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ICSE Academy

International Centre for STEM Education

Pädagogische Hochschule Freiburg
Université des Sciences de l'Education · University of Education

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DISSEMINATION LEVEL	
X	PU=Public
	PP=Restricted to other program participants (including the EC)
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EXECUTIVE SUMMARY

STEM education has been in the emphasis on various EU and national reports during the last twenty years with an emphasis on meeting the shortage in STEM professions, while at the same time offering an education for all students. Despite the various STEM related efforts, underachievement in STEM is still a problem in EU partner countries. Furthermore, more recent reports highlight the need for a STEM education which breaks the traditional boundaries between the STEM disciplines, is more interdisciplinary, focuses on competences rather than content knowledge only, and considers the 2030 SDG goals. The ICSE Academy project aims to support pre- and in-service STEM teachers to improve their knowledge, skills and competences. Thereofore, an analysis for identifying the current situation in partner countries in relation to STEM Education was contacted (Part A), whilst a policy needs analysis report was developed for the purposes of the ICSE Academy (Part B). Considering the first part, nine important findings were identified across partner countries.

Finding 1. STEM is understood and defined as four separate disciplines in almost all partner countries.
For most of the partners defining STEM education was not straightforward. Consequently, variation among countries' understanding of STEM was observed

Finding 2. The majority of the partner countries do not have a STEM curriculum.
Most countries follow an interdisciplinary approach by giving emphasis for example on the integration of technology.

Finding 3. Partner countries have serious STEM action plans but none of the partner countries has a STEM education policy.
Different initiatives, such as education centres offering STEM education programs to students, teacher professional develepement centers for STEM education, development of STEM schools etc. were observed about STEM education across countries.

Finding 4. None of the countries has STEM teachers, all countries have teachers of different STEM disciplines.
In most countries, teachers are separated in different disciplines or there are teachers who have a double major.

Finding 5. Policies regarding the training of the in-service teachers vary across the partner countries.
In-service training programs are compulsory in some countries and not in others. Additionally, there are countries with no specific in-service training programs.

Finding 6. Most of the partner countries prepare STEM teachers primarily as content experts and then as experts in pedagogy.
The requirements to become a STEM teacher are different across countries. The most common way to become a STEM teacher, is to complete a degree in any subject giving emphasis on content knowledge including pedagogical knowledge and/or Pedagogical Content Knowledge (PCK) or after the completion of the degree in one of the STEM subjects, to acquire a pedagogical qualification

Finding 7. Most of the countries face challenges with teacher shortages on STEM subjects.
Teacher shoratges is an issue in most of the countries due to the big numbers of teachers that have retired in recent years and because of problems recruiting new

STEM teachers since teaching considered as a challenging profession.

Finding 8. None of the countries offer training in a structural way to teachers for teaching STEM in an interdisciplinary way.
In most of the partner countries, teachers have the option to attend a professional development program which depends on the educational institution offering it. For example, universities offer courses related to interdisciplinary teaching.

Finding 9. In most countries, there is no systematic training for inservice teachers considering STEM education.
Through the analysis, it was observed that there is not a obligatory training for inservice teachers and at the same time not a systematic CPD in most of the countries with some exceptions coming from universities which offer master programs in STEM education.

Based on the policy needs analysis the following eight needs have identified

Need 1. Set up STEM policies on national and EU level.
STEM education is currently defined as cross-curricular, project oriented and aiming to increase learners interest and competences in the STEM areas. Additionally, the need to link STEM with the SDGS (sustainability, new technologies, future challenges, awareness of societal challenges) is identified. STEM is presented is presented as an approach and an opportunity for teachers training through authentic daily life problems, combining the practices and the content from the different disciplines. Despite the aforementioned, there is agreement deriving from the policy analysis that there are no specific policies in ICSE Academy partner countries or at EU level regarding STEM education, and therefore there is a need for national and EU level STEM policies.

Need 2. Support development of interdisciplinary STEM education to promote competences and entrepreneurial skills.
The policy needs analysis has identified STEM education as important to prepare future citizens with the necessary competences and knowledge to understand the problems we are facing as a society and propose solutions. Furthermore, STEM education is viewed as a way to prepare future STEM professionals and promotes analytical and critical thinking skills which are important for scientific literacy among all citizens. As highlighted by some policy makers, engaging in an interdisciplinary STEM education will provide students with the communication and entrepreneurial skills that are necessary for future employment.

Need 3. Prepare curricula that is breaking the boundaries between the disciplines and is competence oriented and linked to everyday problems.
In all ICSE consortium countries the needs analysis report has identified that it is common to teach only within one discipline/subject, with some cases teaching two subjects but in a separated way. All policy makers identify the importance of breaking the boundaries between disciplines and suggest that the goal of an interdisciplinary STEM approach would be to support students to develop competences through STEM education with lessons that are based on real life problems, are open and planned around project based pedagogies and include collaborations with companies and universities and other stakeholders. Policy makers also highlight the fact that industry is now interdisciplinary, and by preparing the students to work in this way they will be ready for the industry.

Need 4. Teacher professional development in line with new societal changes (i.e. emphasis on inclusion, sustainable development)
The policy needs analysis has identified that STEM education in the ICSE consortium countries

remains unchanged and is still not addressing interdisciplinarity, communication and entrepreneurial skills and engaging students in discussion and problem solving of current societal issues. Furthermore, emphasis should be shifted on inclusion in STEM (i.e. children with behavioral problems, integration, language difficulties, girls) and promote STEM-friendly cultures in schools, e.g., through more cross-curricular, project-oriented STEM instruction or by strategically combining the areas of STEM instruction, STEM continuing and further education, educational and career orientation, and reflective gender education.

Need 5. Bottom-up approach to identify teachers need in professional development and longer professional development courses

According to policy makers, teacher professional development needs are not always met by the professional development courses offered, as professional development usually focuses on topics linked with content knowledge or with the field or management issues in the classroom. A bottom-up approach should be used to identify teachers' training needs. Additionally, policy makers suggest that teacher professional development courses should be longer in duration to prepare teachers to change their practice.

Need 6. Develop exemplar STEM teaching materials

It was reported across the consortium responses that exemplar STEM curriculum materials are not always available for teachers as good examples of practice.

Need 7. Prepare teachers to discuss ethical issues and uncertainties in STEM.

Most of the current STEM topics have ethical considerations which the students and teachers should be prepared to discuss and understand. Examples of ethical issues include the use of AI, and sustainable development. STEM teachers need to be prepared to engage in discussions of ethical issues and controversies.

Need 8. Promote mobility of STEM teachers and exchange of training in STEM

Professional development and teacher training in the ICSE Academy consortium countries are very specific to the local context, but at the same time the issues with which STEM education is engaging with are international. Therefore, engaging in exchange of ideas with teachers from other EU countries can support teachers to understand the global perspective of STEM problems and find ways to engage their students with a more global perspective as well. Therefore the need for teacher mobility is imperative.

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Introduction

The main purpose of this document is to outline the necessary requirements for STEM education and in consequence STEM teacher education for the 21st century, based on research available and needs analysis carried out in the consortium. In order to prepare the policy brief a comprehensive policy-needs-analysis was carried out with the help of the consortium members and policy makers of the consortium. Initially a brief questionnaire was answered by the consortium members (Austria, Cyprus, Czech Republic, Germany, Greece, Lithuania, Malta, the Netherlands, Norway, Slovakia, Spain, Sweden and Turkey) describing STEM education and teacher professional development in their countries. Based on the questionnaire responses and a desk research of available STEM education policies in Europe we have prepared a list of findings. Additionally, a questionnaire was prepared and circulated with members of the National Policy Committees of the consortium countries (Austria, Cyprus, Czech Republic, Germany, Greece, Lithuania, Malta, the Netherlands, Norway, Slovakia, Spain, Sweden and Turkey) to identify current policies and needs related to STEM education and STEM teacher professional development in their countries. The current document, Deliverable 6.1 includes the full needs analysis and report, including at the end of the document a strategy to inform policy makers. The policy-needs-analysis as well as the strategy will be updated once a year. Also on an annual basis, we will compare our strategy to inform policy makers with our performance and rectify our proceeding if deemed necessary.

This needs analysis includes information about STEM teacher education in general, definitions of STEM education, policies in partner countries related to STEM education and teacher professional development and analysis of the existing training programs in each country. An Executive Summary, presented as a policy brief is included at the beginning of this Deliverable tailored to policy makers, whilst the whole document presents the comprehensive policy-needs-analysis from the two questionnaires and the desk analysis.

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Background Information on STEM Education and Policies

The STEM acronym stands for Science, Technology, Engineering and Mathematics. The emphasis on promoting STEM education goes back to the period of the cold war when countries realized the role of STEM fields in supporting them with a technological and consequently financial development. Ever since then almost all developed countries, including EU countries, established various initiatives to promote STEM and achieve successful implementation in schools. In 2004 the EU Research Commissioner Philippe Busquin stated that " Excellence in scientific and technological development is central to securing Europe's future" and set up a group of experts to explore ways to attract more people to follow STEM careers. One of the main outcomes of the report of that group of experts suggested that school science is not linked to everyday life and work experience, and that elitist policies in science should be avoided (EU, 2004). In 2008, the report Science Education in Europe: Critical Reflections (Osborne & Dillon, 2008) reported on the failure of the educational system to provide curricula that will meet the needs of the majority of the students. This report, for the first time moves the emphasis from a science and STEM education focused on producing the next workforce of Europe, to the need of a science and STEM education for all, that will offer universal value for all students, and not only for those interested in STEM careers. Based on the same report, science should focus on making the connection with the real world, emphasis should be placed on improving the education of teachers, and developing the ways in which science is taught with an emphasis on competences and not content knowledge only.

Various reports in Europe for the past 20 years highlight the need for the importance of promoting mathematical thinking and problem solving, and the use of technology in mathematics education, rather than focusing on content knowledge only. The Eurydice report "Mathematics Education in Europe" (2015) focused on the competences in mathematics as integral to a range of disciplines and everyday life and explored how partner countries tried to tackle under-achievement in mathematics, by focusing also on initial teacher education programs. Early technology education reports identified the need to incorporate technology in education (i.e. eLearning Action, 2001) and later on digital competences for citizens (Carretero et al., 2017; Vuorikari et al., 2022) and focused on digital competences for educators (Punie &, Redecker, 2017). Information and policy reports about engineering education in Europe is mostly focusing on higher education and examining the needs of engineering in relation to the education of future engineers in Europe.

The report 'STEM Skills for a Future-proof Europe' by the EU STEM Coalition in 2016 highlights that despite the pockets of excellence in Europe, we are still not keeping pace with demand for STEM skills, and employers in the EU have difficulties in finding people with the right skills. Especially, they report a lack of problem solving and communications skills. At the same time international studies (i.e. TIMSS, PISA) show a decline in students' scores in mathematics and science in Europe. According to the EU report (2019) titled 'PISA 2018 and the EU', the underachievement rate of less than 15% that was set by the EU for 2020 was not reached neither in science nor in mathematics, but on the contrary students' performance in science deteriorated, and in mathematics remained stable. As reported in a Scientix Observatory Paper in 2018 titled 'STEM Education Policies in Europe', while European countries would like to implement STEM education, an integrated strategy is not observed on national and European level. What is also noted in the same report and in the OECD (2018) report is that that a culture of inclusion in schools and the availability of high-quality resources and extracurricular activities can support students to achieve better results in STEM, and a European framework of reference for STEM education is of importance.

Defining STEM education and STEM literacy

The definition of STEM education varies across EU countries which results in a broad ambiguity of its definition. This inconsistency may result in different approaches and implementation of STEM education across countries, but also within countries. The first definition of STEM education was given in the 1990s by the National Science Foundation (NSF) and continues to be followed by many educational practitioners. Based on this definition, STEM refers to the four separate and distinct fields known as science, technology, engineering, and/or mathematics.'

The other definition of STEM education considers also the four subjects (science, technology, engineering, mathematics) but at the core of its meaning is the teaching approach that is preferred which moves from the traditional instruction. Consequently, it refers to the teaching and learning of these subjects in an integrated and interdisciplinary approach, while it also promotes students' competences linked with critical thinking, problem-solving, and inquiry-based learning and supporting them to become responsible citizens. It is considered as an interdisciplinary approach which focuses on teaching the four different subjects or disciplines in a more integrated ways using a problem-based approach and based on read world applications (EU Choice Report, 2021).

The report 'STEM Skills for a Future-proof Europe' by the EU STEM Coalition in 2016 suggested to ensure that STEM subjects in higher education can potentially equip students with transversal skills and competences including creativity, flexibility and entrepreneurial mindset. Furthermore, the same report highlights the need for a collaboration between educators and other stakeholders to reach a common understanding of the necessary skills that people need in the modern society. The same report is suggesting a bottom-up approach for formulating a national STEM strategy to fit to each member state needs. Furthermore, according to the OEDC (2019), STEM education seeks to develop and provide innovative solutions to global issues, with an emphasis to the 2030 SDGs (Sustainable Development Goals. The report highlights the need for education to rethink boundaries between the traditional curriculum subjects and place an emphasis on competency-based curricula "that prepare young people with required competences to live sustainable, fulfilled and healthy lives in the rapidly changing world of the 21st century" (p.3, OECD, 2019). According to the same report there is limited understanding of the challenges that teachers face in implementing such a curriculum, and this should be considered by teacher trainers.

Finally, the OECD (2019) report explains the importance of an integrated STEM approach as a way to prepare multidisciplinary workforce that will be equipped with skills that require the integration of multiple disciplines. At the same time the report highlights that there is still limited understanding and limited research of the STEM competences (i.e. knowledge, skills, attitudes and values) that must be considered in order to implement an integrated curriculum.

Trends in STEM policy reports

Despite the emphasis on STEM education during the last twenty years, EU countries are still struggling at a national and European level to have a common framework and a common understanding of STEM education. Furthermore, students' outcomes in STEM related subjects does not show any considerable improvement based on evidence from international studies (i.e. TIMSS, PISA), and shortage in STEM workforce is still at place.

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The trends in more recent European Policy reports highlight the need for a STEM education which breaks the traditional boundaries between the STEM disciplines, is more interdisciplinary, focuses on competences rather than content knowledge only, and places an emphasis on the 2030 SDG goals. Furthermore, when it comes to STEM teachers, the Eurydice (2017) report on 'The Teaching Profession in Europe', highlights that teachers express the need for professional development in teaching methods and not content knowledge, and that less than 1/3 of the teachers have been abroad for professional purposes. Most of the teachers have benefited from the Erasmus+ scheme for their mobilities. Finally, in most of the EU countries there is a shortage of STEM teachers and, teachers according to the report state that the PD offered does not match their needs.

In summary, more recent policy reports as presented in previous sections focus on the following: (a) Emphasis in STEM education should be on competences; (b) STEM should be referring to an integrated and interdisciplinary STEM approach, breaking the traditional boundaries between the discipline; (c) Collaboration between the workforce, government and educators to identify the necessary skills and competences for STEM in the future; (d) Educating the educators on how to implement STEM approaches in their teaching and (e) Providing opportunities for mobility for STEM teachers.

Description of STEM education in consortium countries

To identify the current situation in partner countries in relation to STEM Education, STEM teacher professional development and teacher training and national policies, a questionnaire was designed and administered to all thirteen partners. The questionnaire (see Appendix I) includes questions about the definition of STEM in each country, local STEM curricula, STEM teacher training and teacher education and challenges they face. The consortium countries include Austria, Cyprus, Czech Republic, Germany, Greece, Lithuania, Malta, the Netherlands, Norway, Slovakia, Spain, Sweden and Turkey. The analysis below presents the current situation in all thirteen partner countries as reported by the consortium members.

Finding 1. STEM is understood and defined as four separate disciplines in almost all partner countries

For most of the partners defining STEM education was not straightforward, probably because in most of the countries there is not a specific curriculum or specific programs for STEM education. In GER, STEM is defined as a promotion of Natural Sciences and technology. In Greece and Cyprus, STEM education refers to the aspects of teaching the four different subjects as part of the national curriculum. In the Netherlands, STEM education is approached through (inter)disciplinary activities for secondary school students and teachers and the connection of students with scientists and science studies. In Norway, STEM education was one approach for the former Government's strategy for stimulating talents and high performing students, eg. funding learning centers for STEM talents and encouraging local regional levels to offer local learning centers for STEM education. In Spain STEM education is conceptualized as an opportunity for teachers training through authentic daily life problems, combining the practices and the content (need to know principles) from Science, Mathematics Education, Technology and Engineering. A more specific and well-structured definition comes from Austria which characterizes STEM as a cross-curricular, project-oriented perspective – considering all the four disciplines. Through this definition, students have the chance to cultivate important skills such as problem-solving skills, to increase their interest about those areas, but also to deal with diverse topics important for society. Austria is closer to the definition of integrated STEM education, while Greece is closer to the first definition which approaches Science, Technology, Engineering and Mathematics as subjects which are taught separately. In the rest of the countries, interdisciplinarity is preferred, however the extent to which this interdisciplinarity takes place is not clear. From these definitions or descriptions, it is obvious that each country defines and understands STEM education differently. However, through the reports, most of the countries highlighted the significance of STEM education in teaching.

Finding 2. The majority of the partner countries do not have a STEM curriculum.

The majority of the partner countries reported that they do not have a specific curriculum on STEM, with the exception of Austria in which a curriculum for interdisciplinary subject called MINT (STEM) has been developed and followed by 58 middle schools during the academic year 2022-2023. In general, across countries the STEM subjects are taught independently, although some of the responding countries declared that interdisciplinary is supported by their curricula to some extent. In Norway for example, technology has been an important part of the Norwegian school in the form of the compulsory, multidisciplinary subject since 2006. Technology remains a core element as in secondary schools students have the option to select the subject of technology in practice, while from 2020, technology has been integrated in the new curriculum and in particular aspects of programming

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and modeling. In the Netherlands a focus on technology has also been observed but in combination with a subject called Nature. In primary schools there are interdisciplinary attainment targets for the domain ''Nature and Technology'', while in upper secondary education the NLT (Nature, Life and Technology) subject is offered which promotes interdisciplinary. In Spain, the new curriculum encourages at some extent the future implementation of STEM interdisciplinary, as it states that ''key competence in mathematics, science and technology'' which might be considered a STEM competence and it also makes a strong argument for context-based learning in order to provide meaningful and relevant situated learning. At the moment there is an interdisciplinary subject *Natural Sciences* including content knowledge of Biology, Geology, Physics and Chemistry at the lower secondary education and students in primary education learn about the social and natural environment within a unique subject but in both cases, it does not mean that students are taught in an interdisciplinary way. In the Czech Republic, there are educational areas for secondary education, such as Man and Nature (Physics, Chemistry, Biology and Geography), Mathematics and its application, Informatics, Man and World of Work (technology). Germany follows a federal educational system, so there is variation across the country regarding the curriculum. There are "STEM" subjects combining more than one STEM-science but not or almost not in the sense of integrated STEM (NWT – Naturwissenschaft und Technik, i.e. Science and Engineering). Factually, these are mostly topics of different STEM science integrated in one subject. However, teachers can comparatively choose topics in these "STEM" subjects freely, so it highly depends on the teacher if there is an "integrated STEM" or not. In ML, students follow a mathematics curriculum and an integrated science curriculum up to year 8. Then from year 9 to 11 students study at least one from Biology, Chemistry or Physics. They may opt to study two or three of these. In state schools and some non-state schools Physics is compulsory. Physics used to be a compulsory subject in all schools up till some years ago. Finally, Cyprus introduced an integrated STEM curriculum in primary schools in nine pilot schools during the academic year 2019-2020 that was delivered by teachers with an MA in STEM education, and during the current academic year the first STEM high-school opened its doors in Cyprus with a curriculum under development.

Finding 3. Partner countries have various STEM action plans but none of the partner countries has a STEM education policy.

Austria is currently developing a national STEM education policy which gives an emphasis on the reduction of the gender gap in STEM-related fields by obtaining and increasing the retention rates of girls / women for training in the STEM focus area of computer science and technology. Furthermore,

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the policy aims to broaden the activity of existing potential for IT and technology (social cohesion), but also to promote a connection between STEM and STEAM approach. However, educational centers offering STEM Education programs to students, master programs focusing on STEM Education, and programs for teacher professional development on STEM have been identified in some countries. In Germany, there are several STEM-education plans. The most famous is the MINT Aktionsplan (STEM Action Plan). The idea behind this plan is to get students interested in STEM at a low level by establishing extracurricular learning sites throughout Germany. In addition to children and young people, parents should also be better informed about STEM subjects so that they can support their children in pursuing a STEM career. However, the rest of the countries have not yet introduced a specific STEM Education Policy. In Norway, there is a National Center for Science Recruitment (NSR) which is located at NTNU, Trondheim and was established by the Ministry of Science and Technology in 1998 to coordinate and lead recruitment for science and technology in Norway. Nowadays its contribution is to increase the recruitment to STEM education in Norway to ensure a competitive, sustainable and equal society. In the Netherlands, the national policy for the subject NLT (Nature, Life and Technology) has been developed and its main objective is to connect schools with innovative and interdisciplinary developments at university and in the world of work. In Greece, some attempts have been made in the context of university studies where masters' programs are offered (e.g. at University of Thessaly, NKUA, International University of Greece), while there are also offered STEM programs to students in private centers (e.g., Herakleidon Museum, and private STEM education centers). Furthermore, a Research Institute in STEM education has been proposed at NKUA to be established in the next year. In Spain, the first STEM teacher professional development center was founded, the CEFIRE CTEM in Valencia. In Malta, the main policy is the one outlined in the national curriculum framework for education in general. With regards to science, the aim is to: develop the scientific literacy of all learners; enable them to make informed decisions to improve their life in a changing world; develop skills and ways of thinking that use evidence to make decisions; lays foundation for those who want to pursue science-related careers; increase the number of students taking science options; and improve their performance. Although, there is not an overall policy specifically for STEM, each year there are many initiatives organized by Education Officers responsible for STEM subjects targeting STEM. These include National STEM Awards 2021; STEM Career Expo 2021; STEM Challenge; STEM Practices and Needs at Primary Level; STEM through storytelling; Thematic STEM Debate; STEM Community Fund. Finally, Cyprus has announced the development of one STEM high school in every city in 2023 but no STEM policies have been released yet.

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Finding 4. None of the countries has STEM teachers, all countries have teachers of different STEM disciplines

In most countries, teachers are separated in different disciplines (e.g., Slovakia, Cyprus, Greece, Lithuania) or there are teachers who have a double major. In Chezh Republic, some teachers have a double major in subjects from STEM or in subjects which one of them is not related with STEM (e.g., chemistry and German language). In Germany, someone can study multiple STEM sciences but not STEM as an integrated approach. In Norway, teachers are required to have either a dedicated didactics subject of their teaching subject, or an integrated math/science discipline-didactics subject (e.g., Physics didactics). In Greece, Lithuania, Turkey and Cyprus, teachers are also separated in different disciplines, but in some cases where the school is small, a science teacher may teach mathematics or vice versa. Similarly, in Malta, in most of the primary schools the class teacher teaches mathematics and science. Some schools, mostly non-state, have specialized teachers in mathematics teaching Years 5 and 6 (9 to 11 years). For Science, it is usually the class teachers who are usually not specialized in Science, who teach science but there is a group of peripatetic teachers specialized in primary science who visit schools and support teachers. Considering secondary schools, in both state and non-state schools, in Science, there are specialized teachers in Years 7 and 8 (ages 11-13 years) and teachers specialized in Chemistry, Biology and Physics teaching Years 9 to 11 (14 to 16 years). In Mathematics, teachers are specialized in Years 7 to 11.

Across countries, though, it is more common for a teacher to become STEM-oriented in primary education. In the Netherlands, primary teachers have the option to become STEM-oriented, however this is not the case for teachers in secondary level where each teacher focuses on a discipline. In Spain, primary school teachers receive a general education including STEM background, but not necessarily with a focus on integrated interdisciplinary and context-based teaching. Secondary teachers, though, are separated in different disciplines. In Austria, most of the teachers are also focused on a specific discipline, however in the last decades an emphasis has been given to the development of a comprehensive subject didactics within all relevant STEM specific areas accompanying pre-service and in-service training courses for teachers.

Finding 5. Policies regarding the training of the in-service teachers vary across the partner countries.

Some countries offer options regarding in-service training but they are not compulsory. In Norway for example, for year 1-10 in the integrated teacher education (Pedagogic/didactic and discipline subjects is mixed) and for the more specialized teacher education for year 11-13, there are 100 days mandatory full day in-service practice. In the Netherlands, there are no specific in-service training programs. In Greece, Turkey and Lithuania, there is no a systematic policy about in-service education, however at the moment there is in-service education related to a new curriculum (including mathematics, science and information technology). In Spain, an increasing offer in STEM teacher professional development courses on a national level is observed, but they are optional (not compulsory) and do not have a fix length or structure, therefore they can vary from workshops or conferences to a several months long course. In Malta, in-service teachers, in general, are expected to do a professional development training as per government agreement and this usually involves up to 26 hours of school-driven professional development sessions (held within school hours) and a possible additional 14 hours centrally provided by the Ministry of Education (also held within school hours). In Cyprus, compulsory teacher professional development for high school teachers takes place once a year for one day during teaching hours within each school and there is also optional training offered either by the Cyprus Pedagogical Institute which is the formal body offering teacher professional development, or through conferences and workshops.

Finding 6. Most of the partner countries prepare STEM teachers primarily as content experts and then as experts in pedagogy

The requirements to become a STEM teacher are different across countries. However, the most common way to become a STEM teacher, is to complete a degree in any subject and then to acquire a pedagogical qualification. In Norway for example, for someone to study at the university or university college in Norway one needs to pass the upper secondary school with some mandatory theoretical subjects, such as math, language, foreign language, science, history etc. In addition there are different requirements from study to study. For primary/lower secondary school teacher study you need a certain level of marks in math and Norwegian language, and for some traditional master studies in STEM (taking the extra year with pedagogic) you will need some specialized STEM subjects from year 12-13 in upper secondary school. In addition, the most popular Universities have requirements for quite high average grades, due to competition. In the Netherlands, it is possible to apply for teacher education after finishing havo (5 years secondary school; pre-higher vocational level), or vwo (6 years of secondary school; pre-university level). In Greece and Cyprus, someone can pursue a 4 year university studies in a Science Faculty (a discipline degree) and a teaching certificate (at the moment it is a part of the programme and it includes a few subject education courses. In Turkey becoming a secondary school teacher includes becoming an expert in a STEM subject and then training in pedagogical content. In Spain, primary school teachers should pass a 4-year undergraduate course

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and secondary school teachers should have a previous disciplinary university degree and afterwards pass 1-year post-graduate course integrating pedagogical and pedagogical-content-knowledge related to their initial disciplinary background. In Slovakia, there are three options for becoming a STEM teacher. First, someone can obtain a degree in teacher education in one/combination of two STEM subjects. Secondly, there is the option of gaining a Master degree in the STEM field accompanied with 2-year pedagogical education. In Austria, completion of a relevant course of study at a recognized post-secondary educational institution with a minimum of 180 ECTS credits. Relevant professional practice of at least 3,000 hours; Master's degree (120 ECTS-AP, at least 4 semesters) - offered exclusively according to the demand for graduates in the respective teaching subjects. In the Czech Republic, a teacher can gain a Master degree at university (5 or 3+2 years of study programs, double major or single major) or to gain a M.A. level of university study (master level on non-teachers oriented field) and additional pedagogical qualification (1 or 1,5 year). In GER, someone needs an A-level exam (Abitur) to study any subject of STEM-education. Also, after graduating from university, you have to pass a 1,5 year training on the job phase with practical teaching exams in the end. In Malta, after optaining a degree in one of the STEM fields there is a 90 ECTS course from the Faculty of Education on pedagogical training.

In the Netherlands , the general aim for STEM teacher education is to become a pedagogy-, lifelong-learning- and content-wise skilled teacher. Research in universities acknowledges the importance for teachers to have research experience into discipline. However, the rest of the partner countries offer teacher education programs focused on STEM specific subjects or on a combination of two or three subjects. In Austria for example, subjects such as Mathematics, Technology, and Design (Werken), Biology and Environmental Education, Digital Literacy, Geometric Drawing, Physics and Chemistry, are offered. In the Czech Republic teacher education programs are focused on STEM separated subjects ansd they consist of content knowledge, pedagogical and psychological knowledge, and Pedagogical Content Knowledge (PCK). In both Bachelor and Master levels, subject didactic is implemented which lasts 2-3 semesters in master level and one semester in bachelor level. In Slovakia, teacher education program consists of content knowledge in the same level as bachelor in the field including pedagogical knowledge and Pedagogical Content Knowledge (PCK). One semester is dedicated to the subject didactic but the time depends on the department culture and its priorities. Similarly, in Spain, teacher education focuses on specific disciplines and the aim is to offer teachers a disciplinary, pedagogical and pedagogical-content knowledge and to set the basis for lifelong learning and continuous professional development update. In Greece and Cyprus, for primary teachers, Science, Mathematics and Technology education are courses that are offered in education departments. In Mathematics, Science and Computer Science departments and faculties where mostly secondary teachers attend, the education of teachers is not very systematic. Few courses on subject education are offered and are all optional. In Greece there is a lot of discussion about the teaching certificate and a new law has been voted for offering education background programs at the university level for prospective secondary school teachers. In Cyprus, after completing a degree in one of the STEM areas, prospective teachers must attend a nine-month program focusing on education background. In Malta, the general vision for science is to: a) develop the scientific literacy of all learners; b) enable them to make informed decisions to improve their life in a changing world; c) develop skills and ways of thinking that use evidence to make decisions; d) lays foundation for those who want to pursue science-related careers; e) increase the number of students taking science options; f) improve their performance. Each subject, though, supports specific aims considering these general aims.

Finding 7. Most of the countries face challenges with teacher shortages on STEM subjects

Most of the partners face challenges with teacher shortages due to the big numbers of teachers that have retired in recent years, and because of problems recruiting new STEM teachers since teaching considered as a challenging profession. In Slovakia, there is a lack of teachers of physics, mathematics, and technology, as many in-service teachers are close to or in retirement age. Similarly, in Austria, there is a lack of teachers within Austrian institutions of elementary, primary and secondary education as a large number of teachers have retired in recent years and this trend will continue in the years to come. In the Czech Republic, there is a lack of teachers of all STEM subjects, mainly of physics, mathematics, chemistry, and informatics. This shortage of teachers is mainly observed in Prague and rural areas. Also, the average age of STEM teachers is above 45 years. Teaching is not considered as a good career but in recent years this situation is improving, e.g. increasing salaries, support for teaching practice, professional development etc. In the Netherlands and Spain, teacher shortage is a challenge, in particular for mathematics and computer science or technology. However, this challenge makes it easier and more attractive to become a teacher without decreasing the quality of teacher education. Similarly, a shortage of 40,000 teachers is expected throughout Germany. STEM sciences are among the most sought-after. Accordingly, there are cancellations of lessons and teachers must teach outside the subjects, which has an extreme effect on the quality of teaching. On the contrary, in Greece and Cyprus teacher shortage is not an issue as many teachers with a first degree in one of the STEM disciplines want to become teachers. In Malta, the main challenge for teachers who teach mathematics is usually to cover the content prescribed in the syllabus and to integrate more student-centered approaches to teaching (e.g., inquiry-based learning). In science, overloaded curricula and the examination-oriented school system are challenges that teachers face. These circumstances discourage teachers from adopting student-centered approaches that are time-consuming.

Finding 8. None of the countries offer training in a structural way to teachers for teaching STEM in an interdisciplinary way.

In most of the partner countries, teachers can attend a professional development program or universities offer courses related to interdisciplinary teaching. In Norway, a new curriculum (2020) has been introduced giving an emphasis on cross-disciplinary themes, such as Public Health, Democracy, and Citizenship and Sustainable development. For example, it is supported that it is easier for projects to be conducted across traditional subjects (math/science/science disciplines) in primary schools which have no summative assessment with marks than in year 12-13 where the traditional university STEM subjects from university are taught separately. However, there are schools which follow a cross-disciplinary approach and schools that prefer a more traditional approach. In the Netherlands there is no systematic information on this issue, but most HEIs spend some time on working interdisciplinary. In Greece, teachers can participate in relevant Professional Development programs (e.g., Mascil) which offer a disciplinary approach. In Spain, in some university degrees for primary school teachers, there are subjects to support future teachers to implement interdisciplinary teaching approaches such as project-based learning, but there is no specific subject on integrated STEM teaching. However, STEM education and STEM teacher professional development is becoming more and more popular on a national level, and in-service teachers are being offered specific courses on STEM education. For instance, the University of Jaaen is participating in a 6-month long program in collaboration with the STEM teacher center in Valencia. So far, 260 in-service teachers are enrolled in that course. The course focuses on how to use real life contexts and socio-scientific issues to promote relevant, meaningful and integrated STEM learning. In Austria, there are some courses addressing this issue during professional development activities at universities and universities of teacher education. Similarly, in Germany, training is offered depending on the educational institute. In the Czech Republic, teachers usually specialize in two subjects and rarely have possibilities to include interdisciplinary courses during their pre-gradual study or in CPD. Faculties also have possibilities for extending teachers qualification about next (third or second major) but it is not very often applied in the STEM area. In Malta, Teachers receive Initial Teacher Education (ITE) through the Faculty of Education at the University of Malta or the Institute for Education. The course for specialization for Mathematics is different from that of science. For science subjects there is one course (that is for Biology, Chemistry

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and Physics together) with only one study-unit focusing on the separate science subjects. In Turkey there are several training programs on STEM education, some linked to funded research programs and others organized by national networks. In Cyprus, only teachers' participation in workshops that are part of local or European funded projects are currently offering training in teaching interdisciplinary STEM.

Finding 9. In most countries, there is not systematic training for in-service teachers considering STEM Education.

Therefore, there are differences across countries regarding the type of training provided. In some places in NOR, there is a mentoring arrangement for STEM in-service teachers in the first year of work. In NL, the training is offered in the universities, teachers need to complete four years at universities for Applied Sciences and 5-6 years at research universities. In GR, there is some training of short duration before getting into a job, but there is no systematic CPD. Last year, though, a CPD in the context of the new curriculum of 8 weeks was offered and it is online – synchronous and asynchronous. In ES, in-service teachers can participate voluntarily in courses offered by teacher centers in collaboration with universities. Those courses do not have a fixed length or structure; therefore, they can vary from particular workshops or conferences to a several months long course. In SV, there are 4 stages of a teacher career; a) all beginning teachers undergo an initial in-service education via mentoring by more experienced colleagues from the same school. This lasts for one year and it takes place in the first year of practice; b) teacher; c) teacher with attestation; d) teacher with second attestation. Attestations are exam-based, and teachers have to prepare the portfolio of their activities, write a thesis with no supervision. Attestations are based on Methodologic and pedagogical centers located in each region in Slovakia. The examiners are teachers and in-service teacher educators with at least 10 years of practice and one member of the committee needs to have PhD in (subject)education. To be able to ask for the attestation, teachers need to prove their professional development in the way of a portfolio. PhD degree in subject education is considered as a second attestation. In AUS, the training duration varies according to the school type the teacher is working in and often depends on their personal engagement. This also applies to the style of in-service training chosen. Since 2017 ("Bildungsreformgesetz"), the headperson of a school is in charge of guiding and overseeing all CPD activities. A continuing education plan that carves out the needs and the development plan of the specific school site and plans its CPD activities accordingly should be its basis. However, this practice still waits for its broader realization. In general, one key influencer for STEM CPD are the ministries of education. Our role for CPD policy is versatile; the steering of STEM CPD is

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implemented by means of curricula or by funding opportunities and decisions. Another important quarter steering CPD offers are universities and universities of teacher education. Similarly, in CZ, participation in training it is on the hands of teachers self or on the hands of their headmasters. Universities and other institutions (incl. private and non-governmental) offer courses of CPD accredited by Ministry of Education. PhD degree in subject didactics is next possibility for teachers, to continue in self-development research based. In GER, there is not also an obligatory training for in-service teachers, however every 5 years there is a teaching quality assessment. In ML, universities offer training usually through the Master programs they offer. For example, IfE has just launched the Master of Science in STEM Education and Engagement which is a 3-year part-time program.

Description of STEM Policy Needs in Partner Countries

To identify the policy needs in the partner countries, a questionnaire was designed and disseminated in the partner countries. Each partner country has already set up a National Policy Committee (NPC) consisting of five STEM policy experts. Consortium partners were asked to contact at least one member from their local NPC to complete the questionnaire (available in Appendix II). Twenty-one policy makers completed the questionnaire as shown in Table 1 below.

Table 1. Information about STEM policy makers who completed the questionnaire

Country	**Number of questionnaires**	**Type organization**
Austria	1	Public/Ministry of Education
Cyprus	1	Public/Coordinator of STEM high school
Czech Republic	3	Public/teacher trainers
Germany	5	Private / providers of informal learning in STEM
Greece	1	Public / Supports the Ministry of Education
Malta	1	Public/ Science Centre

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Netherlands	1	Public/ University
Norway	3	Public
Slovakia	1	Public
Spain	3	Teacher trainers at public university
Turkey	1	Teacher trainers at public university

The responses from the questionnaires were analyzed by two research members from the University of Nicosia using a thematic approach. Each question was read separately and then themes and conclusions were formed for each question. The main highlights from the analysis are presented as Highlights below. Each highlight is followed by a need that is identified based on the analysis of the country reports.

Highlight 1. Policy makers define STEM as interdisciplinary and connected to competences.

Almost all policy makers define STEM as cross-curricular, project oriented and aiming to increase learners interest and competences in the STEM areas. Additionally, policy makers identify the need to link STEM with the SDGS (sustainability, new technologies, future challenges, awareness of societal challenges). STEM is presented by almost all policy makers an approach and an opportunity for teachers training through authentic daily life problems, combining the practices and the content from the different disciplines. There is also agreement between the policy makers that there are no specific policies in their countries regarding STEM education.

Need 1. Set up STEM policies on national and EU level

Highlight 2. STEM education is important for all policy makers in partner countries at it is seen as a way to prepare future citizens.

All policy makers identify STEM education as important and to prepare future citizens with the necessary competences and knowledge to understand the problems we are facing as a society and propose solutions. Furthermore, STEM education is viewed as a way to prepare future STEM professionals and promotes analytical and critical thinking skills which are important for scientific literacy among all citizens. As highlighted by some policy makers, engaging in an interdisciplinary STEM education will provide the students with the communication and entrepreneurial skills that are necessary for future employment.

Need 2. Support further development of interdisciplinary STEM education as a way to promote competences and entrepreneurial skills.

Highlight 3. Despite the need for interdisciplinary STEM education, teachers continue teaching withing their own disciplines.

In all partner countries it is common to teach only within one discipline/subject, with some cases teaching two subjects but in a separated way. All policy makers identify the importance of breaking the boundaries between disciplines and suggest that the goal of an interdisciplinary STEM approach would be to support students to develop competences through STEM education with lessons that are based on real life problems, are open and planned around project based pedagogies and include collaborations with companies and universities and other stakeholders. Policy makers also highlight the fact that industry is now interdisciplinary, and by preparing the students to work in this way they will be ready for the industry.

Need 3. Prepare curricula that is breaking the boundaries between the disciplines and is competence oriented and linked to everyday problems.

Highlight 4. STEM education is not in pace with changes in the society

Policy makers identify that STEM education in their countries remains unchanged and is still not addressing interdisciplinarity, communication and entrepreneurial skills and engaging students in discussion and problem solving of current societal issues. Furthermore, policy makers identify that emphasis should be shifted on inclusion in STEM (i.e. children with behavioral problems, integration, language difficulties, girls) and Promote STEM-friendly cultures in schools, e.g., through more cross-curricular, project-oriented STEM instruction or by strategically combining the areas of STEM instruction, STEM continuing and further education, educational and career orientation, and reflective gender education.

Need 4. Teacher professional development in line with new societal changes (i.e. emphasis on inclusion, sustainable development)

Highlight 5. Teacher professional development needs are not always met

Policy makers identify in their responses that teacher professional development needs are not always met by the professional development courses offered as professional development usually focuses on topics linked with content knowledge in the field or management issues in the classroom. Furthermore, policy makers suggest that teacher professional development courses should be longer in duration.

Need 5. Bottom-up approach to identify teachers need in professional development and longer professional development courses

Highlight 6. Exemplar STEM materials are not always available

Almost all policy makers report that exemplar STEM curriculum materials are not always available for teachers as good examples of practice.

Need 6. Development of exemplar STEM teaching materials.

Highlight 7. STEM education should focus on the ethical perspective as well

The policy makers have reported in their questionnaires that most of the current STEM topics have ethical considerations which the students should be prepared to discuss and understand. Examples provided in the questionnaire referred to the use of AI and on sustainable development. STEM teachers are not prepared to engage in discussions of ethical issues and controversies.

Need 7. Prepare teachers to discuss ethical issues and uncertainties in STEM.

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Highlight 8. Teacher professional development and teacher training can benefit from mobility

The policy makers have reported that the professional development and teacher training in their countries are very specific to the local context, but at the same time the issues with which STEM education is engaging with are international. Therefore, engaging in exchange of ideas with teachers from other EU countries can support teachers to understand the global perspective of STEM problems and find ways to engage their students with a more global perspective as well.

Need 8. Mobility of STEM teachers and exchange of training in STEM

CONCLUSIONS

The needs analysis based on questionnaires submitted by policy makers and consortium partners and the desk research, we have identified that at a European and national level in the partner countries there is a lack of STEM education frameworks and STEM education is still viewed as separate subjects. The following needs have been identified:

- Need 1. Set up STEM policies on national and EU level
- Need 2. Support further development of interdisciplinary STEM education as a way to promote competences and entrepreneurial skills.
- Need 3. Prepare curricula that is breaking the boundaries between the disciplines and is competence oriented and linked to everyday problems.
- Need 4. Teacher professional development in line with new societal changes (i.e. emphasis on inclusion, sustainable development, supporting girls)
- Need 6. Development of exemplar STEM teaching materials.
- Need 7. Prepare teachers to discuss ethical issues and uncertainties in STEM.
- Need 8. Mobility of STEM teachers and exchange of training in STEM

Strategy to inform policy makers

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The following strategy has been set up during the first stage of the project in order to inform policy makers and also involve them in the process of preparing new policies.

- Set up a National Policy Committe (NPC) in each partner country. The NPC will meet yearly to discuss issues and concerns related to the ICSE Academy. The first meeting will take place on March 9th and will be an international meeting between all national NPCs.
- During the first NPC meeting the policy makers will be informed about the ICSE Academy aims and objectives and will also be presented with the structure and aims of the European STEM professional development course of the ICSE Academy. The policy makers will be asked to comment on the content and structure of the course.
- Contact an annual policy needs analysis. This will be performed in collaboration with partners, the national NPCs and policy makers from other EU organizations (i.e. European Schoolnet, STEM coalition).
- Contact focus groups and interviews with policy makers to receive feedback on various stages of the project (i.e. development and implementation of the STEM professional development course).
- Round Tables at national and European level as described in the proposal.
- Policy Briefs every six months. The first policy brief will be circulated in March 2023 and will advertise the project and the course for professional development. The policy briefs will be disseminated to the national NPCs, to policy makers in Europe, partners of other Teacher Academies, and social media.

The current strategy will be reviewed annually.

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APPENDIX 1. Questionnaire for Partners

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Questionnaire for Partners

This part contains general questions about the current situation and the context in each of the partner countries. Please fill in the questions within your local research group.

Country Name and partner name:

1. Do you have a STEM curricula or something similar (interdisciplinary)?
2. Do you have a national STEM education policy in your country? If yes, could you briefly describe the policy? Please provide information about the curriculum, the educational level for which the policy is relevant and the main objectives of this policy.
3. Do you have STEM teachers, or are teachers separated in the different disciplines (i.e. science teacher, mathematics teacher etc)?
4. What is the length of in-service training for STEM teachers in your country? If there are differences in the different educational levels (i.e. primary and secondary) or the different disciplines (i.e. science, mathematics, technology) please note.
5. What are the general aims for STEM teacher education? If you have different subjects/ disciplines (i.e. science, mathematics, technology) please provide information about the different disciplines.
6. Does your country face any challenges with STEM teachers? If yes, please explain.
7. Do you face challenges with recruiting STEM teachers?
8. Do teachers receive training to teach STEM (interdisciplinary)? If yes, what kind of training?
9. Where does pre-service education of STEM (i.e. science, mathematics, technology teachers) take place (i.e. university) and what kind of degree do they receive?
10. What are the requirements to become a STEM teacher in your country?
11. What training do STEM in-service teachers receive in your country? What is the duration? What kind of qualifications are provided?
12. How are in and pre service teachers assessed during their studies (i.e. projects, exams, assignments, teaching practice, combination)?

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APPENDIX 2. Questionnaire for Policy Makers

Part B. Questions for the policy makers

1. Name and institution/organization
2. Please describe your role in your institution as a STEM policy maker?
3. What is STEM education for you and your organization?
4. Is STEM education important for your country and organization? Explain why.
5. Would you say that in your country you have STEM teachers, or teachers who teach different STEM subjects (i.e. science, mathematics, technology)?
6. Is it important to have STEM teachers who teach interdisciplinary? Explain why.
7. Do you follow a STEM curriculum at your organization? If yes, could you briefly describe the overall aims?
8. What challenges would you identify for STEM education in your country and in Europe?
9. What challenges do you see in STEM education in primary and secondary schools?
10. What are the challenges in pre-service teacher training related to STEM education?
11. What are the challenges in in-service teacher training related to STEM education?
12. Do you face any challenges that are linked to the different European Union priorities and how these should be implemented within the local curricula? For example, do you have any challenges related to teachers' digital competences, teachers' understanding of green deal?
13. Does STEM education include sustainability necessities (social: democratic, ethical aspects; "being a good human who is doing technique")? What policies could enforce a stronger focus on environmental challenges we face?
14. What is the status in your country in regards to STEM teacher recruitment? How easy is it to recruit and sustain STEM teachers? If there are differences between the different disciplines please note.
15. What do you do to ensure the quality of STEM PD? What are the features of effective PD from your perspective/experience?
16. How could we enrich teacher professional development in the STEM field by including inspiring international experiences? What can ICSE Teacher Academy offer in this respect?
17. How do you think teacher professional development in the STEM field can benefit from international perspectives?
18. To what extend teacher professional development in the STEM field is culturally and nationally dependent? How could we favor good practices exchange?

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