives of the activity with the students,
- Plan guided discussions and questions to help students focus,
- Plan the writing/recording tools with students.

Content and language integrated learning

Content and language integrated learning (CLIL) is a well-established pedagogical approach that emphasises integrating a foreign language and thematic content within the context of all school subjects. CLIL is a pedagogical approach that enables teachers and students to use a foreign language as the medium of instruction in non-linguistic subjects, allowing the practice and improvement of the second language and the inclusion of subjects that may vary from science subjects to humanities. According to Cenoz et al. (2013) '*the European Commission and the Council of Europe have funded many well-received initiatives in support of CLIL because it responded to a need in Europe for enhancing second-language (L2) education and bilingualism*', and research further supports that CLIL is applied successfully in task-based pedagogies.

In relation to the application of CLIL in the science classroom, specific advantages have been observed. Those include enabling learners to learn a curriculum subject using the respective second language they are learning while providing more authentic learning settings and utilising the resources available in their school and supporting learners' cognitive skills by equally supporting language practice and the teaching of science content.

A practical advantage of CLIL in STEM education is that it is based on active, interactive, and dynamic activities such as laboratory/workshop experiences, experiential learning, peer, and group work etc., and all these strategies and techniques align with effective hands-on STEM teaching.

Some of the key principles of CLIL are:

- **Additional-language instruction is more effective when integrated with content instruction:** This means that acquiring a foreign language is easier when the object of the learning is not simply the language itself, but more specific content delivered through a foreign language as a medium for instruction.
- **Explicit and systematic language instruction is important:** A metalinguistic reflection on the use and structure of the language is a key aspect of the learning process, as 'languaging' makes thinking visible (Swain, 2001).
- **Student engagement is the engine of learning:** Students in the 21st century are constantly exposed to a wide range of inputs attracting their attention. CLIL may be the key

to arouse their curiosity, interest, and enthusiasm to effectively learn and enhance their learning experiences.

- **CLIL activities are often peer or group activities** based on collaborative and cooperative learning or on projects (project-based learning), with practical outputs (posters, interactive products, digital content etc.). In this context, the collaborative effort from the group or the whole class makes the learning process more effective.

How can CLIL be used for developing a STE(A)M integrated learning scenario?

There is no one single method for designing a CLIL learning scenario since it focuses on the delivery rather than content of a STEM lesson. And while some teachers may lack confidence in implementing CLIL in STEM lessons, they should be reassured that many technologies are available that can provide useful tools to do so. There is a wide range of webtools and repositories that can be used to find and adapt resources and materials or create tailor-made activities that are in line with students' needs and competences. Some of these online resources include Khan Academy[5], Ted Ed[6], and the European Schoolnet Academy[7], all of which provide high-quality videos, online courses, and interactive learning pathways on different topics in multiple languages. Other widely used webtools include Learning Apps[8] or WordWall[9], where teachers can share content on different subjects through interactive activities, quizzes, games etc.

5 https://www.khanacademy.org/
6 https://ed.ted.com/
7 https://www.europeanschoolnetacademy.eu/
8 https://learningapps.org/index.php?overview&s=&category=0&tool=
9 https://wordwall.net/

What is the status of STE(A)M integration in European education

In this section, we summarise the current state of STE(A)M teaching in European education. The summary is based on the analysis conducted during the evaluation process that helped determine the resources needed to support STE(A)M education.

The full analysis is available in ***Integrated STEM Teaching State of Play***, available here: https://steamit.eun.org/integrated-stem-teaching-state-of-play/.

Teachers

Teachers are in essence the prime agents for STE(A)M education, and the challenges teachers face, and the support they receive, will be the main elements that either support or hinder successful STE(A)M integration in European classrooms.

One of the key requirements for primary and secondary teachers in advancing STE(A)M teaching is collaborative pedagogical design. Collaboration in this context implies teachers' ability to share their knowledge and expertise of their respective fields and get together to conduct said collaboration.

This in turn led to the observation of two key challenges:

1. The lack of relevant knowledge and skills:
The subject-based and fragmented STEM teaching paradigm currently means that teachers (in particular at secondary level) are experts in their field only. Teachers therefore need to be able to collaborate meaningfully to construct STE(A)M lessons that will benefit students and explore all the topics included in a meaningful way (thus avoiding 'tokenism' of subjects, where one or more subject is only used to promote another). To remedy their lack of expertise in specific fields, teachers seek opportunities for profes-

sional development and access to resources provided by other stakeholders. Another key observation from the work undertaken with the STE(A)M IT pilot teachers is that this lack of expertise can lead to decreased confidence in teachers attempting to integrate STE(A)M topics.

2. The lack of space and time for meaningful collaboration:
Teachers are busy professionals with a lot of institutional constraints such as curriculum requirements, student assessment, cost, and time constraints that seem that hinder a wider uptake of STE(A)M. In practice, this means that to accommodate STE(A)M teaching, teachers have to resort to finding the time, and their own motivation to collaborate with others, whether they be other teachers from their schools, teachers from other schools, or professionals outside of schools.

Ministries of education (institutional setting)

Ministries of education are key in deciding how STEM is taught in class as they develop curricula, allocate resources to schools, and recruit teachers.

Again, some key observations can be highlighted:

1. The complex endeavour to integrate STE(A)M teaching through curriculum adaptation:
Although several ministries of education undertake reforms for STEM integration, a silo approach to STEM education with a segregated and discipline-based structure still exists. This is a paradox that presents a difficult challenge for teachers attempting to offer STE(A)M learning.

2. The difficulty to implement certain STEM subjects:
Another paradox in some integrated STEM teaching initiatives is that some STEM disciplines, in particular engineering, are not often incorporated despite engineering design (along with project-based learning and educational robotics) seemingly being considered a good opportunity for promoting STEM education. This presents even more of a roadblock if other subjects outside of STEM are to be incorporated.
3/ The need for a synergistic approach to STE(A)M education: In addition, an inter-group aspect for ministries of education that hampers STE(A)M integration is the perspective that it can only succeed when the establishment of each STE(A)M discipline has been secured. While it is true that each STE(A)M subject must be secured, there is a clear need to recognise that the value of STE(A)M teaching is greater than the sum of its parts. Each STE(A)M topic taught in integration strengthens the other subjects and can help secure its implementation.

Industry partners

Industry is a key beneficiary of STE(A)M teaching in the sense that they will reap the benefits of a knowledgeable and dynamic workforce in the future.

The key observations are:

1. The need for visibility and connections:
The increasing number of industry-led STE(A)M education programmes indicates that there is an interest in the development of knowledge and skills needed in the workforce through STE(A)M education. Nevertheless, networking opportunities between teachers and industry and visibility for the above-mentioned programmes are still lacking and crucial information about STEM careers remain difficult to access for teachers.

2. STE(A)M education versus specific needs:
There are numerous opportunities to bridge the gap between industry and education through the establishment of a collaboration between industry and other stakeholders and the development and funding of STE(A)M education programmes. However, there is always the risk of developing initiatives that do not systematically connect to the curriculum but are instead aligned to the main function of the provider.

STE(A)M EDUCATION: RESOURCES

The analysis of the current status of STE(A)M education has highlighted specific needs for resources that can help empower teachers to implement STE(A)M teaching, bridge the gap between STE(A)M education and industry, and support decision makers in creating the policy background to facilitate STE(A)M education.
These resources have been designed to integrate all the core elements and requirements identified through the research process and are provided below with descriptive details and guidance.

The resources and assets created by the STE(A) M IT project have been integrated into the Scientix platform to ensure the widest reach possible and to pave the way for a long-term contribution to the educational landscape in Europe.

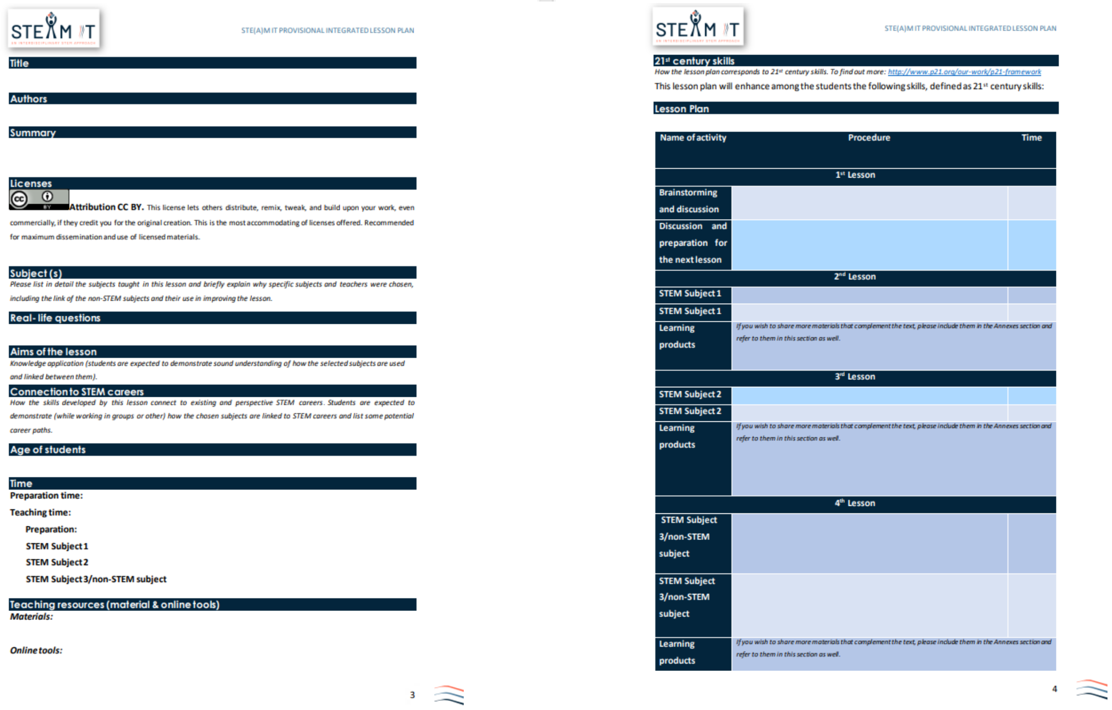
Teaching resources

Master learning scenario

The STE(A)M IT integrated master learning scenario template is the centrepiece of STE(A)M teaching for teachers to use and adapt in their lessons and has been used extensively in the STE(A)M IT integrated STEM teaching massive open online courses (described in the next section on continuous professional development).

The master template includes an exhaustive list of sections that are common to most learning scenarios and lesson plans such as title and summary, subjects and aims of the lesson, learning objectives, tools (online and offline), and the age of the students for whom it is designed.

Building on the observations made in the previous section of the framework, a unique feature of the STE(A)M IT learning scenario is the section dedicated to real-life questions teachers choose to address (e.g., relevant to the environment, science, societal issues, and why those specific questions are important), the-21st century skills the lesson seeks to develop in the students, and the STE(A)M jobs and careers that will be introduced.



STE(A)M IT PROVISIONAL INTEGRATED LESSON PLAN

Title

Authors

Summary

Licenses

Attribution CC BY. This license lets others distribute, remix, tweak, and build upon your work, even commercially, if they credit you for the original creation. This is the most accommodating of licenses offered. Recommended for maximum dissemination and use of licensed materials.

Subject (s)

Please list in detail the subjects taught in this lesson and briefly explain why specific subjects and teachers were chosen, including the link of the non-STEM subjects and their use in improving the lesson.

Real- life questions

Aims of the lesson

Knowledge application (students are expected to demonstrate sound understanding of how the selected subjects are used and linked between them).

Connection to STEM careers

How the skills developed by this lesson connect to existing and perspective STEM careers. Students are expected to demonstrate (while working in groups or other) how the chosen subjects are linked to STEM careers and list some potential career paths.

Age of students

Time

Preparation time:

Teaching time:

Preparation:

STEM Subject 1

STEM Subject 2

STEM Subject 3/non-STEM subject

Teaching resources (material & online tools)

Materials:

Online tools:

3

STE(A)M IT PROVISIONAL INTEGRATED LESSON PLAN

21st century skills

How the lesson plan corresponds to 21st century skills. To find out more: http://www.p21.org/our-work/p21-framework

This lesson plan will enhance among the students the following skills, defined as 21st century skills:

Lesson Plan

Name of activity	Procedure	Time
	1st Lesson	
Brainstorming and discussion		
Discussion and preparation for the next lesson		
	2nd Lesson	
STEM Subject 1		
STEM Subject 1		
Learning products	*If you wish to share more materials that complement the text, please include them in the Annexes section and refer to them in this section as well.*	
	3rd Lesson	
STEM Subject 2		
STEM Subject 2		
Learning products	*If you wish to share more materials that complement the text, please include them in the Annexes section and refer to them in this section as well.*	
	4th Lesson	
STEM Subject 3/non-STEM subject		
STEM Subject 3/non-STEM subject		
Learning products	*If you wish to share more materials that complement the text, please include them in the Annexes section and refer to them in this section as well.*	

4

Figure 1 - The STE(A)M IT integrated learning master learning scenario template

The activities table is intended to be exhaustive and to ensure replicability and therefore should include as many sections and as much detail as needed for the activities to be clear, the processes to be easy to replicate, and the content to be adapted by other teachers. Figure 2 shows an example of an activities table and the level of detail required. After implementation, the learning scenario should be expanded to include the material and products created by the students, and the outcome of the students' assessment of the lesson to help improve it and guide other teachers who may wish to replicate the lesson.

Integrated STE(A)M IT Learning Scenario:
Catapults as a working machine in STEM lessons and as a war machine in History

Name of activity	Procedure	Time
Learning products	At the end of the lessons we are going to have the following learning products: • 2 tables of experimental data of axes x and y about horizontal projectile motion (these products are going to be used in the lesson of mathematics for linearization and in the lesson of IT for using online tools of making a graph) • Experimental data for the initial velocity and the dependence • 4 presentations and explanations about their experimental data from projectile motions in different cases. • The students completed their worksheets with all experimental data in different cases	
	3rd Lesson	
STEM Subject 2	Informatics Technology	45΄
Data analysis	Use data extracted from Physics Experiment to plot graphs. Evaluate the software / online tool used.	45΄
Procedure	The students are divided in three (3) working groups. Each group uses a specific open source software/online tool for plotting graphs. Group 1 will use GeoGebra (Annex 2, **Online Tools**), Group 2 will use Google Spreadsheets (Annex 2, Online Tools) and Group 3 will use Graph 4.4.2 (Annex 2, **Open Source Software**). The teacher gives Instructions and guidelines to each team about their task. The students are not familiar with the software/online tools mentioned above. Therefore, they will have to explore and experiment with the software /online tools in order to learn how to plot graphs. During this process, the teacher monitors each group and offers help and guidance. The students can use the internet to look for help e.g. video tutorials on YouTube. The purpose is for the students to feel confident to learn by themselves how to use a software / online tool.	5΄ 10΄ 20΄ 20΄

Integrated STE(A)M IT Learning Scenario:
Catapults as a working machine in STEM lessons and as a war machine in History

Name of activity	Procedure	Time
	After the experimentation and learning of the software / online tool, the teacher asks the students to use the data which they recorded from their Physics Lesson experiment and plot a graph. Each group will prepare a short presentation for evaluating the software / online tool they used and presenting the graph they created. In the presentation, each group should include the difficulties they encountered in learning and using the software / online tool, advantages and/or disadvantages and whether they would recommend it or not. Presentations of their work and final discussion.	15΄ 10΄
Learning products	The students plotted graphs (quadradic and Linear expression) using Google Spreadsheets (Annex 2, Graphs, Graphs 1). The students plotted graphs (quadradic and Linear expression) using GeoGebra (Annex 2, Graphs, Graphs 2). The students plotted graphs (quadradic and Linear expression) using Graph 4.4.2 (Annex 2, Graphs, Graphs 3.) Each working group evaluated the software / online tool they used and prepared a presentation.	
	4th Lesson	
STEM Subject 3	Mathematics	90΄

Figure 2 - STE(A)M IT master learning scenario complete template

STE(A)M EDUCATION: RESOURCES

Finally, the STE(A)M IT integrated master learning scenario template has a dedicated section for annexes. The first annex describes the pedagogical approaches that are most appropriate for the lesson and the second annex should be used to present additional guidelines, assessment worksheets, presentations, graphs and charts, text and visuals, and any other elements that are useful as a point of reference.

Download the **master learning scenario** here: https://bit.ly/STEAMIT_MasterLS

STE(A)M IT repository of integrated learning scenarios

As a starting point and a source of inspiration for teachers interested in implementing STE(A)M lessons, the framework offers a selection of integrated learning scenarios, created with and by teachers, to use or adapt in the classroom. The learning scenarios, their topics, and the subject that they integrate are outlined in the tables below (Table 2 outlines primary school level and Table 3, secondary).

Discover the pilot learning scenarios here: https://steamit.eun.org/category/integrated-stem-learning-scenarios/

You can also find links in the footnotes to access the resources directly, and the learning scenarios can additionally be downloaded from the Scientix Resource Repository[10].

Of course, the selection of themes and topics differs significantly between primary and secondary school students. While secondary students are more capable of exploring complex topics and elaborate activities, primary school activities lend themselves to more creativity-based outputs. The selection provided showcases that numerous subjects can be integrated at both levels, and that the real-world challenges and themes are common to both.

At primary level, sustainability offers a rich source of experimentation and a relatable topic for students. There are, however, significant differences in the approach of each learning scenario, with foci on ecology, recycling, water retention, and sustainable living spaces. Up to five different subjects are included in each of the learning scenarios and the age of students ranges from 8 to 11 years old.

10 http://www.scientix.eu/resources

Table 1 – Primary education STE(A)M IT integrated learning scenarios

TITLE	SUBJECT 1	SUBJECT 2	SUBJECT 3	SUBJECT 4	SUBJECT 5
Together we can make a difference (environment)[11]	Mathematics	Physics	Natural sciences	Art	Language
The solar system and the Earth: where could humans live? (space/environment)[12]	Mathematics	Science	Technology	Art	Language
Let's save our planet (environment)[13]	Mathematics	Art	Technology	Physics	---
A drop of water makes a difference (environment)[14]	Natural sciences	Mathematics	Art	Art	Citizenship

The activities table is intended to be exhaustive and to ensure replicability and therefore should include as many sections and as much detail as needed for the activities to be clear, the processes to be easy to replicate, and the content to be adapted by other teachers. Figure 2 shows an example of an activities table and the level of detail required. After implementation, the learning scenario should be expanded to include the material and products created by the students, and the outcome of the students' assessment of the lesson to help improve it and guide other teachers who may wish to replicate the lesson.

Table 2 - Secondary education STE(A)M IT integrated learning scenarios

TITLE	SUBJECT 1	SUBJECT 2	SUBJECT 3	SUBJECT 4	SUBJECT 5	SUBJECT 6
Graphene - miraculous 21st-century material[15]	ICT	Physics	Chemistry	English	---	---
Catapults in STEM and historical use)[16]	Mathematics	Physics	ICT	Sports	History	---
More light, less lighting[17]	Mathematics	Physics	Chemistry	Biology	Art history	Art design
Ocean acidification and its influence on the dissolution of calcium carbonate[18]	Geology	Physics	Biology	Chemistry	Philosophy	---
Light up future homes[19]	Mathematics	Physics	Technology	Art	---	---
Pollution and the greenhouse effect[20]	Biology	Physics	Chemistry	Art	Literature	Social science
Energy resources in the household[21]	Mathematics	Physics	Chemistry	---	---	---

11 http://steamit.eun.org/together-we-can-make-a-difference-environment/
12 http://steamit.eun.org/the-solar-system-and-the-earth-where-could-humans-live/
13 http://steamit.eun.org/lets-save-our-planet/
14 http://steamit.eun.org/a-drop-of-water-makes-a-difference-environment/
15 http://steamit.eun.org/graphene-miraculous-21st-century-material/
16 http://steamit.eun.org/catapults-in-stem-and-their-historical-use/
17 http://steamit.eun.org/more-light-less-lighting/
18 http://steamit.eun.org/ocean-acidification-and-its-influence-on-the-dissolution-of-calcium-carbonate/
19 http://steamit.eun.org/light-up-future-homes/
20 http://steamit.eun.org/the-pollution-and-the-greenhouse-effect/
21 http://steamit.eun.org/energy-resources-in-the-household/

Guidelines for teachers to overcome barriers in STE(A)M teaching/learning implementation

The practical implementation of STE(A)M learning materials and activities illustrated some frequent issues and challenges that teachers faced while taking the material to the classroom, presenting it to their students, and designing their own STE(A)M teaching material. As a result, we designed a set of guidelines that included an evaluation of the challenges faced and ways to overcome them, thus enabling teachers to feel more confident in implementing and creating resources.

The data to support the evaluation was collected through the STE(A)M IT school pilot activities, pre and post-implementation surveys, interviews with the pilot teachers, and stories of implementation written by the teachers who participated in the STE(A)M IT competitions during the Scientix STEM Discovery Campaigns 2021 and 2022.

To ensure that the document will be valuable for teachers and will also provide sound academic value for researchers who may wish to further explore the topic of STE(A)M teaching, the guidelines were drafted by the National Institute for *Documentation, Innovation and Educational Research* (INDIRE) and the *University of Cyprus*.

The guidelines for teachers to overcome barriers are available here: https://bit.ly/STEAM-IT_Guidelines-Barriers

The blog of the STEM Discovery Campaign, which includes the stories of teachers that have implemented the STE(A)M IT learning scenarios in their classrooms, and created additional learning scenarios, can be read here: https://sdw-blog.eun.org/

Explore further: framework for reforming STEM curricula

As the strategic link between the recognised needs and matching educational provision, the purpose of this framework for reforming STEM curricula[22], developed by the CHOICE project [23], is to serve as a source of inspiration for stakeholders who are directly involved with the further development and applications of STE(A)M pedagogy. The framework outlines the main challenges related to STEM teaching and learning and potential strategies to cope with them.

1. *A more* **integrated, cross-disciplinary curriculum** *to encompass more subjects instead of the prevalent silo-based single-subject approaches* – this document (CHOICE Framework on reforming STEM curriculum) aims to address exactly this by collecting examples of needs and linking them with good practices and methodologies that have proven effective in teaching STE(A)M and in the development of desired skills and competences.

2. *A more* **innovative, high-quality educational material** *to reinforce students' interest in the field* – addressed in CHOICE through 20 innovative Open Education Resources to be co-produced by teachers, students and experts from STEM field on the basis of this Framework.

3. *More* **accessible professional development and training of teachers** *in the STE(A)M approach and use of ICT tools* - CHOICE MOOC will provide teachers with OERs for their STE(A)M teaching practice including guidelines on how to use the MOOC in class and an introductory part on STE(A)M approaches in teaching. Teachers in the four implementation countries will be also trained on STE(A)M approaches and the implementation of the MOOC on STE(A)M education.

Figure 3. The main needs addressed by the CHOICE framework
(source: https://www.euchoice.eu/_files/ugd/6c0a6f_f71673b89fae4baab73030ab957865e6.pdf)

As a relevant strategic document, the framework contains both the areas identified as needing improvement and suggestions for the principal topics to be addressed through cross-disciplinary and creative pedagogical approaches in STE(A)M and has been designed within the scope of five macro-areas (see Table 3).

Table 3 – List of macro-areas

Macro-area 1	**Connecting STEM and art**
Macro-area 2	**Experiential projects**
Macro-area 3	**Stronger focus on languages in science and maths lessons**
Macro-area 4	**Technology in social sciences**
Macro-area 5	**Sports in STEM education**

Continuous professional development resources

Massive open online courses

To support teachers who wish to discover STE(A)M teaching, the STE(A)M IT framework offers two massive open online courses (MOOCs), which are available on the European Schoolnet Academy (EUNA). The courses are designed for teachers in primary and secondary school and serve as an introductory course for teachers of all levels with little or no experience in integrated STEM education. They cover the basics of STE(A)M integration and the pedagogical approaches that support it and introduce a range of activities and resources.

While the two moderated runs of the courses took place in late 2020 and late 2021, both courses are permanently available through the European Schoolnet Academy and can be accessed by teachers who are interested in expanding or revisiting their knowledge on STE(A)M integration (without simultaneous activities and certification, which were only available in the original 5-week runs of the courses).

The courses are primarily designed for teachers and are offered in English only, but any educational organisation, training institute, or ministry of education can download, adapt, translate, or even reformat them to fit their needs.

22 https://www.euchoice.eu/_files/ugd/6c0a6f_f71673b89fae4baab73030ab957865e6.pdf
23 https://www.euchoice.eu/

Both courses consist of four modules that are outlined in the table below:

Table 4 - Integrated STE(A)M teaching courses structure

Module	Title
1	Introduction to integrated STEM teaching and relevant pedagogies
2	STEM subjects and how STEM careers are contextualised at school
3	Examples of integrated STEM teaching and learning scenarios
4	Create your learning scenario and peer-assessment

In **Module 1**, integrated STEM teaching and how to 'STE(A)M IT' are defined. The main pedagogies that can be applied while implementing STE(A)M lessons are outlined and participants learn to familiarise themselves with the master learning scenario template.

Module 2 is dedicated to the way STEM careers are contextualised in the classroom and provides an overview of STEM career paths and the opportunities and challenges of bringing career awareness in class.

Module 3 presents the repository of integrated STEM teaching learning scenarios created and tested by the STE(A)M IT pilot teachers. Four learning scenarios are shared with the course participants for primary teachers and seven for secondary school teachers, providing ideas and practical examples for implementation and adaptation. Every learning scenario is supplemented with a video by the authors who explain how they collaborated as a team, worked on the learning scenario, tested it with their students, and how students reacted.

Module 4 guides the participants through the process of creating their own integrated STEM learning scenarios (the original run of the MOOCS also included a peer-assessment process that can be replicated by teachers as they co-create resources with their colleagues).

Access the integrated STEM teaching course for primary education here: https://bit.ly/STEAMIT_MOOC_Primary

Access the integrated STEM teaching course for secondary education here: https://bit.ly/STEAMIT_MOOC_Secondary

Scientific publication

Within the frame of the STE(A)M IT Project, The University of Cyprus published a scientific article in the International Journal of STEM Education. Specifically, UCY focused on the MOOC and the instrument we developed for measuring teacher responses to core dimensions of integrated STE(A)M education. The research objectives were to: (1) Check the validity and reliability of the instrument; (2) use that same instrument to assess the MOOC; (3) explore differences in responses between primary and secondary teachers; (4) explore heterogeneity in the sample and how it was influenced by sample characteristics. The results revealed that the instrument was valid and reliable and can be used for analogous purposes. Based on a pre- post-test comparison of questionnaire data from primary (N=95) and secondary teachers (N=164) who completed the MOOC, the later seems to have been successful in: (1) increasing participants' self-efficacy in integrated STE(A)M education; (2) improving their views on available resources, organizing principles and professional development programmes for integrated STE(A)M education. Primary teachers presented a higher pre-questionnaire factor score than secondary teachers for resource availability, while secondary teachers had a higher post-questionnaire factor score than primary teachers for self-efficacy. With regard to the heterogeneity of the sample, a cluster analysis showed that a percentage close to half of the sample (46.03%) did not present any significant increase after completing the MOOC. Teachers who recorded engineering among their subject areas tended to belong more to this cluster, while teachers with a motivation to exchange with like-minded colleagues or with a motivation stemming from colleagues/friends taking the MOOC tended not to belong to this cluster. A key suggestion from the study is that teacher networks are decisive for promoting integrated STE(A)M education and these networks need to be sustained and supported through teacher collaboration in pedagogical design, implementation, and assessment.

Read the full publication here: https://bit.ly/STEAMIT_Scientific-publication

STEM career resources

As described in previous sections (see *Why use the STE(A)M IT Framework?*), promoting STEM careers offers opportunities to support STE(A)M teaching and helps engage students with STEM while providing exciting career prospects. Therefore, STEM careers are introduced in two separate ways through STE(A)M IT teaching, first through learning scenarios in class and second by helping teachers develop career guidance skills.

The repository of STEM job profiles

To give visibility to STEM careers and raise awareness of the skills needed to pursue them, the STE(A)M IT framework offers a repository of STEM job profiles that showcases career prospects and introduces STEM experts.

The 'STEM job profiles repository' supports teachers and career advisers in their mission of fostering STEM career awareness among students through a collection of career sheets, video interviews, and podcast episodes. The career sheet is an exhaustive written document that introduces the expert's job, their personal experience, their journey through STEM education, and the skills needed to perform their job.

This document can be explored by students in groups or on their own, in class or as homework. The video interview and the podcast episode present similar components in a more succinct format and offer a more dynamic experience that can be used in class.

The repository is very useful for supporting teachers in contextualising STEM subjects. With the teacher's guidance, students can use the career sheets to initiate an introspection process, connect STEM knowledge to the job market, and familiarise themselves with career opportunities that they may not have considered otherwise. The repository can also be used by other stakeholders to raise awareness and share information and materials pertaining to STEM jobs.

In the *Guidelines on how to present STEM jobs in classrooms* publication, we provide suggestions on how to integrate the topic of STEM careers using career sheets, video interviews, and podcasts and through activities and follow-up suggestions. To make the material even more accessible to teachers who may have limited time to explore long documents, we created and published an abridged version of the guidelines titled *How to use the repository of STEM jobs profiles*[24], which summarises the key points and practical tools available in the full document.

Each of the 11 learning scenarios published on the STE(A)M IT and Scientix websites links to three career profiles that are relevant to the scenario's theme. The objective is for the community members to gain immediate access to a complete toolkit consisting of a learning scenario, three career profiles, and podcasts so they immediately have core material needed for their own learning scenario.

Explore the STE(A)M IT Repository of STEM Job Profiles: http://steamit.eun.org/category/stem-careers/

Read on how to present STEM Jobs in the classroom here: http://steamit.eun.org/guidelines-on-how-to-present-stem-jobs-in-classrooms/

Importance of STEM careers in STE(A)M integrated learning

To facilitate the contextualisation of STEM education, the master learning scenario template has been drafted to include a section with activities that focus on STEM career profiles. While selecting activities, tools, and materials to be used in class, teachers are advised to consider which STEM career profiles they will introduce to their students to better contextualise the learning scenario objectives and linking to relevant STEM skills.

Each of the learning scenarios that are available through the repository of pilot learning scenarios includes STEM job profiles and activities. For example, the secondary school learning scenario 'Together, we can make a difference', with a focus on environmental conservation and the reduction of atmospheric and oceanic pollution, introduces a range of career options, such as marine biologist, atmospheric climate modeller, physicist, and geographer.

The STE(A)M IT Career Advisers Network

Because teachers are increasingly tasked with offering career advice to their students, the STE(A)M IT framework includes the first of its kind Career Advisers Network (CAN).

Through this network, members benefit from STE(A)M IT and STEM Alliance[25] support to perform their function as a bridge between students and industry.

24 https://bit.ly/STEAMIT_STEM-jobs-class
25 http://www.stemalliance.eu/home

In practical terms, members are offered training to develop their science communication skills and their organisational and pedagogical practices, and to strengthen their networking abilities. Teachers also receive state-of-the-art knowledge about current and future STEM careers directly from key industry partners.

At the end of the STE(A)M IT project, the Career Advisers Network will become a part of the Scientix services, thus pursuing its mission to promote STEM careers to future generations of students.

Networking and visibility

Career advisers (CAs) benefit from exchanging and collaborating with other career advisers and educators across the pan-European network through frequent networking events, co-creation workshops and informal online gatherings. Specific events organised in partnership with the STEM Alliance allow STE(A)M IT CAs to get access to STEM practitioners seeking to develop new partnerships and to gain practical knowledge about STEM jobs. Additionally, the career advisers' profiles are showcased on the network page, giving them visibility, and all network members are given a network badge to promote their participation in the network in their own communications, social media, etc. To nurture a sense of belonging while encouraging further participation from the members, the CAs can further their status both inside and outside the network by contributing to the CAN activities, thus gaining a 'CAN mentor' status (with a new badge). Through cooperation, mentorship, and initiating activities themselves, the network is driven by its members and expands continuously.

Training

To support members in their everyday activities as career advisers, they receive practical skills training such as communication, scheduling, and pedagogy through workshops (closed events that are exclusive to the network members), and frequent refreshers on how to use the STEM jobs repository in their teaching.

However, because the advisers' practical skills are only part of the equation, CAs are also given the opportunity to expand their knowledge of STEM jobs and career opportunities and the skills required to pursue them. Since this core knowledge needs to be regularly updated to reflect the ever-changing needs of the industry, advisers can attend webinars organised in partnership with the STEM Alliance to hear directly from industry partners who provide up-to-date information, offer insight into the future of STEM jobs, and even give practical advice on how to reach out to STEM professionals.

Finally, teachers outside the network (or those wishing to join, as the CAN is open to all those interested in STE(A)M career guidance) can learn more about good practices in career guidance through the **Handbook for Career Advisers**, published in late 2022. This handbook offers theory on career guidance, advice and good practice, and a range of examples and tools on how to introduce STEM jobs in the classroom and successfully motivate students to pursue a career in STEM. This handbook was created by the members of the network themselves under the supervision of the STE(A)M IT pedagogical staff.

Discover the members and join the network here: https://steamit.eun.org/career-advisers-network/

Read the advice from Industry on reaching out to STEM professional here: http://files.eun.org/scientix/STE(A)M-IT-SA-CAN-Advice-from-Industry.pdf

Access the Handbook for career advisers here: https://bit.ly/STEAMIT_Handbook-CAs

Explore further: competence framework for STE(A)M educators

Competence-based strategies provide flexibility and personalised learning opportunities with better learner engagement because the content is relevant to each learner and tailored to their unique needs. In addition, this method lets learners acquire skills that they find challenging at their own pace, allowing them to practise as much as they need, and move rapidly through other skills in which they are more proficient.

The STE(A)M competence framework for educators[26], developed by the STE(A)MonEDU project[27], has two main objectives:

The first one is to be a user-friendly self-assessment tool for educators to evaluate themselves and identify the specific competences that they need to improve. Educators benefit from using self-assessment and reflection tools that can help them assess their fundamental beliefs and assumptions about learning, learners, and teaching, and the differences between their perceptions of practice and those held by students in their classroom.

The second objective of the STE(A)M competence framework for educators is to support the professional development of STE(A)M educators by providing guidance on formulating learning outcomes for specific training programmes, and by offering an assessment tool for evaluating STE(A)M-focused training programmes.

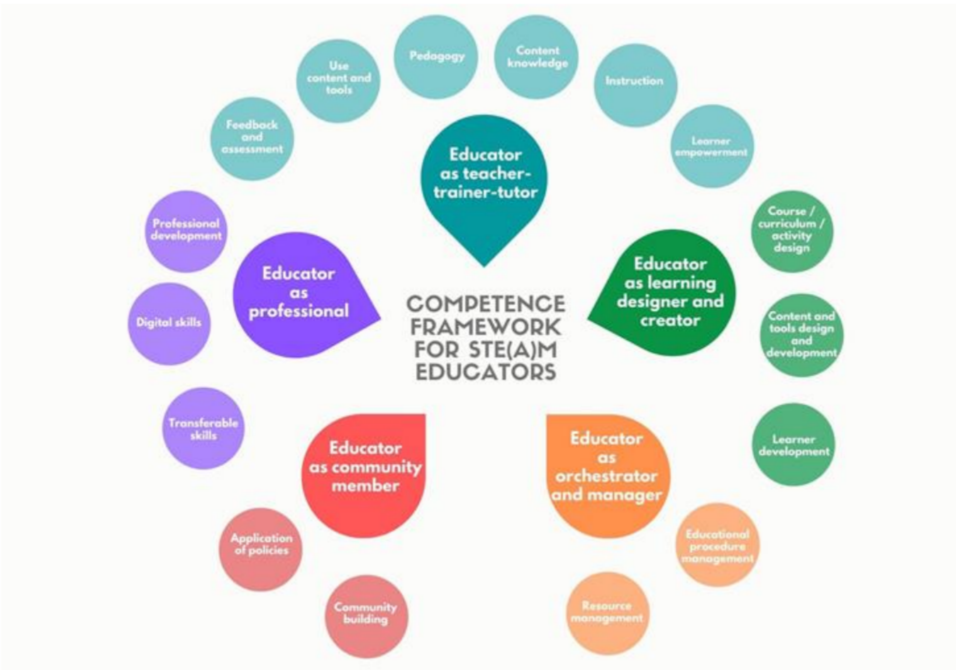


Figure 3 – Overview of the Competence Framework for STE(A)M Educators (Source: https://steamonedu.eu/wp-content/uploads/2022/01/D8.2-STEAM-educator-competence-framework-and-profile.pdf)

26 https://steamonedu.eu/wp-content/uploads/2022/01/D8.2-STEAM-educator-competence-framework-and-profile.pdf

27 https://steamonedu.eu/

WAY FORWARD: ADVICE FOR STAKEHOLDERS

In this final section, we introduce some key advice for stakeholders that can help them support the integration of STE(A)M subjects. Whether it be in the classroom, in school, at decision-making level, or in the professional world, everyone will find some guidance here!

The list of advice is non-exhaustive, and stakeholders are encouraged to explore all the solutions for STE(A)M integration on their own, find new ideas, and be creative to support and implement STE(A)M teaching.

Educators

- **Make use of technological tools and resources that foster STE(A)M integration:** Teachers should use the material provided within the framework, learning scenarios, and activities with STEM professionals in the field. Additionally, teachers should seek to incorporate educational robotics and engineering, which have been identified as an ideal subject and STEM experience, to support STE(A)M integration. In the digital age, using blended learning has also become mandatory to equip students with 21st-century skills. Therefore, switching between hands-on and digital learning experiences will foster the enrichment of student learning paths and help achieve the desired learning outcomes. Finally, while initially perceived as an impediment on teaching, distance learning activities mandated by the COVID-19 restrictions should be viewed as an opportunity to overcome distance and successfully achieve previously challenging activities. The difficulty of organising a visit with a STEM professional is now easier thanks to web conferencing tools.

- **Establish good collaboration with colleagues:** A key prerequisite for STE(A)M integration is collaboration between teachers in designing and implementing STE(A)M learning scenarios. Peer collaboration is a necessary precondition for overcoming the currently dominant silo approach, especially in secondary education, which sets a crucial barrier to STE(A)M integration. Teachers should use the guidelines to overcoming barriers that are provided in the framework to find inspiration in successfully organising themselves with colleagues and help them design collaborative activities that will support STE(A)M integration. In addition, individual initiatives that showcase successful teacher collaboration in designing and implementing STE(A)M learning scenarios can set the stage for a full-scale uptake of STE(A)M integration at school level and provide examples of good practice for inspiration and transfer.

- **Participate and contribute to teacher communities of practice:** Peer feedback and support are key resources in a teacher's initial effort to orient themselves in STE(A)M education, understand the potential of such an integration, and choose the trajectories that best fit their needs and desires as an educator. In practice, peer networks of teachers engaged in STE(A)M education will act as communities of practice and catalysts for STE(A)M integration. These networks are easier than ever to organise using online platforms and resources and provide useful for exchange and peer support.

Heads of school

School management, and heads of school in particular, has a significant role to play in mainstreaming STE(A)M-integrated learning and teaching.

- **Foster a supportive and collaborative school environment:** Heads of school have the capacity to foster an open and innovative school culture that supports the introduction of new pedagogical approaches. They can also promote collaborative culture among teachers and provide practical arrangements that will allow peer learning among teachers who are interested in introducing STE(A)M integrated learning.

- **Shape an enabling environment for STE(A)M integration:** Heads of schools should reconsider time allocation and management and strive to strike the best balance between structure and flexibility on daily, weekly, and annual schedules within schools to give the opportunity to teachers to work together on designing and implementing lesson plans for STE(A)M integration. Additionally, school administrations should look to extend the enabling environment for STE(A)M integration to school surroundings through strategies like the Living Labs[28] and Open Schooling[29], building long-lasting synergies and ecosystem hubs with communities and other schools.

- **Promote long-term school projects:** School projects of a longer duration are more likely to promote STE(A)M integration. Heads of school should encourage teachers to design and implement such projects while encouraging them to work in teams. Furthermore, each new initiative should build on the experience gained from previous projects. In addition, project-based learning at each school may capitalise on the perspective of learning progressions, which are designed to enable the accumulation of students' knowledge and skills in specific topics of the curriculum across different grades.

Ministries of education (MoEs)

Emergency teaching situations like the ones experienced during the COVID-19 pandemic highlight that the success of innovative and potentially transformative methodologies like STE(A)M teaching rely on the readiness, flexibility, and adaptability of teachers. These features can be limited by low technological literacy and limitations in accessing equipment.

- **Provide diversified training** on a recurring basis, for pre and in-service teachers on how to design and implement STE(A)M teaching.

- **Facilitate the inclusion of STE(A)M teaching to the existing curricula:** Help mainstream STE(A)M teaching by including it in the curriculum either formally or as part of suggested pedagogies that teachers are encouraged to explore and implement, both in pre-service and in-service training.

- **Adapt school textbooks and teachers' supportive material** to highlight interdisciplinary links and to include suggestions of integrated activities (i.e., revise textbooks, reform foreseen didactic materials that should be covered throughout the year based on overlaps in learning objectives and content).

- **Facilitate the exchange of good STE(A)M teaching and learning practices** and sharing experiences and expertise among teachers by promoting the creation of communities of practices at local and national level. A good starting point is promoting the work of early adopters of STE(A)M integration who can serve as mentors and motivators for the entire school community.

28 https://enoll.org/
29 https://www.openschools.eu/

- **Carry out curriculum analysis** at national and European level to identify the current status and potential for STE(A)M integration. Although the need for STE(A)M integration cannot be disputed, the current conditions in everyday school practice are still lagging and may prove quite discouraging for students, teachers, and policymakers. A curriculum analysis is needed to showcase the current level of STE(A)M integration and the opportunities for more integration, based on small-scale changes that are easy to visualise and implement. Small and achievable activities are the first step towards a realistic uptake of STE(A)M integration as they remove unnecessary overlaps and exploit existing synergies between STEM disciplines.

Industry

Industry should strive to develop and maintain bonds with schools and the education community.

This, of course, includes providing access to materials and equipment, but should also include frequent participation in events and training programmes that raise awareness of current STEM careers and new emerging job fields, and provide information about study paths and the skills needed to pursue those careers.

- **Identify the skills needed in their respective fields and provide guidance for STEM teachers to help educate students in these specific skills.** This can be achieved by providing information about the skills and studies required through events with professionals to present a practical example of a career, and by offering role models that will help students identify with the issue and career through career profiles. Skills and jobs are always best introduced at a local and personal level as this provides realistic career paths for students. Therefore, companies should strive to reach out to local schools (when possible).

- **Provide equipment and other incentives (like scholarships)** to students or facilitate the introduction of extra-curriculum programmes to inform about STEM jobs, involving school alumni when possible.

- **Strengthen the company's corporate responsibility** department. In addition to major issues like ethical commerce or transparency, large focus should be placed on reasserting Europe's position as a workforce and corporate power following the recession and the brain drain of the past decade. This can only be achieved by actively investing in finding and nurturing talent.

Researchers

As education is moving to a new era, the need to provide students with adaptable solutions and methodologies that will help them bridge cognitive gaps and develop the adequate skills becomes imperative. Research will also have a role to play in further investigating how STE(A)M integration contributes to current educational needs and provide tools and solutions that will help teachers maximise its impact.

- **Develop and assess a toolkit for evaluating and supporting STE(A)M education:** A challenge for a full-scale adoption of STE(A)M education across all educational levels is developing a toolkit for evaluating STE(A)M education. This is a complex task that will require the realignment of learning goals and standards with learning activities and learning products. Given the significant logistics and time required for a comprehensive evaluation of STE(A)M teaching resources, a first realistic step would be to focus on the learning products of the resources as a proxy for quality outcome.

- **Provide/develop certification of integrated STEM skills and competences:** The assessment toolkit suggested above could be used to certify integrated STEM skills and competences. If further adapted to non-formal and informal learning settings, thus creating solid bridges with formal learning settings, the toolkit would also be valuable for vocational training and life-long learning. Overall, a certification like this should be designed to close the skill and competence gaps between formal education and the needs of the STEM industry.

- **Investigate the relationship between integrated STEM teaching/learning and the development of soft skills:** STE(A)M integration and its connection to soft skills also affects the way it is perceived and how much traction it can gain. Soft skills, also known as common skills or core skills, are skills that are applicable and desirable to all professions and are deeply connected to employability. These include critical thinking, problem solving, public speaking, professional writing, teamwork, digital literacy, leadership, professional attitude, work ethic, career management, and intercultural communication.

REFERENCES

Barron, B., & Darling-Hammond, L. (2008). Teaching for meaningful learning: A review of research on inquiry-based and cooperative learning in *Powerful Learning: What We Know About Teaching for Understanding*. Jossey-Bass/Wiley.

Black, P., & Wiliam, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability* (formerly: Journal of Personnel Evaluation in Education), 21(1), 5-31. https://doi.org/10.1007/s11092-008-9068-5

Braund, M., & Reiss, M. (2006). Towards a More Authentic Science Curriculum: The Contribution of Out-of-School Learning. *International Journal of Science Education*, 28, 1373-1388. http://dx.doi.org/10.1080/09500690500498419

Bulte, A. M. W., Westbroek, H. B., de Jong, O. & Pilot, A. (2006) A Research Approach to Designing Chemistry Education using Authentic Practices as Contexts. *International Journal of Science Education*, 28:9, 1063-1086. https://doi.org/10.1080/09500690600702520

Bybee, R. W. (2011). Scientific and engineering practices in K-12 classrooms. *Science Teacher*, 78(9), 34-40. https://static.nsta.org/ngss/resources/201112_Framework-Bybee.pdf

Cenoz, J. (2013). The influence of bilingualism on third language acquisition: Focus on multilingualism. *Language Teaching*, 46(1), 71-86. https://doi.org/10.1017/S0261444811000218

Demirel, F. (2019). The role of education in human nature and future human design according to Edgar Morin. *New Trends and Issues Proceedings on Humanities and Social Sciences*, 6(6), 18–29. https://doi.org/10.18844/prosoc.v6i6.4464

Dewey, J. (1966). *Democracy and education: An Introduction to the philosophy of education*. Free Press.

Dunning, P. J. H. (2000). *Global Capitalism at Bay* (1st ed.). Routledge. https://doi.org/10.4324/9780203186039

Gardner, P. (1994). Representations of the Relationship between Science and Technology in the Curriculum. *Studies in Science Education*, 24:1, 1-28. https://doi.org/10.1080/03057269408560037

Gilbert, J.K. (2006). On the nature of "context" in chemical education. *International Journal of Science Education*, 28 (9), 958. http://www.sciepub.com/reference/184736

Greeno, J. G., Collins, A. M., & Resnick, L. B. (1996). Cognition and learning. In: D. C. Berliner & R. C. Calfee (Eds.), *Handbook of educational psychology* (pp. 15–46). Macmillan Library Reference USA, Prentice Hall International.

Jones, B. F., Rasmussen, C. M., & Moffitt, M. C. (1997). Real-life problem solving: A collaborative approach to interdisciplinary learning. *American Psychological Association*. https://doi.org/10.1037/10266-000

Krajcik, J. S., & Blumenfeld, P. C. (2006). Project-based learning. In: Sawyer, R. K. (ed.), *The Cambridge Handbook of the Learning Sciences*. Cambridge University Press. https://doi.org/10.1017/CBO9780511816833.020

Laur, D., & Ackers, J. (2017). *Developing Natural Curiosity through Project-Based Learning: Five Strategies for the PreK-3 Classroom* (1st ed.). Routledge. https://doi.org/10.4324/9781315528410

Levy, F., & Murnane, R. J. (2012). The new division of labor. In: *The New Division of Labor.* Princeton University Press.

Linn, M. C., Davis, E. A., & Bell, P. (Eds.). (2004). *Internet environments for science education*. Lawrence Erlbaum Associates Publishers.

Markham, T., Larmer, J., & Ravitz, J. (2003). *Project-Based Learning Handbook: A Guide to Standards Focused Project-Based Learning for Middle and High School Teachers.* Buck Institute for Education.

Mayer, R., E. (2002). Rote Versus Meaningful Learning. *Theory into Practice*, 41:4, 226-232. https://doi.org/10.1207/s15430421tip4104_4

Moore, T., Stohlmann, M., Wang, H., Tank, K., Glancy, A., & Roehrig, G. (2014). *Implementation and integration of engineering in K-12 STEM education*. In: Purzer, S., Strobel, J., & Cardella, M. (Eds.), *Engineering in Pre-College Settings: Synthesizing Research, Policy, and Practices.* Purdue University Press. https://doi.org/10.2307/j.ctt6wq7bh

Moursund, D. G. (1999). *Project-based learning using information technology*. Author.

Nagel, N. G. (1996) Learning Through Real-World Problem Solving: The Power of Integrative Teaching. Corwin Press.

National Research Council (2006). *America's Lab Report: Investigations in High School Science*. The National Academies Press. https://nap.nationalacademies.org/catalog/11311/americas-lab-report-investigations-in-high-school-science

Organisation for Economic Cooperation and Development (OECD) (2019), *future of education and skills 2030: OECD learning compass 2030*. https://www.oecd.org/education/2030-project/teaching-and-learning/learning/learning-compass-2030/OECD_Learning_Compass_2030_Concept_Note_Series.pdf

Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A. N., Kamp, E. T., Manoli, C. C., Zacharia, Z. C., Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle, *Educational Research Review*, Volume 14, 47-61. https://doi.org/10.1016/j.edurev.2015.02.003

Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Walberg-Henriksson, H., & Hemmo, V. (2007). Science Education Now: A Renewed Pedagogy for the Future of Europe. High Level Group on Science Education, Directorate General for Research, Science, Economy and Society, European Commission. https://www.eesc.europa.eu/sites/default/files/resources/docs/rapportrocardfinal.pdf

Sanders, M. (2009). STEM, STEM education, STEM mania. *The Technology Teacher*, 68(4), 20–26. https://www.researchgate.net/publication/237748408_STEM_STEM_education_STEMmania

Savery, J. R. (2006). Overview of Problem-based Learning: Definitions and Distinctions. *Interdisciplinary Journal of Problem-Based Learning*, 1(1). https://doi.org/10.7771/1541-5015.1002

Schroeder, C. M., Scott, T. P., Tolson, H., Huang, T. Y., & Lee, Y. H. (2007). A meta-analysis of national research: Effects of teaching strategies on student achievement in science in the United States. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, 44(10), 1436-1460. https://doi.org/10.1002/tea.20212

Silva, E. (2009). Measuring skills for 21st century learning. *Phi Delta Kappan*, 90(9): 630–634. https://doi.org/10.1177/003172170909000905

Swain, M. (2001). Integrating language and content teaching through collaborative tasks. *Canadian Modern Language Review*, 58(1), 44-63. https://doi.org/10.3138/cmlr.58.1.44

Thomas, J. W. (2000). *A review of research on project-based learning*. Autodesk Foundation. http://www.bobpearlman.org/BestPractices/PBL_Research.pdf

Thomas, J.W., Mergendoller, J.R., & Michaelson, A. (1999). *Project-based learning: A handbook for middle and high school teachers*. The Buck Institute for Education.

Trilling, B., & Fadel, C. (2009). 21st century skills: Learning for life in our times. Jossey-Bass/Wiley.

Whitehead, A. N., (1929) *The Aims of Education and Other Essays*. Macmillan.

Wilensky, U., & Resnick, M. (1999) Thinking in Levels: A Dynamic Systems Approach to Making Sense of the World. *Journal of Science Education and Technology* 8, 3–19. https://doi.org/10.1023/A:1009421303064

Woods, R., & Barrow, R. (2006). *An Introduction to Philosophy of Education* (4th ed.). Routledge. https://doi.org/10.4324/9780203969953

STEAM IT

AN INTERDISCIPLINARY STEM APPROACH

STEM Alliance

inGenious education & industry

COORDINATOR

European Schoolnet

PREMIUM PARTNERS

AMGEN Cisco Networking Academy GSMA IBM LEGO education Lenovo Microsoft TRANE TECHNOLOGIES

GENERAL PARTNERS

AIRBUS FOUNDATION COBIE.IO DARTEF DELL Technologies elias key2enable KOTOKAN Notebloc Scanner OneStream Qualcomm SKRIWARE Texas Instruments