ATS STEM

Report #2 of
ATS STEM Report Series

Government Responses to the Challenge of STEM Education: Case Studies from Europe

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This is Report #2 of #5 in the ATS STEM Report Series. All reports in the series are available from the project website: **http://www.atsstem.eu/ireland/reports/**

- Report #1: STEM Education in Schools: What Can We Learn from the Research?
- Report #2: Government Responses to the Challenge of STEM Education: Case Studies from Europe
- Report #3: Digital Formative Assessment of Transversal Skills in STEM: A Review of Underlying Principles and Best Practice
- Report #4: Virtual Learning Environments and Digital Tools for Implementing Formative Assessment of Transversal Skills in STEM
- Report #5: Towards the ATS STEM Conceptual Framework

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FOREWORD

Assessment of Transversal Skills in STEM (ATS STEM) is an innovative policy experimentation project being conducted across eight European Union countries through a partnership of 12 educational institutions (**www.atsstem.eu**). The project is funded by Erasmus+ (Call reference: EACEA/28/2017 - European policy experimentations in the fields of Education and Training, and Youth led by high-level public authorities). The project aims to enhance formative digital assessment of students' transversal skills in STEM (Science, Technology, Engineering, and Mathematics). ATS STEM is co-financed by the ERASMUS+ Programme (Key Action 3 - Policy Experimentation). The project partnership comprises ministries of education, national and regional education agencies, researchers and pilot schools.

The countries and regions in which the digital assessment for STEM skills is being piloted are **Austria, Belgium/Flanders, Cyprus, Finland, Ireland, Slovenia, Spain/Galicia,** and **Sweden** as per below:

- Dublin City University, Ireland
- H2 Learning, Ireland
- Kildare Education Centre, Ireland
- Danube University Krems, Austria
- Go! Het Gemeenschapsonderwijs, Belgium
- Cyprus Pedagogical Institute, Cyprus
- University of Tampere, Finland
- Ministry of Education, Science and Sport, Slovenia
- National Education Institute Slovenia
- University of Santiago De Compostela, Spain
- Consejería De Educación, Universidad Y Fp (Xunta De Galicia), Spain
- Haninge Kommun, Sweden

Dublin City University (DCU) is the project coordinator. A core element of DCU's vision is to be a globally-significant university that is renowned for its discovery and translation of knowledge to advance society. DCU has an interdepartmental team of experts from three different research centres bringing their combined expertise to bear to help lead and deliver the project goals. These centres have expertise in digital learning, STEM education and assessment and are respectively the National Institute for Digital Learning (NIDL), the Centre for the Advancement of STEM Teaching and Learning (CASTeL) and the Centre for Assessment Research, Policy and Practice in Education (CARPE).

NIDL
National Institute for Digital Learning

The National Institute for Digital Learning (NIDL) aims to be a world leader at the forefront of designing, implementing and researching new blended, on-line and digital (BOLD) models of education **(https://www.dcu.ie/nidl/index.shtml)**. The NIDL'S mission is to design, implement and research distinctive and transformative models of BOLD education which help to transform lives and societies by providing strategic leadership, enabling and contributing to world-class scholarship, and promoting academic and operational excellence.

CASTeL
Centre for the Advancement of STEM Teaching and Learning

The Centre for the Advancement of STEM Teaching and Learning (CASTeL) is Ireland's largest research centre in STEM education **(http://castel.ie/)**. CASTeL's mission is to support the development of STEM learners from an early age, and so enhance the scientific, mathematical and technological capacity of society. CASTeL encompasses research expertise from across the Faculty of Science and Health and the DCU Institute of Education, one of Europe's largest educational faculties.

CARPE
Centre for Assessment Research, Policy and Practice in Education

The Centre for Assessment Research, Policy and Practice in Education (CARPE) is supported by a grant from Prometric to Dublin City University **(https://www.dcu.ie/carpe/index.shtml)**. The centre was established to enhance the practice of assessment across all levels of the educational system, from early childhood to fourth level and beyond.

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EXECUTIVE SUMMARY

This report (Report #2) was written as part of a research project titled, *Assessment of Transversal Skills in STEM (ATS STEM)*. The project is funded by Erasmus+ (Call reference: EACEA/28/2017 - European policy experimentations in the fields of Education and Training, and Youth led by high-level public authorities). The project aims to identify transversal skills that may enable a common approach to the delivery of STEM education in European schools and to identify and develop a set of digital tools that will measure the effective teaching of these skills. The report is based on outputs related to the first deliverable in work package one of the ATS STEM project, as outlined in Appendix A—namely *STEM Conceptual Framework* (WP1).

The report aims to plot a common pathway for developing an integrated approach to STEM education. It endeavours to trace the policy landscape across the eight partner countries and map overlapping areas of interest. Intersecting areas of interest are key to formulating an integrated approach to teacher education and curriculum development where teachers may operate in very different contexts but may have similar digital tools and platforms available to them. To this end, a survey was conducted in 2019 that investigated government responses to the challenges of developing STEM education.

The report first scans other selected relevant STEM Education policies both inside and outside of Europe. Whilst some notable policies exist such as in Australia and the United States, these are not widespread and within Europe, as results of a search found that there is a dearth of published official Governmental policies on STEM education. A notable example, however, is the Scottish STEM education policy which has, in turn, influenced other European policy moves in this direction.

Given the lack of widespread published policies per country in Europe, the report details the development of a survey instrument to help capture more details about policy development in the European countries/regions that are partners in this project. This was distributed to experts drawn from the partnership in each country/region who responded with reference either to explicit published policies in their region or other Government-led initiatives in STEM education of which they were aware. Four countries out of eight reported having a specific detailed framework or policy in place for STEM education. The survey also targeted the scope of the policy at different levels and six of the eight countries reported having a policy focus at pre-primary and post-primary level. The survey attempted to seek details focused on the development of transversal skills and initiatives in teacher development and continuous professional development (CPD). **Every expert representing their country/region recognised the importance of identifying and teaching transversal skills in order to support the integration of STEM learning.** The report also highlights STEM policy and educational initiatives targeted at specific underrepresented groups. A segment detailing the role of industry in STEM education policy initiatives addresses partnerships across a diverse stakeholder group. It highlights the rich collaborative efforts to engage in partnerships focused on STEM education on the ground in the partner countries. The policies and initiatives in this report are both ongoing, in implementation, and also those in developmental stages and launched as recently as 2019.

INTRODUCTION

In Europe, over the past decade our way of living, earning, and learning has been impacted by digital transformation. The transformative nature of new digital technologies is expected to continue over the next decade, particularly driven by developments in Artificial Intelligence (AI), with major implications for the future of work. In the future, new skills will be required as governments and employers seek to promote jobs, growth, and global competitiveness.

Set against this backdrop, this report explores how Governments of European regions and countries are addressing the challenges posed by using digital tools to formatively assess STEM skills. The first part of the report outlines the scope, objectives, and methodology of the ATS STEM project and summarizes primary concepts in relation to STEM education. It then provides, based on desk research, a brief overview of relevant literature relating to national and international policies. After establishing that a handful of national policy initiatives exist reflecting a holistic or integrative perspective, the report describes the development of a scoping survey to assess the current state of STEM education policies in partner countries. Through the combination of desk research and this European scoping survey, the report aims to identify best practices, common approaches, and dissimilarities in STEM education. In particular, the report discusses areas where policymakers and educators can take an integrated approach to STEM education for the development of core transversal skills and competences for the next decade and beyond. In doing so, the report aims to help plot a way toward a common understanding of STEM education for future developments in both theory and practice, using the European countries and regions involved in the ATS STEM partnership as an example.

Objectives of the ATS STEM Project

The objectives of the ATS STEM project are twofold: (i) to identify transversal skills that may enable a common approach to the delivery of STEM education in European schools; and (ii) to identify and develop a set of digital tools that will measure the effective teaching of these skills. The project involves thirteen partners from eight countries/regions across Europe and aims to support teachers by customising their learning designs to better meet the needs of their students. This aim will be achieved through the creation of practical examples of how the potential of new digital technologies can be harnessed to foster STEM skills and competences in students.

The ATS STEM project deliberately uses the term Integrated STEM. This term signifies that our approach is based on highlighting the linkages, interdependencies, and cross-cutting concerns of STEM. That is, we are seeking to approach STEM holistically. The long-term aim of the project is to influence policymakers and curriculum developers by raising greater awareness of best practice examples.

Objectives of this Report

The objective of this report is to document and analyse how governments are addressing the challenge of STEM education by collecting case studies across Europe. National STEM policies in partner countries are described and so, based on the results of a survey of regional experts, the report endeavours to provide insights into local policymaking. The report provides evidence of partner countries/regions' stance on STEM and STEM education, including the definition of STEM in practice. It notes both common and unique approaches to STEM education from an integrated perspective. Moreover, the report details industry cooperation within STEM education and policy networks, with case studies across partner countries/regions. It also attempts to gauge the extent that STEM education policy promotes socially inclusive aims and measures. The report aims to ultimately provide information for students, teachers, parents, policymakers, those in higher education, and industry concerned with STEM education.

BACKGROUND

STEM Education

There has been a significant increase in academic literature published on STEM education and its promotion through policy over the last 30 years (European Schoolnet, 2018; Martin-Paez et al., 2019; Thomas & Watters, 2015). Clearly, there is a growing level of academic interest in the area but what motivations lie behind this increase? Various drivers are mentioned in the literature for the promotion of STEM education. These range from claims of STEM graduate shortages (European Schoolnet, 2018; US National Academy of Sciences, National Academy of Engineering, Institute of Medicine, 2007), economic competition with other countries or regions (Corlu et al., 2014), and to improve social, environmental and/or economic outcomes (Kelley & Knowles, 2016). This discourse has been critiqued as promoting Neo-liberal values (Santiago de Roock & Baildon, 2019) and is often underpinned by arguments that countries with strong and growing economies have successful education systems that place a high value on STEM education (Marginson et al., 2016). These imperatives sit alongside claims that educational systems are failing to teach students to solve real-world problems using knowledge gained through study of STEM disciplines (Bybee, 2013; National Governors Association, 2007; Ritz & Fan, 2015). Reform of curricula and pedagogies is called for, in particular to equip students with what have come to be known as "21st century skills". All of these factors are summed up by Bybee and Fuschs (2006, p. 350) in the appeal that "we need high quality teachers, rigorous content and coherent curricula, appropriate classroom tests, and assessments that align with our most valued goals".

This claim demonstrates that designing STEM education for the 21st century is a complex challenge requiring work at many different levels to affect significant change. The following discussion touches on some of these challenges before then focusing on relevant policy developments.

Firstly, there is a question of what skills do students require for the 21st century? In a review of skills frameworks, Economou (2006) starts by emphasising that the terms 'skills' and 'competences', are found to be used inconsistently and interchangeably in the literature. It has been argued that there are few genuinely new 21st century competences and that only genuinely original ones are those that are focused on information literacy and information management (Kirschner & Stoyanov, 2018). In an attempt to bring a common language to bear around this area of digital skills there has been a detailed focus on it at European policy level, in particular through the development of the Digital Competence Framework for Citizens, also known as the Digicomp Framework (Ferrari 2013; Vuorikari, Punie, Carretero, & van den Brande, 2016; Carretero, Vuorikari, & Punie, 2017).

The Digicomp framework identifies five competences: information and data literacy; communication and collaboration; digital content creation, and safety and problem solving. It maps these competences across several dimensions and provides examples of the practical application of the framework. These examples are useful as such skills and/or competences frameworks are general purpose tools and the mapping to specific tasks relating to particular educative learning outcomes is not always straightforward. They can be applied to specific domains or areas but as of yet there is a lack of their application to the area of integrated STEM education. We discuss this gap in application of integrated STEM education in more detail in several related reports arising from the ATS STEM project. In Report #1, for example, "STEM Education in Schools: What can we learn from the research?", we analyse how specific integrated STEM skills are treated in the research literature and what skills predominate. From this review, the research team arrived at eight core competences central to integrated STEM learning as it has been conceived in the research literature: collaboration, problem-solving, innovation and creativity, critical thinking, disciplinary skills, and competences, self-regulation, communication, and metacognitive skills (Report #1).

As mentioned above, such a holistic approach seeks to transcend disciplinary silos with the ultimate aim for learners to enable deep integration of their knowledge and skills so as to tackle complex problems. Although there has been much written about STEM education, there is little international consensus as to what it really is, particularly from an integrated perspective. As Bybee (2013, p. x) somewhat wryly notes:

> There is an interesting paradox I have observed concerning definitions in education: Many request a definition, and few agree with one when it is presented. So it is with STEM education.

One common issue that bedevils STEM is its use as a synecdoche for one or more of its constituent disciplines, particularly science (Bybee, 2013). This dilutes STEM to a generic label that can be applied to almost any subject outside of arts and humanities. Moving beyond this, STEM can be seen as comprised of more than one discipline, though there may be different numbers and varieties of constituent disciplines that comprise the acronym. Within STEM, particular subjects may have relative levels of prominence, for example as a dominance of mathematics, or a relative dearth of emphasis on engineering (Hochlander, 2015). Technology, as embodied in computing and computational thinking education (Wing, 2006), is, of course, an area of rapid development that has implications for many other disciplines, especially given the growing importance of software tools, data analysis, and modelling to various professions. In addition, the nature of the relationship between the disciplines can vary greatly. Achieving a true integration of the essence of the disciplines, to the extent that they can truly be classed as an entirely new entity of STEM, is a complex issue.

Bryan et al. (2016) simplify integration to content used to teach topics from discipline, the context in which problems are situated, and use learning objectives to propose various ways these can be simply blended together, but with a pragmatic approach of grounding either content, context, or a learning objective in a home discipline. In a similar vein, English (2016) warns against seeking some form of "total integration", lest it undermine core disciplinary learning, and instead advocates a focus on creating integrated STEM activities, that can consolidate and extend lesson content. Lastly, the emergence of STEAM represents an attempt to widen STEM to include arts (Robelen, 2011). This is not uncontroversial and the same issues exist as to how arts are defined and how it can or should be either infused or integrated with the other disciplines (Colucci-Gray et al., 2019). Nonetheless, it has been well argued that we rely on the contribution of the arts for "making science content more accessible, understandable or acceptable by the public" (Funtowicz & Ravetz, 1999).

A challenge in developing a shared vision of STEM education is its highly context-dependent nature as a form of work carried out by teachers in diverse socio-cultural contexts. STEM is posited as a form of universal language that can help us explain and build our world. In this conceptualisation, it can increase social mobility, equipping learners with skills that have application in industries around the world. However, every country or region where STEM is taught has unique factors that impact upon the educational environment. The range and emphasis of constituent STEM subjects taught in schools can vary greatly along with the types of underrepresented groups in STEM, the drivers impacting upon the development of policy, and the status and situation of STEM teachers in a country or region.

STEM Education Policy

Educational policy may be seen as the formal articulation of a Government's intent to help shape an educational system it has responsibility for. Policy may be conceived of as an intent to solve specific perceived problems (Hall & McGinty, 1997). It may produce a formal document that sets out a policy, but is also a process of engagement and discussion for the policy which can only arise as the result of listening to particular voices and stakeholder groups. Whose voices we hear in the final policy, whose voices are not heard, and how the conversation was framed are of course important questions that may not be easy to answer. Rizvi and Lingard (2010) warn against policies that are merely "symbolic", that come without any real commitment to their implementation, such as proper funding.

It is worth noting that the drivers of STEM education policies, and who they are designed to benefit most, is not universally agreed upon. It has been argued that the private sector's deep interest in public education (Cuban, 2004; Engel, 2000), may represent a conflict of interest. Claims coming from industry regarding the nature or quality of education being offered in public schools deserve some scrutiny (Sharma, 2016). Some researchers for example have questioned the reality of claimed skills gaps, and have pointed out that there may be industry incentives to produce a glut of graduates to drive wages down (Capelli, 2015; Salzman, Kuehn, & Lowell, 2013). This STEM skills gaps narrative is closely allied to those fearful that a country or region will fall behind another due to diminishing standardised test scores in STEM disciplines in schools (Capelli, 2015; Carnoy, 2015). The point being made here is that direct correlations between rising and falling test scores of students and economic future prosperity are not always necessarily clear-cut.

There may be no simple solutions to the role of business and industry in STEM education and its policy development. The private businesses of the STEM industry that are a source of innovation and research are also major employers. They interact and interface directly with citizens and so must have some role to play in education. As a consequence, commentators have sought to shift the emphasis of the policy imperative from industry and towards a society more broadly conceptualised- such as comprising communities (Mohr-Schroeder, Cavalcanti, & Blyman, 2015; Tsupros, Kohler, & Hallinen, 2009). Policy development for the role of business and industry in STEM education can further seek to emphasise ideas of ethical practices, responsible research, public understanding of science, and of both the benefits and consequences of STEM research and development (Hazelkorn, 2015).

REVIEW OF THE STEM POLICY INITIATIVES

STEM Policy Initiatives

Various policy initiatives and related studies from around the world have contributed to the debates and competing discourses on STEM education. An overview of some of the more significant and recently published of these policies both globally and in Europe is presented below before discussion of specific country examples.

We conducted web searches for governmental policy documents relating to STEM education published worldwide in English. Within each relevant policy document, we conducted both forward and backward searches of citing documents according to a "pearl growing" methodology (Schlosser, Wendt, Bhavnani, & Naila, 2006). This was accomplished by searching the bibliography of each policy for other potentially relevant polices (backward search) and by looking at what documents had cited the policy (forward search) using Google Scholar. We then iterated this process for each new relevant policy found until we found no new relevant policies.

It should be noted that determining the relevance of policies is a subjective exercise. The relevance of the policies we draw on was determined by the judgement of experts from the partnership and subsequent policies that they believed were best for their regional context. Although "policy borrowing", as a method of comparative educational research, is well established, it is not unproblematic (Beech, 2006; Steiner-Khamsi, 2016). Solutions cannot be transplanted from one place to another given the highly context-dependent nature of education. Moreover, we are conscious that the reports draw on examples from the Anglosphere and the so-called Global North. This bias is not to infer any primacy, but is because these are the areas with the most mature STEM policy landscapes and that are more comparable to European contexts (Steiner-Khamsi, 2016).

In addition to this broad search for global STEM policies, a focused search was conducted of European STEM education policies. The Eurydice web portal comprises data on national education systems, comparative reports, and statistical data on European Education from a network of 43 national units based in the 38 countries of the Erasmus+ programme. We searched this database and the report on the National Education System of each country for relevant STEM education policies. A discussion of STEM education policies now follows starting with major policies outside of Europe before detailing some European exemplars.

Policy Initiatives outside of Europe

In Australia, the aim of the STEM: Country Comparisons report of 2013, was to discover what various countries were doing to develop participation and performance in the disciplines of science, technology, engineering, and mathematics. It also sought to observe the take-up of STEM in the labour market, and research systems, and to draw possible lessons and ideas for STEM policy and strategy. The report found an almost universal preoccupation with STEM-related issues in education and the economy, but examination of government strategies and programs revealed overlap and similarity but also warned that the issues are not 'the same' everywhere (Marginson et al., 2013). It is noteworthy that along with an emphasis on increasing participation for girls and women in STEM, the study mapped STEM education and indigenous groups and found an underrepresentation of indigenous communities pursuing STEM education. Another further report from the Office of the Chief Scientist, Australia, in 2015 averred that getting primary school teaching right was vital to securing Australia's STEM pipeline, equipping students with the creative problem-solving, critical thinking, active learning and quantitative skills they need for a future dependent on STEM (Prinsley & Johnston, 2015, p.7).

In the United States, a recent report by the Committee on STEM Education of the National Science & Technology Council (2018), noted that the character of STEM education has been evolving from a set of overlapping disciplines into a more integrated and interdisciplinary approach to learning and skill development. It also acknowledges, in relation to policy and government involvement, that the Federal Government has a key role to play in furthering STEM education by working in partnership with stakeholders at all levels and seeking to remove barriers to participation in STEM careers, especially for women and other underrepresented groups (Committee on STEM Education, 2018).

Policy Initiatives in Europe

A 2015 report of the Scientix project – focused on fostering a community for science education in Europe - addressed recent, current or planned priorities, policies, and initiatives aimed at improving the relevance and quality of STEM education. The aim was to encourage more students to study and choose a career in STEM. It found that around 80% of the 30 EU countries surveyed describe STEM education as currently a priority area at national level, at least to some degree (Kearney, 2015).

In a desk review by Man (2016) for the project "Edu-Arctic – Innovative educational program attracting young people to natural sciences and polar research", survey data was collected from the project members, who included Norway, France, Poland, Faroe Islands, and Iceland. The report studied STEM understanding among the five countries/regions and drew on the results gathered from the reports of many European institutions that focus on education in STEM. The focus of the conceptualisation of STEM was strongly weighted towards science but it provides a useful overview of many relevant EU research projects that in turn contribute to policy development process and highlight aspects of STEM. The Edu-Arctic report argued that skills in STEM disciplines are becoming an increasingly important part of basic literacy in today's knowledge-based economy. The report also made the claim that to keep Europe's economy growing, one million additional researchers in STEM would be needed by 2020. The report argued however, that science education can no longer be viewed as elite training for future scientists or engineers. It highlighted the importance of science-aware citizens who can make informed decisions and engage in dialogue on science-driven societal issues.

A more recent report on Key Competences for Lifelong Learning, posited the change to a competence-oriented approach in education, training, and learning, represents a paradigm shift (European Schoolnet, 2018). A shift that will impact not only on the structure of curricula, but also change the organisation of learning. In the compilation of the report, a survey was sent to STEM representatives from 14 European countries with questions on: the place of STEM in the education system, reform projects linked to STEM education, the situation regarding the professional capacity-building of STEM teachers and the development of specific pedagogical and learning resources (European Schoolnet, 2018).

Most recently a Scientix report (European Schoolnet, 2019), discussed challenges to innovative STEM teaching at primary school level. Challenges were discussed between 20 STEM education stakeholders and 22 primary school teachers. Three key strategies were proposed to tackle the most challenging aspects of STEM teaching in primary schools: raising the quality of teacher training, increasing access to high quality teaching resources, and raising the STEM culture in primary education.

The desk research revealed some notable European national/regional STEM policies, such as in Scotland, Flanders, the Netherlands, and Ireland. In the case of the Scottish policy development a wide scope was adopted encompassing STEM education and training across the education system. It aimed to increase enthusiasm, and improve skills, and knowledge of STEM "in order to raise attainment and aspirations in learning, life and work" (Scottish Government, Science, Technology, Engineering & Mathematics: Consultation on a Strategy for Education & Training, Analysis of Responses[1], 2017, p.19). The policy set a target of increasing uptake of more specialist STEM skills through education and training. The policy development process comprised of an extensive public consultation phase. As a mark of transparency, the public responses to the policy were published (and indeed make interesting reading[2]). An analysis of the responses was published and this fed into the articulation of a policy. The policy was further followed by an implementation plan with specific targets.

1 https://www.gov.scot/binaries/content/documents/govscot/publications/consultation-analysis/2017/03/science-technology-engineering-mathematics-consultation-strategy-education-training-9781786528704/documents/00515550-pdf/00515550-pdf/govscot%3Adocument/00515550.pdf

2 https://consult.gov.scot/stem/a-stem-education-and-training-strategy/consultation/published_select_respondent

Ireland followed a model close to that of Scotland in its policy development with a review and consultation phase resulting in the publication of a report which highlighted gaps in STEM education in schools such as for instance a shortage of chemistry teachers. This was followed by the articulation of a STEM policy statement, which provided an integrated definition of STEM and included links to the wider digital strategy for schools. A notable aspect of Ireland's STEM policy framework was the development of guidelines for STEM School-Business/Industry partnerships. These partnerships are seen as a way of providing real-life and on-the-job education opportunities for learners. The guidelines highlighted a governmental inclination towards strong industry/school links and indicate that the two should be very closely intertwined.

The research conducted to date in the reports detailed above indicates that country or regional policies on STEM education do not appear to be widespread in Europe. Or, at the least, that the landscape of policy maturation is uneven. Unlike some of the reports mentioned above, this project has a particular focus on formative assessment, via digital modes, of STEM education. It seeks to provide support for educators in assessing students' transversal skills and providing relevant formative feedback. This emphasis on teacher support was informed by the development of The ATS STEM Conceptual Framework, which highlights how learning outcomes and hence assessment interconnects with the other components of integrated STEM education as a phenomenon (see Report #4). The basic assumption is that assessments should empower educators to take an integrated approach to STEM teaching. Indeed, a feature of many of the reports and policy initiatives to date is either the lack of emphasis of integrated STEM or a limited examination of what this might mean.

In summary, none of the policy reports in the desk-based research described above covered all of the countries/regions in the ATS STEM partnership; and they also had different foci and were carried out at different points in time. As there are rapid developments in this area, we need to continually take the pulse of STEM education in Europe and share new developments with the wider educational community. Given the highly context-dependent nature of teaching environments, we also need to understand more about what STEM at definitional, pedagogical, and policy level actually looks like. Therefore, the challenge is to learn more about how to respond to STEM education at each of these levels with the ultimate aim of shaping policy developments for STEM in Europe as a whole. Hence, we undertook to develop a survey of the ATS STEM project partnership to examine policy developments, how STEM is conceptualised, the transversal skills of STEM, the interfaces of STEM with society, teacher education support and challenges, and how STEM may be digitally assessed. In the next section, we describe the design, development, and distribution of a survey to help us conduct this work.

DEVELOPMENT OF SURVEY INSTRUMENT

In March of 2019, an expert workshop at the ATS STEM project kick-off meeting in Dublin laid the seeds for the development of this report. During this workshop, participants were split into mixed groups, comprising ministry representatives and those from research or teacher education. In these groups, participants were tasked with answering the question of how governments could best respond to the challenge of STEM education in schools. Figure 1, below, shows an example of some of the suggestions arising from this workshop.

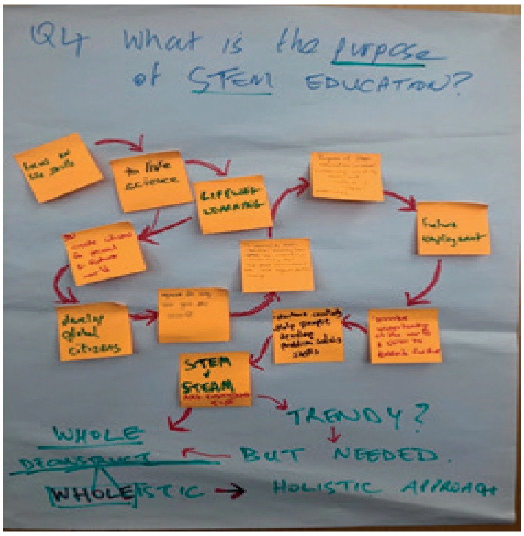

Figure 1. Flipchart from Workshop Session on European STEM policy challenges

Given the relative dearth of available policy literature on STEM education initiatives, the project team decided to develop a questionnaire to more systematically survey expert representatives from each partner country/ region. This survey, designed to provide a more up-to-date horizon scan on the current state of STEM education policy, was developed not only by themes that emerged from the expert workshop but also from the above-mentioned desk research and relevant transnational reports. The survey sought to examine four thematic areas, which are illustrated in Figure 2.

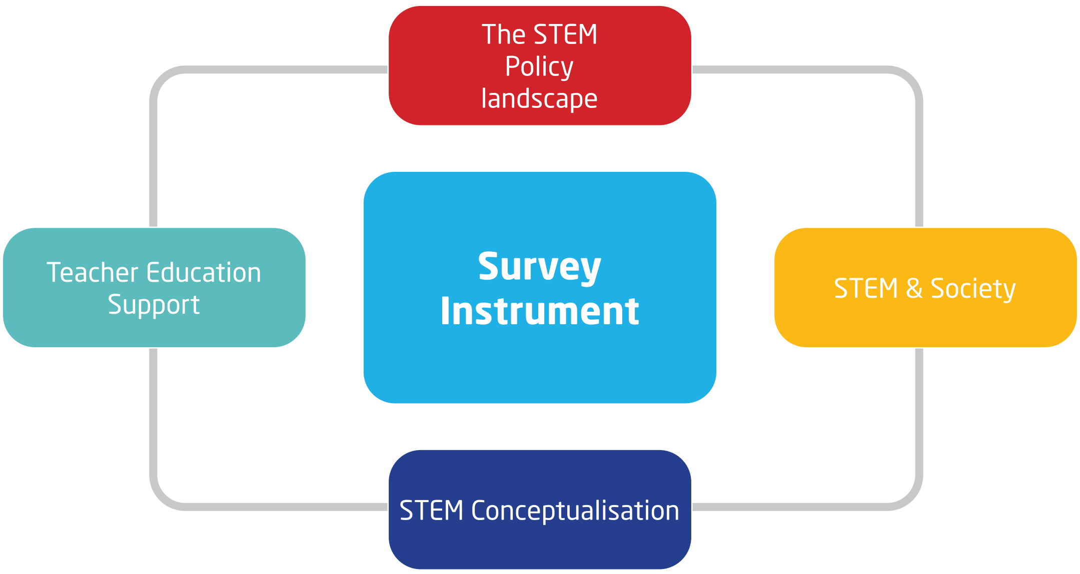

Figure 2: Thematic areas in the survey instrument

These four thematic areas in Figure 2 involved some sub-categories that are as follows:

1. **The STEM Policy landscape**
   - Current policies
   - Coverage of policies
   - Stakeholder input and consultation processes

2. **STEM Conceptualisation**
   - Policies' definitions of STEM
   - Subjects included in STEM
   - Integrated STEM as a subject
   - STEM Education Transversal Skills

3. **STEM & Society**
   - Industry role in STEM Education
   - Policies for underrepresented groups in STEM

4. **Teacher Education Support**

As Government policy or frameworks for STEM education at secondary level were at differing levels of development in European partner countries/regions, the validity of this report could be enhanced by data from local experts. In this way, experts reporting on the situation in their area could do so with reference to specific policy initiatives or with more general reference to their context outside of a dedicated STEM policy or framework. These experts were either representatives from: Ministries of Education or associated governmental teacher development bodies (**Belgium, Cyprus, Ireland, Slovenia, Spain/Galicia**); or STEM education researchers from universities (**Austria, Finland, Sweden**). A pilot version of the survey was tested before it was made available to the wider project partnership. Next, the experts (n = 9) from the partner countries/regions completed the survey between June and September of 2019. Following this step, the results were collated, synthesized, and fed back to the entire expert group for their final comment. As such the views of the experts, although informed by policy documents or conversations are intended to provide a snapshot and highlight key issues and area of best practice rather than a definitive view. They also hence reflect the backgrounds and particular perspectives of the experts. The online survey instrument itself, including the wording of the individual questions, is included as Appendix B.

Findings of the Survey

The STEM Policy Landscape

The local experts were consulted on whether their country or region had a published policy/framework on STEM education that represented an official Governmental response. Four regions/countries – **Austria, Cyprus, Flanders,** and **Ireland** - reported having a framework or policy.

The **Austrian** policy reference - Das Gütesiegel – Hintergrund & Einreichung (in German) can be found online[3] and the **Cyprus** policy reference can also be viewed online[4]. The **Flanders** policy was reported through support documents and website references. The policy references (in Flemish) are available online[5].

In **Ireland**, the Policy Implementation Plan has been a source for the country's STEM education policy statement. The STEM Education Policy Statement 2017-2026 can be found online[6].

STEM conceptualisation: Definitions of STEM

In order to better understand the concept of STEM itself at a definitional level, the experts were asked to give the definition of STEM that appeared in their policy. Where no policy existed, they were requested to answer with reference to what they found to be the commonly understood and articulated definition in their country/region. The range and scope of the various definitions relating to STEM education demonstrated diverse understandings with divergent emphasis on the various aspects.

In **Austria**, STEM is known as "MINT", and the letters stand for Mathematics, Informatics, Sciences, and Technical subjects. The government invites schools to become certified as designated "MINT" schools. To obtain this certificate, the school has to offer STEM based subjects, projects, and initiatives in teaching and teacher education (CPD).

In **Cyprus**, the term STEM is an acronym for Science, Technology, Engineering, and Mathematics, and denotes the educational policy and direction that promotes a complete interdisciplinary approach. Pupils are involved in activities that provide them with the opportunity to make use of their knowledge, concepts, processes, and practices around STEM. They do this in order to address real-world situations and issues. The teaching model of STEM encourages students to make use of creative thinking, supports the development of problem-solving abilities and innovative thinking, and helps them take the initiative and reflect.

Two regions, **Flanders** and **Galicia** have adopted a STEAM format where "A" refers to Arts. Notably, inclusion of the Arts reflects an expanded concept of STEM that is not solely centred on the traditional disciplines. While **Flanders** adheres to the Flemish STEAM framework, the acronym STEM is also used. It was reported as being a concept where the whole is more than the sum of its constituent parts (i.e., STEM is not simply the sum of science, technology, mathematics, and the latterly added engineering). According to the Flanders' outlook, STEM is about interaction between disciplines which allows room for 21st century skills and an interdisciplinary approach. To that end, Flanders advocates ownership of the learning and implementation pathway by teachers, pupils, and school management teams, in consultation with the broad STEM sections outside of school. Hence, the STEM framework adopted by Flanders consists of a core, on which each STEM school division can draw, while also further developing within the school's vision and remit.

3 https://www.mintschule.at/guetesiegel/

4 http://enimerosi.moec.gov.cy/archeia/1/ypp9288a

5 (a) http://outlier.uchicago.edu/s3/, (b) https://washingtonstem.org, (c) https://onderwijs.vlaanderen.be, and (d) http://www.stembasis.be

6 https://www.education.ie/en/The-Education-System/STEM-Education-Policy/stem-education-policy-statement-2017-2026-.pdf

STEM is seen to focus on the interplay between various principles like interaction and coexistence of the separate STEM components of the acronym with respect for each component's individuality. It also includes problem-solving learned through the application of STEM concepts and practices along with researching and designing in a skilled and creative manner. Thinking and reasoning, modelling and abstracting skills while strategically using and developing technology are also noted as key characteristics of STEM. Acquiring an insight into the relevance of STEM in itself and to society, obtaining and interpreting information and communicating about STEM, teamwork, and innovation is also highlighted.

In **Galicia**, there are ambitions for the widespread implementation of STEM education in the coming years. It was noted that STEAM education should not only be limited to the objective of developing scientific vocations, especially in girls, but that its full potential for cooperative, practical, learning-by-doing aspects should be key. As such it is advocated that STEAM be extended to all areas of the school curriculum.

Ireland defines STEM education as multi-faceted and one that goes beyond the main disciplines that constitute the acronym STEM. The foundation for STEM education, according to the Irish STEM framework, is built in early childhood. Right from the earliest years through games played amongst themselves and family environment, children engage with the world in ways that can promote learning related to science, technology, engineering, and mathematics. Young children naturally engage in early STEM exploration through hands-on multisensory and creative experiences. By engaging in these experiences, young children are developing curiosity, inquisitiveness, critical-thinking and problem-solving capacities which are built on through their primary and post-primary school experience.

The four STEM constituent disciplines in **Ireland** were reported as Science, Technology, Engineering and Mathematics and following some aspects of the Scottish definition summarised as follows:

> "*Science* enables us to develop our interest in, and understanding of, the living, material and physical world and develops the skills of collaboration, research, critical enquiry and experimentation *Technology* covers a range of fields which involve the application of knowledge, skills and computational thinking to extend human capabilities and to help satisfy human needs and wants, operating at the interface of science and society. *Engineering* is about the design and creation of products and processes, drawing on scientific methods to provide the skills and knowledge to solve real-world problems. *Mathematics* equips us with the skills needed to interpret and analyse information, simplify and solve problems, assess risk, make informed decisions and further understand the world around us through modelling both abstract and concrete problems" (STEM Education Policy Statement 2017-2026, 2016, p. 6).

Within these four STEM disciplines, there are a wide range of STEM subjects that learners can engage in during their school life. These can range from designing and craft in primary school to Science, Technology, Engineering, and Mathematics at post-primary level. There is no definitive list of STEM subjects and recent consultations with teachers, parents, and learners found considerable variance of views in this regard. In **Ireland**, the policy advocates that STEM education not only involves the teaching of disciplines and subjects in isolation, but it also involves a cross-disciplinary approach. It seeks to build on the content, knowledge, and understanding developed in and across the four disciplines while acknowledging that all STEM learning activities are underpinned by mathematics. It also highlights the strong linkage between STEM and Arts education which fosters design, creativity, and innovation.

Policy Consultation and Development Process

Since effective policies are essential to STEM educational reforms, their development process was scrutinised. The survey requested information on how STEM educational policies were formed and sustained throughout partner countries/ regions.

STEM policy development in **Austria** is overseen cooperatively by the Federal Ministry of Education, Science and Research (BMBWF)[7], the Federation of Austrian Industries[8] Vienna Teachers' University[9], and Wissensfabrik[10] ('Knowledge Factory'- an NGO which aims at networking industry enterprises with schools).

In **Cyprus**, a committee was appointed by the Minister of Education in order to develop a STEM policy[11]. The committee is chaired by an academic from the University of Cyprus and supported by a group of academics and primary and secondary education inspectorates (Physics, Science, Design and Technology, ICT, Mathematics, and Chemistry).

In **Flanders**, the Belgian (Flemish) Department of Economy, Science and Innovation, inspired by the *Dutch Beta Techniek Platform*, set up a STEM strategy titled *Actieplan Wetenschapscommunicatie* (Science Communication Action Plan) in 2009. The Action Plan's main aim is to promote a scientific and innovative culture in all walks of life and ensure a wider participation in the public debate about issues relating to science including STEM and its impact on society. The target audience are young people, teachers, and the general public. The Department of Economy, Science and Innovation is responsible for coordinating and monitoring the actions involved in implementing the Action Plan, and works in close partnership with a wide range of science organizations which form the Science Information Network (WIN). WIN provides coordination and structuring of the operational framework for its partners and stakeholders and ensures the practical implementation of the Action Plan. The network aims to exchange information and expertise both within the government and all organizations working in the field of science communication in **Flanders**. Member organizations can publish their activities and projects on the WIN website, and a monthly newsletter keeps all members up to date with each other's latest news. Uniting all actors on a comprehensive platform, allows the expertise in **Flanders** to be mapped.

The *Technopolis platform* for science and technology, evolving originally from the not-for-profit organization, Flanders Technology International, is central to the Science Communication Plan, by bringing science and technology to the people. The platform mainly targets 8-14 year-olds and their teachers, and involves a large number of partners, including businesses and the media. In 2009, the budget allocated to implement the Science Communication Action Plan was ca. 9.3 million Euros. Since then the amount allocated has decreased yearly, with ca. 7.3 million euros designated in 2011.

Ireland's 'STEM Education in the Irish School System Report'[12] which was developed by the STEM Education Review Group and published in November 2016. The STEM education policy in **Ireland** was developed by employing various methods: consideration for national and international research in the area of concern, the extensive consultation process with over 600 responses on public consultation and stakeholder consultation with 80 attendees. Consultations with learners, parents, and teachers - primary and post-primary - were also crucial in forming the policy along with Early Years Inspectorate and Early Years Unit. The STEM Education Consultation Report 2017[13] was published in result of this process. The development of the policy was overseen by a STEM Education Steering group.

In **Slovenia**, it is expected that the national projects like NA-MA POTI (science and math literacy) will encourage a discussion about the development of STEM strategy.

7 https://www.bmbwf.gv.at/das-ministerium/

8 https://www.iv.at/en/federation-austrian-industries

9 https://www.phwien.ac.at

10 https://www.wissensfabrik.at

11 https://ec.europa.eu/education/sites/education/files/document-library-docs/et-monitor-report-2018-cyprus_en.pdf

12 https://www.education.ie/en/Publications/Education-Reports/STEM-Education-in-the-Irish-School-System.pdf

13 https://www.education.ie/en/The-Education-System/STEM-Education-Policy/stem-education-consultation-report-2017.pdf

Level of Policy Scope

This section reports on the data gathered through the survey where experts were asked to indicate what levels of education their STEM policies sought to cover. Six of the countries/regions i.e., **Austria, Cyprus, Flanders, Galicia, Ireland,** and **Slovenia** reported specific policies directed at pre-school and secondary level. There was a lack of attention reported in STEM for higher education, postgraduate, and adult education.

In **Finland**, the LUMA policy plan was launched by the Finnish government in 1996 (LUMA Centre Strategy 2014-2025, 2014). It focused on improving STEM education and on increasing the number of STEM students. The LUMA programme took a holistic approach to improving science education engaging all the major stakeholders including the Ministry for Education, local government, (responsible for education in Finland), schools, higher education and the business community etc. LUMA Centre Finland is an umbrella organisation for national and international LUMA activities and it functions as an organised network. It consists of 11 LUMA centres operating in conjunction with universities or university consortiums (LUMA Centre Strategy 2014-2025, 2014). The goals of LUMA Centre Finland and its member centres are to reach a high level of know-how in science and technology among pupils, students, and teachers and to ensure a sufficient number of science and technology professionals all across Finland.

Interesting examples of children beginning their STEM education pre-kindergarten were reported from **Flanders** where they learn scientific skills such as observing nature and formulating questions.

Development of Transversal Skills

This section reports on the scope and definition of transversal skills based on responses to the scoping survey. Every expert representing their country/region recognised the importance of identifying and teaching transversal skills in order to support the integration of STEM learning. The definitions of these skills can vary and we provide a synthesis of these from a literature review presented in Report #1 with regard to the ATS STEM education project.

The National Core Curriculum in **Finland** has defined seven key transversal competences: thinking and learning to learn; cultural competency; interaction and self-expression; self-care and managing daily life; multi-literacy; ICT competency; working-life competency and entrepreneurship, and participation, involvement and building a sustainable future. However, these competences apply to all subjects and not only to STEM subjects.

In **Flanders**, transversal skills are referred to as 21st century skills, which are defined as a mix of cognitive, interpersonal and intrapersonal, and social characteristics that support deep learning and knowledge transfer. Cognitive competences include critical, innovative, and creative thinking. The interpersonal characteristics include communication, collaboration, and responsibility, while the intra-personal characteristics include flexibility, initiative, and metacognition. These competences are key to inquiry-led research that is necessary for both design thinking, research, and problem-solving. This skills framework is available online [in Dutch][14].

Ireland lists critical, creative thinking, and communication as transversal skills but adds information management, information processing, being personally effective, staying well, and working with others to the list.

The overall goals and guidelines in the National Curriculum for Compulsory School[15], preschool class and school-age education in **Sweden** cites communication as being a part of transversal skills. This list of transversal skills includes mathematical reasoning and problem-solving ability demonstrated by transforming ideas into action in a creative and responsible way. Application of knowledge including prerequisites for good environment and sustainable development from scientific, technical standpoint and use of digital tools are also reported as key transversal skills.

14 https://www.slo.nl/21e-eeuwse-vaardigheden/

15 https://www.skolverket.se/publikationsserier/styrdokument/2018/curriculum-for-the-compulsory-school-preschool-class-and-school-age-educare-revised-2018?id=3984

Similarly, all subjects in **Slovenia** have key competences. However, in most development projects (as well as in ATS STEM) special attention is given to the set of recognised transversal skills such as the ones developed in the ATS 2020 project (Economou, 2016) and illustrated in Figure 3.

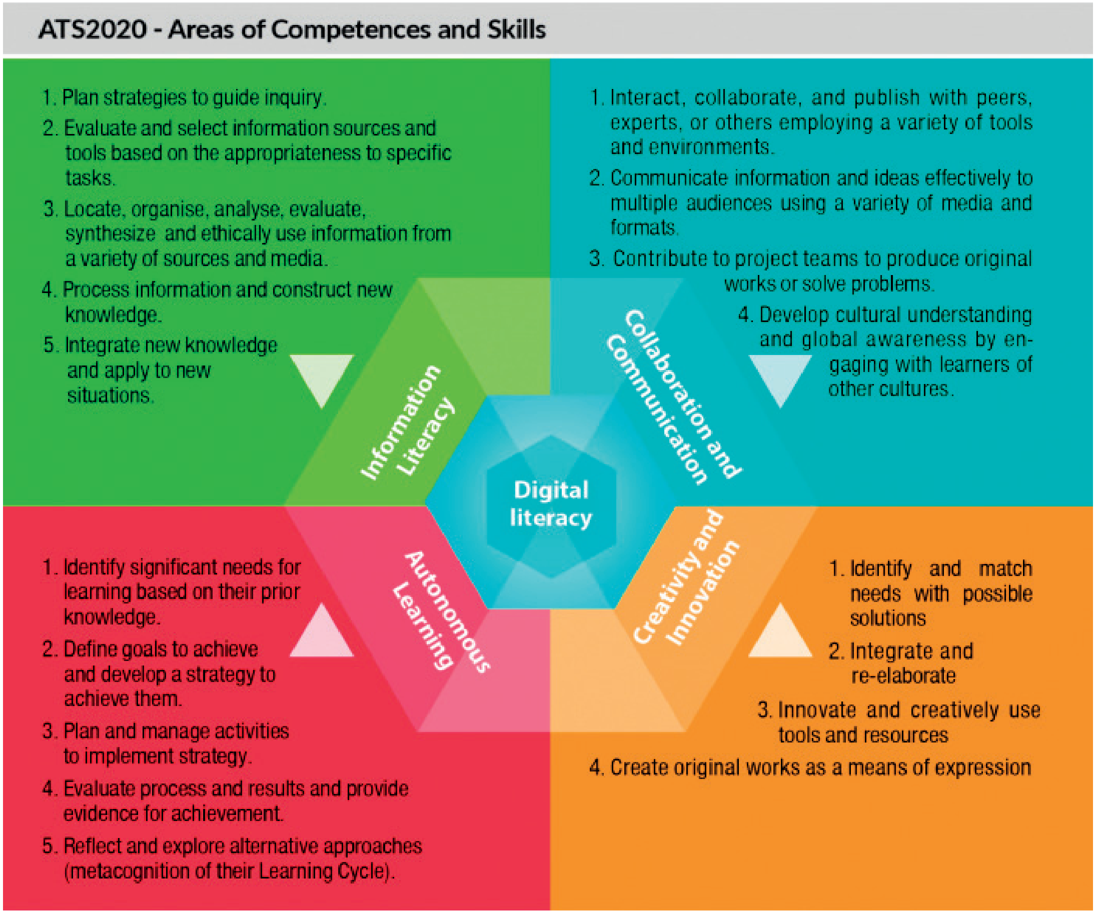

Figure 3: STEM and transversal skills

Cyprus, Slovenia, and Sweden reported the importance of digital skills, self-regulation, communication and collaboration, creativity and innovation, effective thinking (inquiry-based learning, problem-solving, critical thinking,) multi-literacy and identity (attitude, ethics, emotions, values, motivation) as essential transversal skills recognized in their countries.

Slovenia has categorised transversal skills into two areas: Self-Regulation skills and Digital Skills in the Assessment of Transversal Skills ATS 2020 Country Report[16].

Galicia identified a broad approach for teaching STEM subjects to promote a scientific, rigorous, orderly, and critical mentality; to facilitate the learning processes of students. The development of transversal skills such as creativity, sense of initiative and entrepreneurship, problem-solving, teamwork, critical thinking, and global citizenship are included.

16 https://www.zrss.si/pdf/AssessmentofTransversalSkills.pdf

Assessment of STEM Competences and Digital Tools

This section reports survey responses in relation to formative assessment methods undertaken by the partner countries/regions in the implementation of STEM education. The survey also gathered data from experts in relation to the utilisation of digital tools to support the process of STEM learning.

In **Austria**, there are some examples of relevant formative assessment centred teaching initiatives (in German) such as IMST-Awards 2019[17], Technische Bildung[18] and Leuchtturmprojekte[19].

In **Cyprus**, a rollout of a new STEM approach was planned for schools in the 2019 school year and it is hoped that the ATS STEM project will help contribute to it. The curriculum will apply formative assessment, along with summative assessment in various subjects.

In **Flanders**, evaluative support is provided for STEM learning as a process through formative assessment. The philosophy followed is that STEM education requires a focus on the learning process and so guiding and support is central. Openness to an evaluation in which students play an active role is necessary. In this way, the student receives valuable feedback and can test his or her own frame of reference to help shape their own learning process. The aim is for each student to get an opportunity to grow based on their own strengths and needs. **Flanders** uses formative evaluation methods for STEM, such as the creation of portfolios, self-assessments and peer assessments, and where the students are involved in the preparation of the evaluation criteria.

In **Ireland**, there are classroom-based assessments at Junior Cycle and exams at Junior Cycle/Senior Cycle. There is also an emphasis on the practical element of curricula.

In **Slovenia**, both summative and formative assessment was reported to be important in schools: summative assessment is compulsory and formative assessment is in its development phase and is being adopted in many schools.

Sweden emphasises formative assessment as a part of the teaching and learning process while adapting to student needs which are addressed in both the Swedish Educational Act as well as the national curriculum.

17 https://www.imst.ac.at/award

18 https://www.technischebildung.at/startseite/

19 https://www.wissensfabrik.at/Initiativen/Leuchtturmprojekte

STEM & Society

This section reports the survey responses from experts on how the policies in their countries/regions interact with society, particularly industry support and collaborative efforts to engage in partnerships focused on STEM education. The second half of the section focuses on policies for under-represented groups in each country/region based on data gathered through the survey.

Industry Role in STEM Education

In **Flanders**, a number of initiatives were reported in partnership with industry such as Ondek Techniek Talent and Design Your City. The RVO-Society is a not-for-profit organization which acts as a portal between research and education in the areas of technology and science learning. The RVO-Society develops educational resources related to the latest developments in science and technology, and provides in-service teacher training and professional development for teachers. Partnerships between schools, companies, universities, and research centres are actively fostered by the RVO-Society's work, RTC.

In **Ireland**, it was reported that the Irish Policy Statement talks about enhanced partnerships with business/industry and the importance of working together to progress the STEM Agenda. Based on an analysis of responses, some of the initiatives already in practice are BT Young Scientist, business/industry working through Business in the Community and Junior Achievers Ireland, Accenture/DCU STEM Teacher Internship Programme, and business/industry that connects with schools in their community.

In **Sweden**, reportedly a significant number of industry-related initiatives focus on STEM, in accordance with its national curriculum goals. For example, there are partnerships with various industries like Teknikföretagen[20] (Association of Swedish Engineering Industries), The Royal Swedish Academy of Engineering Sciences[21], and The Royal Swedish Academy of Sciences[22].

Policies for under-represented groups

STEM education is often criticized for not being inclusive of girls and other underrepresented groups. Hence, in this section we report survey responses to a question asking the experts if they had a specific focus on STEM education for girls. Similarly, a question was posed with regard to underrepresented groups according to ethnicity and/or socio-economic status. A question was also asked about two other groups: refugees/migrants, and diverse learners including those with special educational needs/disabilities.

An emphasis on gender representation in STEM was reported by the respondents. As an example, initiatives such as that from **Cyprus**, in 2019, of a conference for secondary school teachers which was held with the intention to inform them on the interconnection between the abilities that students develop through STEM subjects and entrepreneurial thinking skills and innovation. The aim was to highlight the overlap within an educational framework that also promotes gender equity. In April 2019, Cyprus signed The Declaration of Commitment on Women in Digital in Brussels; and a representative was appointed for the first meeting in Brussels in September 2019, with the aim to develop an operational roadmap of actions over the next 6-12 months in execution of the Declaration's actions, with women participation in STEM as one of the priorities.

In 2016, **Flanders** reportedly ranked 26th in the EU for tertiary graduates in STEM education with a low rate of new entrants to related tertiary education fields, in particular for women. The overall implementation of the "STEM Action Plan 2012- 2020" in Flanders shows progress, but the number of STEM secondary graduates in technical and vocational paths has stagnated since 2010. The Emancipation Department of the Flemish Ministry of Education and Culture has launched a policy measure involving the development of special projects to motivate more girls to opt for STEM. Flanders is also attempting a role model approach; whereby female STEM teachers mentor female students to inspire them to take up STEM careers.

20 https://www.teknikforetagen.se/en/

21 https://www.iva.se/en/

22 https://www.kva.se/en/startsida

In **Ireland**, the Policy Statement advocates for increased uptake of STEM learners of all backgrounds, ability, and gender, with a particular focus on uptake by females. This focus has seen the establishment of Gender Balance in STEM Advisory Group with an initial emphasis on females in STEM. This group has been tasked to form a set of recommendations for consideration in this area.

Slovenia cited the example of a Code Week in 2018 when some events were scheduled specifically for girls. For example, winter programming school for girls - *Zimska šola programiranja za osnovnošolke, Smart girls for smart cities – Heckaton for girls - Pametna dekleta za pametno mesto - Hekaton za dekleta*.

In **Sweden**, there are initiatives for indigenous communities such as Sami schools that integrate Sami culture[23] and language at the primary level of education[24]. There are state-sanctioned schools for those with special educational needs[25]. The curriculum taught in these schools[26] does not differ considerably from that of the compulsory schools. There are also initiatives focused on gender equity, most notably the Tekla festival[27] launched by Swedish singer Robyn and KTH Royal Institute of Technology which aims at promoting girls between the ages of 11-14, especially those from disadvantaged social and economic backgrounds, including immigrants, to engage in STEM by providing them with a creative platform.

Experts from **Slovenia** and **Flanders** reported that there is an emphasis on ethnically under-represented groups in STEM. Slovenia cited specific examples such as the launch of initiatives based on underrepresented ethnicities to include the Roma community with a comprehensive project (2012 – 2022) that integrates digital competences as well as project ventures for Hungarian minorities.

The Policy Statement for **Ireland** mentions those at risk of educational disadvantage and learners with special educational needs but there is overall very little policy emphasis across the countries/regions on diverse learners (i.e., those with a disability) and little explicit mention of learners from lower socio-economic backgrounds. There was no mention of STEM inclusion policies to target refugees and migrants.

STEM Teacher Education Support

This section reports on the data provided by the experts on the teacher support in their respective countries/ regions. The support, training, and education of teachers is of key importance in helping them develop new pedagogical skills and competences. In the English speaking literature, the exact nomenclature of this can vary: it may be referred to as Continual or Continuing Teacher Education (contrasted with Initial Teacher Education which happens before a teacher is first qualified to teach). It may be referred to as "teacher training", "teacher learning" professional learning or Continuing Professional Development (CPD). There may be relatively minor semantic distinctions between "training", "education" or "professional development" though some will argue that the chosen terminology reflects underlying assumptions about how the activity is valued and regarded (Hick et al., 2019). We noticed a mix of terminology in use from the respondents to the survey, which might simply reflect cultural and language differences.

Ultimately, irrespective of terminology, the focus here is on ongoing development. Teachers must be supported so that they can learn how to successfully integrate pedagogies and digital tools into their classrooms. The survey hence endeavoured to gather information about what, if any, teacher support, mechanisms or incentives have been proposed, or pertain, in the ATS STEM project countries/regions. Based on the responses, the conditions of employment and provision of resources and policies (which in turn contribute to cultures) around teacher continued education and development can vary greatly between jurisdictions. To get a better sense of this across the partners, and drawing on a similar question from the Schoolnet (2019) survey, we asked respondents how they would best characterise continued teacher education in teaching of STEM subjects and whether it was required, not required or up to the individual.

23 https://www.skolverket.se/undervisning/sameskolan

24 https://www.skolverket.se/undervisning/sameskolan/laroplan-och-kursplaner-i-sameskolan

25 https://www.spsm.se/om-oss/english/our-mission/special-needs-schools/

26 https://www.skolverket.se/undervisning/grundsarskolan/laroplan-och-kursplaner-for-grundsarskolan/laroplan-for-grundsarskolan

27 https://www.kth.se/en/aktuellt/nyheter/robyn-och-kth-arrangerar-teknikfestival-ihop-1.552594

The importance of providing teacher support and development was a common response from all partners. While teacher education is best characterised as a requirement in **Flanders** and **Galicia**, it was seen as more of an individual responsibility in **Cyprus, Finland, Ireland, Slovenia,** and **Sweden**. The survey also sought to identify any issues in each country/region in terms of teacher support and development.

In **Cyprus**, there are STEM-related professional development programs organized by the Cyprus Pedagogical Institute and the relevant inspectorates, on a voluntary basis, for participation. Furthermore, European funded and other research projects are being implemented as pilots in schools.

In **Flanders**, it is mandatory in every school to have a plan for CDP, to be aware of the roles that Science, Technology, Engineering, and Mathematics fulfil in modern society and to be familiar with at least some of the fundamental concepts of each discipline. In countries such as Finland by contrast school plans for CPD are not mandatory[28]. In Flanders, CPD was also reported as important to have a basic level of application, for example, being able to critically evaluate scientific or engineering content to perform mathematical operations that are relevant to daily life.

In **Galicia**, specific STEM training is included with continuous teacher training activities offered around topics that link to STEM. The topics include beginners and advanced courses on working with equipment kits (Robots, Arduino, Raspberry Pi, and 3D printers). Training activities in construction, programming, adaptation and handling of educational robots, basic electronics, computer programming, and computational thinking for all educational levels are also offered as a part of CPD. Other initiatives include seminars and courses oriented to effective use of Maker-spaces, training in complementary methodologies such as visual thinking and design thinking. Emphases of these CPD activities include methodologies of investigation, good STEM practices, and utilising Science Clubs.

With the exception of all the participating schools, **Galicia's** Primary Robotics programs, Science Clubs, Maker-spaces, and STEM-Bach will have specific training activities in centres.

Training activities are added to use in the classroom of two ESERO resources[29] (Educational project of the European Space Agency, ESA).

In **Ireland**, there is a requirement for teachers to be allowed time for CPD, and to provide resources for CPD. However, CPD is elective and teachers who may need STEM CPD may not utilize the resources. There are also initiatives in partnership with industries like- STEM Teacher Internships[30] for students training to become primary or secondary level teachers in a STEM work environment.

In **Slovenia**, CPD for teachers is not compulsory, but there are several incentives designed to interest teachers such as a point-based system for salary increases. Other incentives include participation in interesting projects, possible promotion, and most CPD workshops are free of charge. However, challenges remain such as lack of teacher time (limited hours for continued teacher education on a yearly basis), financial costs of commuting to venues and occasional fees involved. According to the local expert, there is also no comprehensive encouragement from school boards, and courses that may not be clearly aligned to national priorities.

In **Sweden**, teachers must have a CPD plan for 104 hours (as indicative value) per employee per school year during the teachers' regulated working time as negotiated with the Teachers' Union. The school management is responsible for providing the teachers with sufficient resources for the same however there is a lack of sufficient follow-up as the process is decentralised and particular for each school. The Swedish National Agency for Education (Skolverket) has initiatives focused on CPD although it is up to school authorities to choose which initiative their school will enrol in. Teachers can also individually decide on an initiative that best suits their needs and enrol through school administrative approval during working hours or choose to opt for CPD in their spare time.

The Swedish National Agency for Education also has miscellaneous initiatives focused on STEM along with local initiatives within different municipalities.

28 https://www.actuary.eu/documents/Finland_CPD_en.pdf

29 http://esero.es/quienes-somos/

30 https://www.dcu.ie/news/news/2019/Apr/STEM-Teacher-Internship-programme-connects-teachers-and-industry-DCU.shtml

FURTHER DISCUSSION: THEMES AND TENSIONS

This report laid the groundwork for assessing government responses to STEM education by presenting the findings of desk research on major STEM education policy initiatives around the world. The policy initiatives found most comparable to the European context were overlapping in their approach towards integrated STEM education. Common themes such as the significance of introducing STEM at the primary and post-primary level of education are prevalent in most policy initiatives. Some unique aspects were varying levels of emphasis on under-represented groups and/or social, environmental, and economic outcomes of implementing STEM policies in their respective countries/regions. There are also notable variances in stakeholder input and the consultation process followed for the development of the particular policies. Criticism of the drivers of STEM policies was acknowledged with conflict of interest as Michael Apple (2016) noted that the current context of government and educational policies might be a coalition effort of multiple forces to push education in a particular direction.

In the second part of the report, the perceptions of local experts in the countries of the partnership were reported along with more specific details of STEM education policy initiatives gathered through a scoping survey. It is generally agreed across respondents from all of the regions/countries involved that there is a need to formulate and publish national and regional STEM policy frameworks that could help plot a course for a concept that is still not well understood if the aim is a true integrated form of STEM. Although some countries/regions have government policy documents, these are at varying levels of maturity or detail and there is agreement that it is imperative to put these policies into action.

Thirdly, although definitions of STEM vary widely across partners, the common traits of all definitions is the core belief that an integrated approach to STEM teaching is required. Some partners suggest that STEM should be extended to arts subjects (STEAM) to provide a balanced focus. Mathematics nonetheless still looms large in educational systems while digital and information technologies vie for an increasing amount of attention. Each participant country/region accepts that the backbone to promoting STEM education is to provide the training and resources for teachers. The varying levels of teacher autonomy and different laws and cultures relating to the mandatory or voluntary nature of continuing teacher education will always pose a challenge for how to support teachers across Europe to affect educational changes at scale.

Another aspect of the survey that came across strongly, was the role of industry in STEM education. In nearly all partner countries and regions, there is a strong relationship and active projects between schools and industry to promote STEM. There is also a consensus among partners as to the importance of transversal skills, and similar transversal skills have been identified by all of the ATS STEM partners.

Social inclusion and equity are one of the key motivational drivers of STEM educational policy. All regions/countries included here have both aims and active programs on developing more balanced gender makeup of STEM professions. However, the effectiveness of initiatives is hard to gauge. Moreover, the cultures of companies and industries that are more or less welcoming of women may be difficult to change through school based initiatives alone. There also remains the hypothesized gender-equity participation paradox, as studies have suggested that as societies become more prosperous and gain greater gender equality, less women go into STEM careers (Falk & Hermle, 2018; Stoet & Geary, 2018).

There is less emphasis on other under-represented groups in STEM such as people from lower socio-economic groups, ethnic minorities, and learners with special needs. Indigenous communities are conspicuously absent from the European policy discourse in contrast to some outside Europe such as Australia (Marginson et al., 2013). This may, of course, be that Europeans regard themselves as largely indigenous. This perhaps glosses over particular sub-populations within Europe who have been educationally disadvantaged, such as the Sami from northern Scandinavia as we have noted. There is also the Irish National Traveller and Roma Inclusion Strategy 2017-2021, which focuses on marginalised indigenous Traveller and Roma communities. One of the objectives of the strategy emphases on education, mostly inclusion at primary and post-primary levels.

There is an absence of explicit mention of how refugees and migrants can be supported into STEM education. Given the migration crisis that Europe has faced in recent times, more might have been expected although migration does not affect all countries and regions equally and some of those in question are not at the front line of the issue.

Finally, the results of this survey provide a snapshot of the prevailing situation regarding STEM educational policy across a relatively small but nonetheless richly diverse range of European countries and regions. It shows the diversity of approaches to teaching STEM subjects across Europe. The objective of the ATS STEM project is to explore STEM competences that can be used to provide an integrated approach to teaching STEM subjects. By developing appropriate digital tools to assist with formative assessment, the project will support teachers to customise learning designs to better meet the needs of students. As a consequence, the project aims to encourage other second-level schools to follow and improve upon the foundation of the ATS STEM project, thereby encouraging pedagogies that are contextually situated within local practices and allow for a diversity of approaches to teaching and promoting STEM education.

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APPENDICES

Appendix A

Assessment of Transversal Skills in STEM (ATS STEM)

Erasmus+ Call reference: EACEA/28/2017

Terms of Reference for Work Package 1, Tasks 1- 4

Excerpts from the Original Proposal (See pages 61-65)

WP 1 - STEM Conceptual Framework

Work package 1 (WP1) sets the baseline for this project providing the theoretical and operational frameworks for the policy experimentations. It will result in a set of sharable outputs that illustrate a pathway to the improvement and modernisation of STEM education in schools in Europe within the partner countries to develop the skills of learners in the key areas of Science, Technology, Engineering, and Mathematics.

Task 1: STEM Education in Schools: What Research tells us

The initial task will involve:

- A review and synthesis of the research literature on STEM education with particular respect to schools, developing a set of inclusion and exclusion criteria level for the project scope.
- A mapping of the current state of the art of STEM education relevant to the project that provides an evidence base to highlight the areas that the policy implementations must address in particular with respect to key STEM skills for learners.

Output: A review and synthesis of the research literature on STEM education with particular respect to schools. In addition to a written report this output will include an executive summary of not more than one page comprehensible and accessible to each of the target stakeholders. A concise summary of the key takeaways of the full report will be produced for students, teachers, parents, policy makers and those in higher education, and industry concerned with STEM.

Task 2: How are Governments Addressing the Challenge of STEM Education? Case Studies from Europe?

This task will involve a focused review of the STEM education polices in each of the partner countries. This task will work to establish the key policy drivers at a national level that can effect change on a practical level in STEM education through targeted educational interventions.

Output: A review and synthesis of the research literature on STEM education with particular respect to schools. In addition to a written report this output will include an executive summary of not more than one page comprehensible and accessible to each of the target stakeholders. A concise summary of the key takeaways of the full report will be produced for students, teachers, parents, policy makers and those in higher education, and industry concerned with STEM.

Task 3: What is STEM (and how Do We Teach it)?

This task will build on the emergent findings of tasks one and two to develop an Integrated Conceptual Framework of STEM that marries findings from research literature with national policies to realise a shared understanding of STEM amongst the partnership that can also be communicated to external stakeholders.

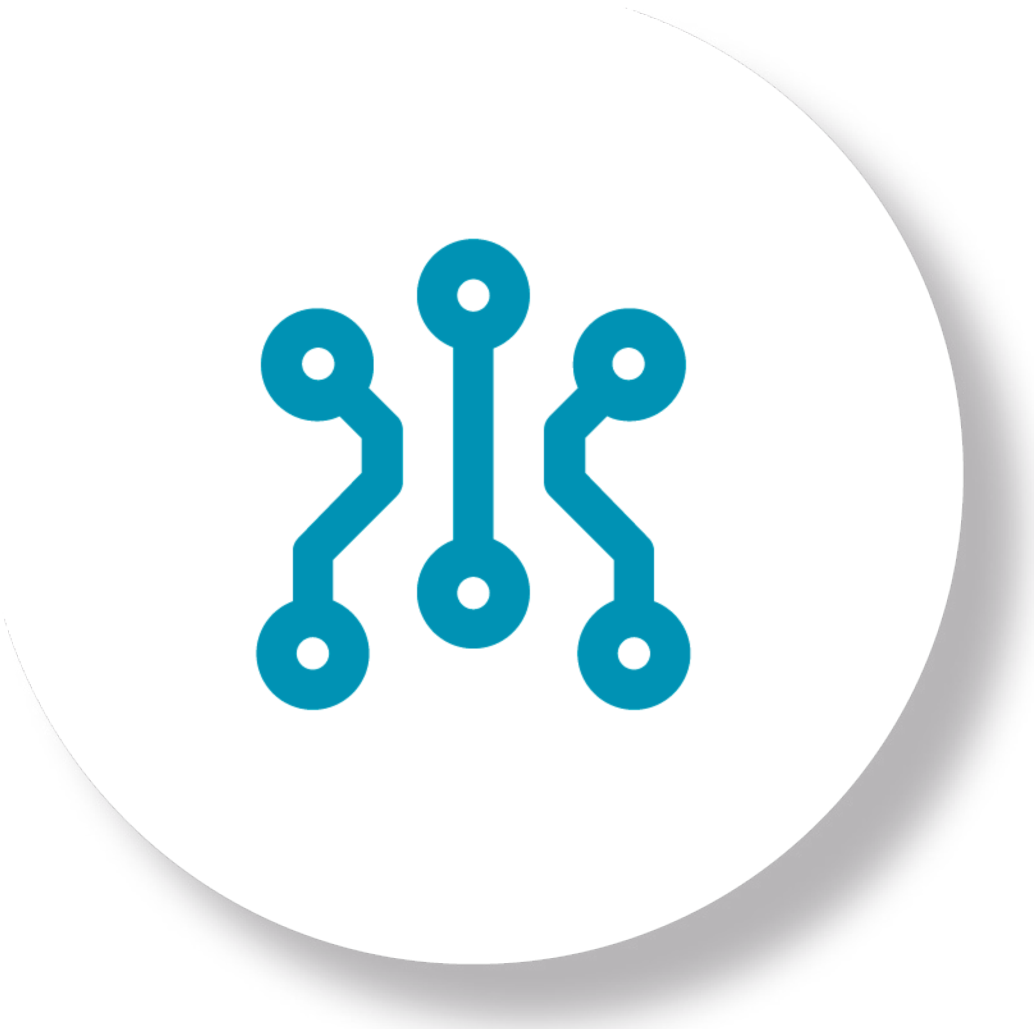
Output: A report showing the result of the development of a conceptual framework for STEM education

Task 4: Review of digital assessment approaches: Digital Assessment of Learning of STEM Skills.

This will involve a review of relevant digital assessment approaches to determine which contemporary technology enhanced approaches are best suited to the teaching and learning of STEM. In particular, it will analyse and report on which approaches can enable:

- Problem-based and research-based learning
- Enquiry-based learning
- Collaborative learning
- Mobile learning

Output: A report that highlights best practice in digital assessment of core STEM Skills and competences. This report will primarily be targeted at the STEM researchers in higher education, policy makers and those in ICT leadership roles in schools.



Appendix B - STEM Survey Instrument

1. Email address

....

2. What Country/Region are you Representing?

....

3. Does your country region have a policy/framework? on STEM education?

- ☐ Yes
- ☐ No

STEM Policy

This section is designed to elicit information about the response of your Government to STEM Education issues and challenges in your country/region if your country region has a policy otherwise you can skip this section.

4. Please upload a copy of the policy using the following link.
 Files submitted:

....

5. In what languages is the policy/framework document published?

....

6. What levels of education does your country/regional STEM policy include?

- ☐ Pre-school Second level
- ☐ Third level undergraduate
- ☐ Post-graduate
- ☐ Adult Education

7. In what year was the policy/framework published?We do not need the exact date. The year will be sufficient e.g. 01/01/2018

....

8. What is the definition of STEM given in the policy/framework?

....

STEM Education Conceptualization

9. What STEM subjects are taught in your country/region at second level?

....

10. List any STEM subjects that are not taught at second level in your country/region.

....

11. Is there any one STEM subject that is given special emphasis or discussion in your country/region (such as in policy)? For example, Physics or Mathematics might a subject that your government considers a priority. Mark only one oval.

☐ Yes
☐ No

12. If you answered yes above, please briefly describe.

....

13. What potential STEM subjects are taught in your country/region but not generally considered as STEM? For example: metal-working, craft, woodworking, 'maths-physics'

....

14. What are the key competences and skills deemed important in your country/region for STEM Education at second level?

....

15. Is there a focus in your country/region on "integrated STEM" teaching across the STEM subjects? Mark only one.

☐ Yes
☐ No

16. List examples (if any) of good practice in, or specific recommendations for, integrated STEM teaching across the STEM subjects

....

17. How extensive was/is the consultation and development process for STEM policy development in your country/region? Please briefly describe.

....

18. Are there specific third level STEM graduate shortages in your country region? If so, please briefly describe.

....

19. Is the role of industry/business in the promotion of STEM education at second level emphasized in your country/region?

- ☐ Yes
- ☐ No

20. If yes, please briefly describe any best practice examples
Are there any specific industry-led initiatives, sponsorships, STEM teacher internships etc.?

....

Social Inclusion & Equity

In this section, we wish to ascertain your country/region's position regarding groups who may be under-represented in STEM Education at second level.

21. Are there actions/strategies identified for specific subgroups in your country/region? Click all that apply. Check all that apply.

- ☐ Gender
- ☐ Ethnicity
- ☐ Refugees/Migrants
- ☐ Socio-economic Status
- ☐ Diverse Learners
- ☐ Unemployed
- ☐ Other: ________________________________

22. What are the main initiatives (if any) to increase participation of girls in STEM at second level in your country/region?

....

23. What are the main initiatives (if any) to increase participation of other under-represented groups in second level in your country/region?

....

Teacher Education Support

In this section we would like to gather information what, if any, support mechanisms have been proposed in your country/region.

24. Is continued teacher education in the teaching of STEM subjects in your country/region?
Mark only one.

- ☐ Required
- ☐ Not required
- ☐ Up to individual teachers

25. Please briefly describe any issues in your country/region identified to support teacher education.

....

Assessment of STEM and Digital Tools

26. What types of assessments are used to measure student achievement in STEM (formative and/or summative) in your country/region?

....

27. Are digital tools to support STEM education a priority in your country region? Mark only one.

- ☐ Yes
- ☐ No

28. If there are specific examples of innovation or best practice in the use of STEM digital tools in your country/region please list here.

....

Appendix C - Report Context

Work Packages and Deliverables		
WP1-ATS-STEM Conceptual Framework		Work package 1 (WP1) sets the baseline for the project, providing the theoretical and operational frameworks for the policy experimentations. It will result in a set of sharable outputs that illustrate a pathway to the improvement and modernisation of STEM Education in schools in Europe within the partner countries to develop the skills of learners in the key areas of Science, Technology, Engineering and Mathematics.
D1.1	STEM Education in Schools: What Research Tells us	A review and synthesis of the research literature on STEM Education with particular respect to schools. In addition to a written report, this output will include an executive summary of not more than one page comprehensible and accessible to each of the target stakeholders. A concise summary of the key takeaways of the full report will be produced for students, teachers, parents, policy makers and those in higher education, and industry.
D1.2	How are Governments Addressing the Challenge of STEM Education? Case Studies from Europe	A report detailing the national STEM policies in the partner countries. Concise summary of the key takeaways of the full report will be produced for each targeted stakeholder group: students, teachers, parents, policy makers and those in higher education, and industry concerned with STEM.
D1.3	What is STEM (and how Do we Teach it)?	A report showing the result of the development of a conceptual framework for STEM Education.
D1.4	Digital Assessment of Learning of STEM Skills	A report that highlights best practice in digital assessment of core STEM Skills and competences. This report will primarily be targeted at the STEM researchers in higher education, policy makers and those in ICT leadership roles in schools.

Work Packages and Deliverables	
WP2-STEM Formative Digital Assessment Approach	Work package (WP2) is focused on digital assessment and provides an evidence-based platform for the formative assessment of STEM learning tasks.
WP3 - Teachers' Professional Development	Development of the CPD materials and delivery of a training session to teachers will have a key role in pilot testing preparation and effective execution.
WP4 - Pilot Implementation	The Pilot Implementation work package is expected to provide the piloting countries with all the necessary guidelines and support to conduct meaningful and effective national implementation of pilot testing activities. This will lead to the successful implementation of the pilot experimentation involving the targeted number of schools, teachers and learners.
WP5 - Pilot Evaluation	The Evaluation of the Pilot Testing Process's goal is to analyse the possibilities of digital assessment in the implementation of STEM methodologies in European schools.
WP6 - Dissemination and Exploitation	The outcomes developed within this project will support national ministries and policymakers to formulate informed policies and implementation strategies in the area of STEM and digital assessment across Europe.
WP7 - Project Management	The project management approaches implemented in the project will take advantage of the traditional elements of planning, organising, executing, monitoring progress, controlling and closing activities while taking note of the inter-personal elements through empowering the project team and stakeholders.
WP8 - Quality Assurance	This work package will produce deliverables and implement procedures in the field of monitoring, quality and evaluation necessary to ensure that the outputs and impact of the project are realised. A key component of this work package will be the monitoring and evaluation of the process within the partnership of 12 organisations representing 8 EU Member States.

ATS STEM