SCIENTIX

The community for science education in Europe

EFFORTS TO INCREASE STUDENTS' INTEREST IN PURSUING SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS STUDIES AND CAREERS

National Measures taken by 30 Countries – 2015 Report

Caroline Kearney

European Schoolnet

Scientix (2012-2015) is supported by the European Union's Framework Programme for Research and Development (FP7) and coordinated by European Schoolnet.

European Schoolnet (www.europeanschoolnet.org) is a network of 31 Ministries of Education from across the European member states, leading educational innovation at European level. As a major international think tank, European Schoolnet operates key European services in education on behalf of the European Commission, member Ministries of Education and industry partners.

European Schoolnet's activities are divided among three areas of work:

- Policy, research and innovation: information sharing and evidence building.
- Schools services: enhancing cooperation between schools across Europe.
- Advocacy: how ICT and digital media contribute to transforming teaching and learning processes.

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

Author: Caroline Kearney

Please cite this publication as:
Kearney, C. (2016). Efforts to Increase Students' Interest in Pursuing Mathematics, Science and Technology Studies and Careers. National Measures taken by 30 Countries – 2015 Report, European Schoolnet, Brussels.

Keywords: Science, Technology, Engineering and Mathematics (STEM); European initiatives; Initial teacher training; Professional development; Online courses; Teacher recruitment; Responsible Research and Innovation

Editors: Patricia Wastiau, Àgueda Gras-Velázquez, Gina Mihai

Design/DTP: Jessica Massini

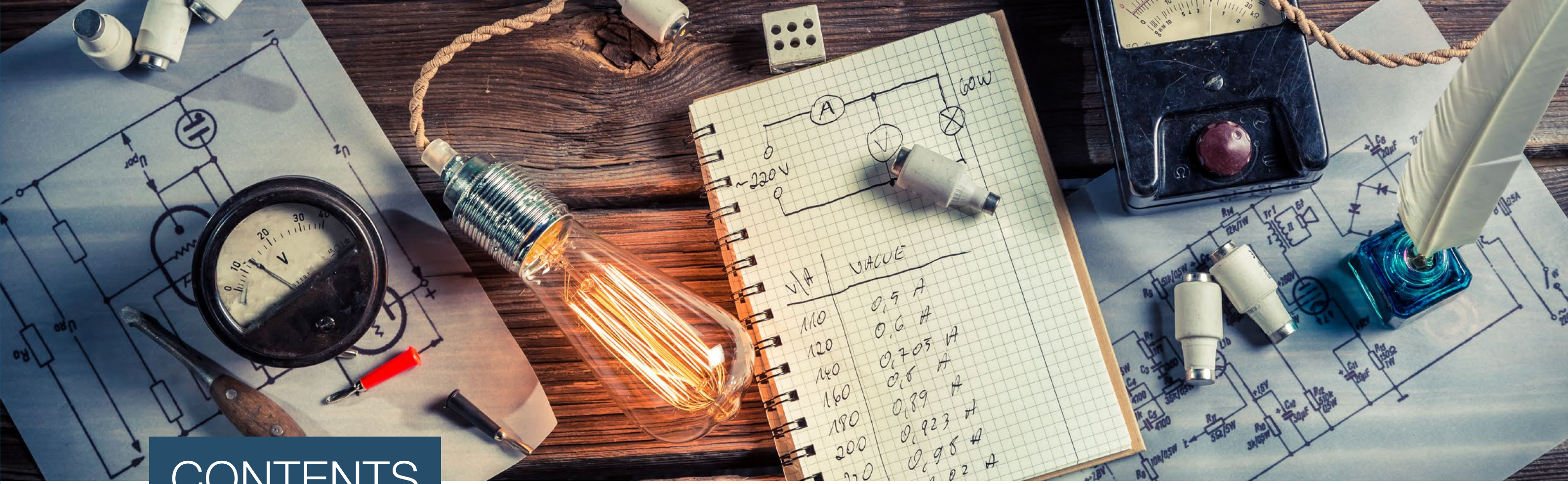
Print run: 1,000 copies

ISBN: 9789491440984

Picture credit: Shutterstock

Published in January 2016. The views expressed in this publication are those of the author and not necessarily those of EUN Partnership AISBL or the European Commission.

The Scientix project and the present publication have been funded with support from the European Commission, under the 7th Framework Programme. This report reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.



CONTENTS

EXECUTIVE SUMMARY

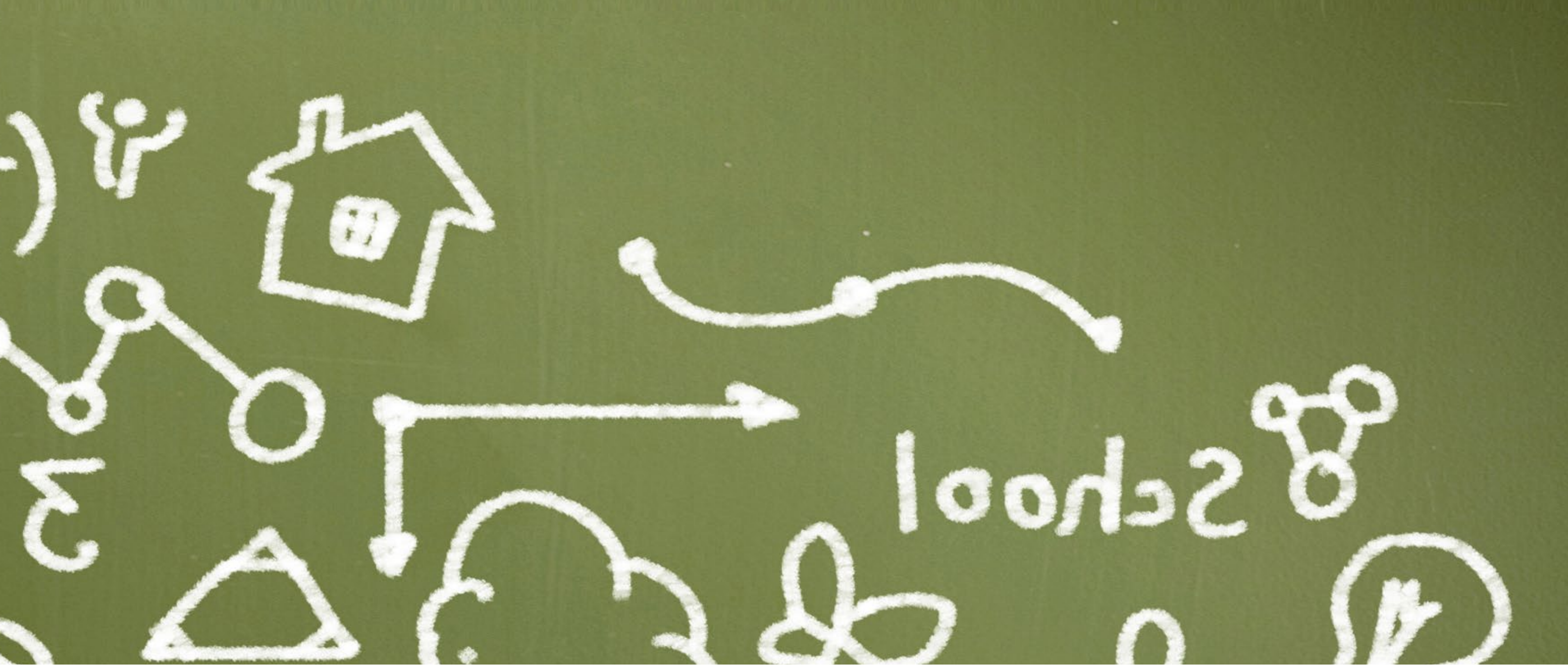
This publication is the latest in a series of reports about national efforts to increase students' interest in pursuing Science, Technology, Engineering, and Mathematics (STEM) studies and careers. The report is the result of an analysis of country responses to a survey launched in the summer of 2015, addressing recent, current or planned priorities, policies and initiatives aimed at improving the relevance and quality of STEM education to encourage more students to study and choose a career in the STEM field. This year sees the inclusion of the largest number of countries to have yet taken part in the survey. The report is written within the framework of the project Scientix – the community for Science education in Europe (http://www.scientix.eu). Scientix promotes and supports a Europe-wide collaboration among STEM (Science, Technology, Engineering and Mathematics) teachers, education researchers, policymakers and other STEM education professionals. The information provided in this report is based on the national contributions received from the Scientix National Contact Points (NCPs) representing 30 countries[I]. This latest report in the series updates the information published on certain issues in the 2011 edition, provides further information where available about ongoing initiatives, as well as new information concerning the additional nine countries who have contributed to this year's report (*BG*, *CY*, *EL*, *HR*, *HU*, *LV*, *MT*, *PL*, and the *UK*)[II]. Moreover, this 2015 edition of the report has a special focus on teacher education policies and initiatives. This focus is the result of the previous edition of the report (covering a wide range of issues in relation to STEM education), which identified improving initial teacher education and continuous professional development at the heart of the drive to make STEM studies and professions a more popular option for young learners. This current edition looks more deeply into how countries are developing initiatives in these areas.

STEM education policies and initiatives continue to receive political and financial support in the face of underachievement and a lack of student interest in STEM studies and careers

Competing in the global, knowledge-based economy and adjusting to the digital age are long-term challenges Europe must continue to address. Investing in human capital is vital in meeting these challenges. High quality STEM education (as well as education and

[I] Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Greece, Hungary, Ireland, Israel, Italy, Latvia, Lithuania, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom

[II] Where a list of countries are referred to in this report they are abbreviated using country codes available on page 94.



training in general) contributes to sustained economic growth, as well as sustainable development by fuelling R&D, innovation, productivity and competitiveness. However, **recent evidence illustrates that in both mathematics and science, underachievement of 15-year-olds remains above the ET 2020 benchmark of 15%, and most countries across Europe continue to face a low number of students interested in studying or pursuing a career in the STEM field.** As illustrated in this report, it is for these reasons, that not only do we observe ongoing strategies, policies and initiatives continuing to receive political and financial support, but also the creation of new ones, many of which have been launched within the last year.

> The majority of countries consider STEM education a current priority and have or are developing strategies to improve teaching and learning and the uptake of studies and careers in this area

Around 80% of the 30 countries surveyed describe STEM education as currently a priority area at national level, at least to some degree. When comparing the results of the last edition of this report published four years ago, promoting inquiry-based learning still remains the most highly ranked issue with 80% of all countries stating it is addressed as a top priority or important issue at national level. All countries (except *AT*, *EL* and *TK*) are currently prioritizing STEM curriculum reform at either primary or secondary level, and this is often linked to incorporating inquiry-based methods and teaching socio-economic aspects of science. Around 70% of countries are prioritizing initiatives relating to the integration of the effective use of ICT in STEM education, while around 60% are focusing on the development of new or revised STEM teaching and/or learning resources, often to accompany a new curriculum. Around 50% of countries are placing particular emphasis on improving initial and/or in-service STEM teacher training. On the other hand, the majority of countries are not prioritizing the promotion of Responsible Research and Innovation principles and practices in STEM education, and the issues of gender balance and career guidance in relation to STEM education are also less high on most national agendas. When asked whether a STEM education strategy exists at national level, just under a third confirmed this to be the case, which appears to be a low percentage considering it is a priority issue in most countries. However, once one adds the countries which mention other overarching strategies in which STEM education is highlighted, as well as the countries currently in the process of planning STEM education strategies, this amounts to 77% of all countries surveyed, confirming its continued significant position at policy level across Europe.

The majority of countries are paying more attention to improving the provision of professional development for in-service STEM teachers than investing in STEM-specific initial teacher training

All countries (except Hungary) mentioned that specific STEM-related professional development has recently been or is currently available for in-service teachers, and/or that there is a specific initiative related to this in place. Around one third of countries (*PT*, *RO*, *PL*, *TK*, *MT*, *HR*, *CY*, *SI*, and *UK* [Scotland]) have STEM in-service teacher education initiatives which have been implemented or are currently being led at central level, either directly through the Ministry of Education, or the national institution responsible for teacher training, often affiliated to the Ministry. Some of the initiatives reported are directly related to national curriculum reform or educational priorities leading to the need to update teachers' STEM knowledge and competences, enabling them to implement the changes in the classroom. On the other hand, 30% of countries report that various providers, including dedicated teacher training agencies, universities and private organizations (sometimes in collaboration) are responsible for the provision of teachers' continuous professional development in STEM teaching. 20% of countries (*IL*, *CZ*, *EE*, *MT*, *FI*, and *NL*) report that widespread reform has recently or is currently transforming their teacher professional development systems at national level. These general reforms in in-service teacher education have impacted STEM professional development in various ways. The Netherlands has launched a new STEM Teacher Academy which provides professional development in cooperation with industry, while France has expanded the reach of its existing La main à la pâte Foundation, by creating a national network of "Houses for science". Finland and Norway on the other hand have received dedicated funding from their governments to invest in STEM specific teacher professional development programmes.

Greece, Slovakia, Ireland and Croatia report professional development courses/conferences, specifically aimed at training in-service teachers in the effective use of technology for teaching and learning. A few countries (*UK*, *IT*, *PT*, and *FR*) have invested in carrying out large scale evaluations of the professional development available for STEM teachers at national level, and it would be of value for more countries to commission such evaluations to ensure that any future funding or measures are decided on the basis of grounded evidence. **Of particular interest are the professional development initiatives in Flanders, Denmark, Latvia and Sweden targeting in-service STEM teachers, which have a special emphasis on teacher collaboration and peer learning.** The focus of these initiatives is on the individual and joint reflective practice of teachers, and the active co-development of teaching methods and resources by peers. In these innovative approaches to in-service education, the teachers themselves become jointly responsible for their own professional development. This approach to professional development is intended to have a lasting impact through the network of teachers established and the continuation of such collaborative learning within their schools and beyond, once the programmes have ended. Should these countries continue or start to invest in evaluating this new approach to professional development, other countries might learn and be inspired to also transform their professional development offer for in-service teachers, so as to include a more central role for peer learning and collaborative practices.

70% of countries (AT, BE, BG, DK, EE, EL, ES, FI, FR, HR, IE, IL, IT, LT, NL, NO, PL, PT, RO, SI, UK) report that they either have implemented, currently have or plan online professional development for STEM teachers, testifying to the increasing popularity and acknowledged usefulness of this mode of training. In the last edition of this report published in 2011, less than half of the countries surveyed reported any activity in the area of online learning for STEM teachers, and often this mostly focused on the availability of online learning resources for teaching. Since then, the range and sophistication of online professional development has dramatically grown, reflected by the sharp increase of countries reporting activity in this area. The format of online professional development offered by different countries ranges from short one-off webinars, to activities on e-learning platforms (such as Moodle), to full Massive Open Online Courses (MOOCs), which are increasingly being developed. Some countries also mention the use of blended approaches, involving online and offline activities. The STEM areas and topics covered by online professional development activities are varied, with the pedagogical use of ICT in STEM teaching and learning being particularly prominent. **Online professional development provides an excellent platform for the creation of professional teaching communities, allowing participants to continue to collaborate and learn from one another beyond the end of a specific online course.**

By contrast, only 50% of countries (AT, BE, BG, CZ, DK, EE, FI, FR, IL, LT, LV, MT, NL, NO, UK) mentioned that specific STEM-related initial teacher training has recently been or is currently available for prospective teachers, and/or that there is a specific initiative related to this in place. A small group of countries are developing new courses or special programmes for the provision of STEM initial teacher education. Malta and the United Kingdom are developing new degree programmes to facilitate and enhance the studying of sciences for prospective science teachers, while Lithuania, Latvia and the Netherlands have updated and modernized their initial teacher training courses to reflect STEM curriculum reforms in their countries and to introduce innovative content and methods. Israel has introduced special programmes to train future STEM teachers, including a school residency programme, and Finland has set up a STEM teachers education forum to promote cooperation between STEM teacher education units in different universities and jointly establish national quality standards for STEM initial teacher education. **Flanders, Estonia and Austria have reported that through collaboration in national or European projects (involving universities, teacher training colleges, teacher networks and other partners), new encouraging developments are entering STEM related initial teacher education at national level. These developments have included the incorporation of innovative pedagogies and resources into initial teacher training programmes, and have also given rise in parallel to the building of professional development networks. In view of certain countries being currently unable to invest in updating STEM initial teacher education at national level (whether for political, financial or other reasons), they might be well advised to focus their efforts in a first step on promoting the rich resources and innovative online communities**

readily available within Scientix, the community for science education in Europe, to their future STEM teachers at national level.

Respondents were asked to indicate whether initial teacher training and professional development provided at national level is sufficient or lacking with respect to 16 knowledge and competence areas, specifically relevant to STEM teachers. **A striking 15 out of 16 knowledge and competence areas for STEM teachers are not adequately covered at national level by initial teacher training (according to at least around 70% of countries), and professional development (according to around 55% of countries).** The only exception, is the most basic and traditional aspect of teacher training - professional content knowledge, which was considered to be sufficiently covered by initial teacher training (according to around 50% of countries: *AT*, *BG*, *EE*, *ES*, *FI*, *HR*, *HU*, *IL*, *MT*, *NO*, *PL*, *SI*) and professional development courses (according to around 70% of countries: *AT*, *BG*, *CZ*, *DK*, *EE*, *ES*, *FI*, *FR*, *HU*, *IL*, *IT*, *LV*, *MT*, *NL*, *NO*, *PL*, *SI*, *UK*). Moreover, strikingly 80% of countries agree that two closely related areas (namely: knowledge and ability to analyze students' beliefs and attitudes towards STEM and, knowledge and ability to teach STEM taking into account the different interests of boys and girls), are not addressed sufficiently in initial teacher education programmes or continuous professional development courses. This may help explain why at present, and since many years, STEM teaching often does not adequately take into account students' STEM-related beliefs and attitudes or their gender-specific interests (Rocard 2007, Osborne 2008, OECD 2015). **This report recommends that national and European policies and initiatives enabling prospective and in-service teachers to be made aware of the importance of attitudes and gender in impacting on students' motivation to study and pursue STEM careers, be developed, including the provision of specific guidance on pedagogical methods and resources available to address the issue in the classroom.**

> The need to recruit more STEM teachers is an issue which faces various countries, with almost 40% reporting that initiatives are planned or in place to address the shortage of STEM teachers in schools, particularly at secondary level

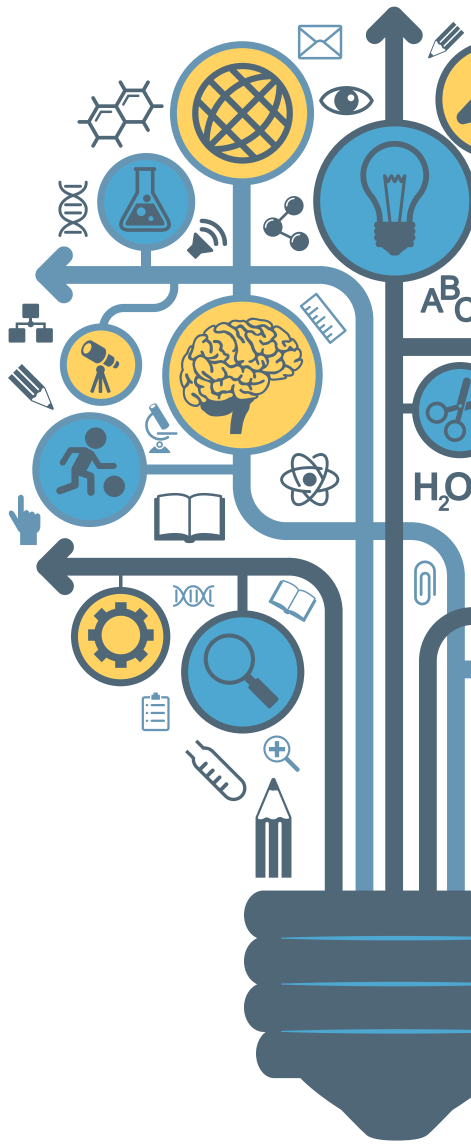
In the United Kingdom, Israel, the Netherlands, Bulgaria and Denmark, several initiatives are being implemented concurrently as part of a concerted effort at national level to tackle the shortage of STEM teachers. In Hungary, Switzerland, France, Israel, and Latvia a general lack of teachers of all subjects (including STEM) is reported, along with accompanying initiatives to address this via various actions. Initiatives range from scholarships and loans, to programmes facilitating students and professionals from non-teaching backgrounds to become STEM teachers, and in some cases allowing participants to combine working as a STEM professional and teaching in the classroom. Often these initiatives target high achieving students with a proven academic record. Additionally, Finland and Sweden report there is evidence available at national level supporting the need to invest further in the recruitment of STEM teachers.

> The Responsible Research and Innovation (RRI) agenda has recently gained prominence at European level, and could play an important role in motivating students to pursue STEM studies and careers, by bringing the societal aspects of STEM to the forefront. However, currently, RRI mostly remains the concern of academia and has yet to be fully embedded within national school education systems

Responsible Research and Innovation (RRI) is a process where all societal actors (researchers, citizens, policy makers, business) work together during the entire research and innovation process in order to align outcomes with the values, needs and expectations of society. Overcoming complex societal challenges in an interconnected, globally competitive world, will require all citizens to have a better understanding of science and technology if they are to participate actively and responsibly in science-informed decision-making and knowledge-based innovation. Science education has a very important role to play in the promotion of RRI, yet it is an area which is still very much addressed solely by academia in most European countries. **A significant majority of 80% of countries stated that the concept of Responsible Research and Innovation in the specific context of STEM school education is not known or established at national level, and that the school education community is not familiar with the principles and practices of this approach and how it involves them.** Just under 15% of countries (*ES*, *IE*, *IL*, *SE*, and Flanders) stated that RRI is either to some extent or well established as a concept within the specific context of STEM education in their countries, and that it is addressed as a top priority or important issue at national level. In these few countries RRI is either incorporated into the curriculum, or stakeholders are involved in national or European projects which promote young people's direct involvement in scientific research for the benefit of society.

It is therefore unsurprising that an overwhelming majority of country respondents stated that teaching the principles and practices of Responsible Research and Innovation (RRI) needs to be more thoroughly addressed in initial teacher training (according to 98% of countries) and professional development courses (according to 88% of countries). **More awareness raising is needed, and countries would benefit from examples of how school education might best contribute to the RRI agenda. It will be interesting to monitor in the future how countries respond to the recommendations and actions suggested by the recent report 'Science Education for Responsible Citizenship' commissioned by the European Commission, and to observe how their implementation might contribute to firmly embedding RRI practices into the education system and lifelong learning process, for the long-term benefit of society.**

Finally, many of the strategies, policies and initiatives described in this report have only very recently been launched. It will therefore be useful for the national and European research and policy making communities to closely follow their development and monitor their impact to inform STEM education progress in the future.



INTRODUCTION

When the first edition of this report was published in 2010, reference was made to STEM education being central to contributing to the European Lisbon Strategy's goal to foster a dynamic and innovative knowledge-based economy. Five years since then, and a new European Strategy, Europe 2020, has taken over from its predecessor, yet the key role of STEM education remains the same, and has even been strengthened. Indeed, building capacities and developing innovative ways of connecting science to society is one of the key priorities of Horizon 2020, the current European Framework Programme for Research and Innovation. This will help to make science more attractive to young people, increase society's appetite for innovation, and open up further research and innovation activities. The continued importance of STEM education for today's society is evident. In the words of the recent report published by the European Commission on science education for responsible citizenship:

> *Knowledge of and about science are integral to preparing our population to be actively engaged and responsible citizens, creative and innovative, able to work collaboratively and fully aware of and conversant with the complex challenges facing society. It helps us to explain and understand our world, to guide technological development and innovation and to forecast and plan for the future. It introduces citizens to an important part of our European culture. This puts science education at the centre of broader educational goals for society as a whole*
> *(European Commission (b) 2015, pp.14).*

The previous edition of the current report was published in 2011. This report is the latest edition, and has been written by European Schoolnet, with the support of the project Scientix – the community for Science education in Europe (**http://www.scientix.eu**). Scientix promotes and supports a Europe-wide collaboration among STEM (Science, Technology, Engineering and Mathematics) teachers, education researchers, policymakers and other STEM education professionals. In its first stage (2009-2012), the project built an online portal to collect and present European STEM education projects and their results, and organised several teacher workshops and networking events to disseminate them. In its second phase (2013 – 2015) Scientix has expanded to the national level. Through its network of National Contact Points, Scientix aims to reach out to national teacher communities, and contribute to the development of national strategies for the wider uptake of inquiry-based and other innovative approaches to STEM education.

The information provided in this report is based on the national contributions received from the Scientix National Contact Points representing 30 countries, in response to a survey on national measures and initiatives to increase students' interest in pursuing STEM studies and careers, launched in the summer of 2015 by European Schoolnet. This main source of data is complemented with information presented by a number of Ministries of Education during European Schoolnet's annual conference, Eminent, on 18-19 November 2015, which was organised by the Scientix project. This latest report in the series updates the information published on certain issues in the 2011 edition, provides further information where available about ongoing initiatives, as well as new information concerning the additional nine countries who have contributed to this year's report (Bulgaria, Croatia, Cyprus, Greece, Hungary, Latvia, Malta, Poland, and the United Kingdom). Moreover, this 2015 edition of the report has a special focus on teacher education policies and initiatives. This focus is the result of the previous edition of the report (covering a wide range of issues in relation to STEM education), which identified improving initial teacher education and continuous professional development at the heart of the drive to make STEM studies and professions a more popular option for young learners. This current edition looks more deeply into how countries are developing initiatives in these areas. The report is divided into seven sections covering the following topics: STEM education priorities; STEM education national strategies; Initiatives related to the recruitment of STEM teachers; STEM related initial teacher education initiatives; STEM related in-service teacher education initiatives; Online professional development for STEM teachers; and Responsible Research and Innovation (RRI) in STEM education. Some countries have opted to make their national responses to the survey, covering a wider range of issues than those analyzed in the current publication, available online. Both the current report and the associated national survey responses are available on the Scientix website (**http://www.scientix.eu/web/guest/observatory/comparative-analysis-2015**).

Due to the difference in the availability and level of detailed information at national level, this report does not aim to be comprehensive or exhaustive, but rather gives an up-to-date snapshot of the main measures and initiatives currently existing at national level related to raising the profile and quality of STEM education across Europe, particularly in relation to teacher education. It serves as a useful update considering that the last comparative reports on STEM policies and initiatives across Europe were published in 2011 (Eurydice (a) 2011, Eurydice (b) 2011, Kearney 2011). The Eurydice reports nevertheless still serve as useful reference documents as they provide comprehensive and detailed information concerning STEM education policies and measures related to all areas, in 33 countries participating in the European Union's Erasmus+ Programme, much of which is still relevant today. The added value of this current report, is that while it does not have the same scope or depth, it provides the most up-to-date information available, including on issues which have recently gained prominence at European and national levels; most notably, concerning school education's involvement in the Responsible Research and Innovation agenda.

The surveys' respondents and the organizations they are affiliated to at national level vary in profile and scope, inevitably impacting on the information provided. Most country contributions include input from at least one representative of the Ministry of Education and/or the national body responsible for STEM education at national level (often funded by or closely associated to the Ministry of Education). In various countries university researchers working on STEM education were also asked for their input. It should be noted that the survey asked detailed open questions, some requiring factual responses, others requiring qualitative judgement (e.g. To what extent is a certain issue a priority in your country? Is a certain issue in teacher training addressed enough at national level? etc.). While contributors were asked to justify their answers on the basis of evidence, this was not always available or possible, resulting in some questions remaining unanswered, while other answers can only be said to represent the views of a particular organization, or a respondent's own professional experience. Where evidence is available, this is described and/or referenced.

1. STEM EDUCATION PRIORITIES

Around 80% of the 30 countries surveyed describe STEM education as currently a priority area at national level, at least to some degree. Promoting inquiry-based learning still remains the most highly ranked issue with 80% of all countries stating it is addressed as a top priority or important issue at national level. All countries (except AT, EL and TK) are currently prioritizing STEM curriculum reform at either primary or secondary level, and this is often linked to incorporating inquiry-based methods and teaching socio-economic aspects of science. Around 70% of countries are prioritizing initiatives related to the integration of the effective use of ICT in STEM education, while around 60% are focusing on the development of new or revised STEM teaching and/or learning resources, often to accompany a new curriculum. Around 50% of countries are also investing in improving initial and/or in-service STEM teacher training. Also worthy of mention, is that the majority of countries are not prioritizing the promotion of Responsible Research and Innovation principles and practices in STEM education, and the issues of gender balance and career guidance in relation to STEM education are also less high on most national agendas.

Around 80% of the 30 countries who responded to the 2015 survey describe STEM education as currently a priority area in their countries, at least to some degree. Around the same percentage of countries stated this to be the case in 2011, when 21 countries were surveyed, illustrating that four years later, STEM education still remains high on national education systems' agenda. Indeed, the continued need for STEM education to be treated as a priority issue is confirmed by the most recent data available in the latest Education and Training Monitor, published in November 2015. The report states that across the EU, 22% of 15-year-olds underachieve in mathematics (among pupils with low socio-economic status, this is a worrying 36.6%), while 17% underachieve in science. This means that in both mathematics and science, underachievement remains above the ET 2020 benchmark of 15% (European Commission (a) 2015. pp. 18). It is important to note that this 'educational poverty' as it has been referred to by the European Commission, is strongly connected to socio-economic status, immigration background and gender. Indeed, underachievement in mathematics, science and reading is about 60% more prevalent amongst boys than it is amongst girls (Council of the European Union, 2015, pp. 4)[III]. Moreover, in the EU, the share of underachievement amongst foreign-born students is almost twice as high as it is amongst the native-born, whether in science (29.9% versus 15.1%) or mathematics (36.3% versus 20.5%) (European Commission (a) 2015. pp. 20).

[III] Following the ET 2020 benchmark, underachievement is measured as the share of 15 year-olds scoring below level two out of six proficiency levels in the OECD's PISA survey.

Therefore, in response to this data, STEM education is also very much on the European policy agenda, illustrated by its inclusion in the new priorities for European cooperation in education and training, adopted by the Council of the European Union on 23 November, just prior to the publication of this report. Under priority area 1. 'Relevant and high-quality knowledge, skills and competences developed throughout lifelong learning, focusing on learning outcomes for employability, innovation, active citizenship and well-being' the first concrete issue mentioned is 'Enhancing targeted policy action to reduce low achievement in basic skills across Europe, covering language, literacy, mathematics, science and digital literacy'. This is one of the key areas to be followed-up through the Education and Training 2020 working methods and tool box, and reflects a common challenge for all Member States as well as the added value of tackling this issue at European level. This is one of the concrete issues which will form the basis for the mandates of the next generation of Education and Training 2020 Working Groups. Member States will select, in accordance with national priorities, those areas and issues for work and cooperation in which they wish to participate (Council of the European Union, 2015).

To further understand exactly which aspects of STEM education are considered a priority and what level of importance they are given at national level, respondents were asked to indicate to which extent 15 STEM education issues are currently addressed in their country, according to a 4-level scale (1 = Addressed as a top priority; 2 = Addressed as an important issue; 3 = Addressed to some extent; 4 = Not addressed).

Four years on since countries were last asked about their STEM education priorities, promoting inquiry-based learning still remains the most highly ranked issue with 80% of the 30 countries surveyed stating it is addressed as a top priority or important issue at national level. Inquiry-based learning is widely considered as forming an important part of the paradigm shift from a content and teacher-led approach to one that is more competence-based, constructivist, and learner-centred. The benefits of inquiry-based learning have been widely evidenced in educational research and include increasing students' interest and attainment levels at both primary and secondary levels while at the same time stimulating teacher motivation (Rocard 2007, pp. 2). Moreover, inquiry-based methods provide students with the potential for opportunities to develop a large range of transversal skills such as working in groups, open-ended problem-solving, written and verbal expression and other cross-disciplinary abilities.

Interestingly however, when asked specifically if at national level countries were actively promoting small group activities in science classes, which can be said to be closely associated to inquiry-based approaches, only 7% (*BE*, *MT*) stated this was being addressed as a top priority and 29% (*AT*, *DK*, *FI*, *IE*, *LT*, *NO*, *RO*, *SE*) as an important issue. One reason for this might be that while inquiry based methods are being encouraged at national level, how this is concretely translated into practice (i.e. through group work on projects for example) is a matter for teachers and schools to decide themselves at local level. It is also true that students can be involved in inquiry-based approaches as individual learners, so it does not necessarily always imply group work, which could also partly explain this difference. However, it is evident that group work allowing for discussion and the testing of hypotheses with peers has the potential to be very complementary to the inquiry-based approach and beneficial to the learner. Indeed, collaborative learning is an important motivational aspect for learners and according to research in this area, it is recommended that group project work with no known answer or no previously learned solution should become an essential activity in science and mathematics learning particularly involving experiments or the construction of models (Eurydice (a), 2011, pp 117). It is interesting to note that activities based on discussion and collaborative working are just as frequently recommended in the majority of European countries' steering documents covering STEM education at both primary and secondary level, as is inquiry-based learning (Eurydice (a) 2011, pp. 71). However, as this current report's survey results show, this does not necessarily mean that it is considered a priority at policy level, nor does it indicate that group work takes place frequently in STEM-related classroom practice.

Following very closely in second position, and in most cases strictly related to the integration of inquiry-based learning, is a focus on STEM curriculum reform at secondary level, ranked by 79% of countries as either a top priority or important issue. 69% of these countries also stated that STEM curriculum reform at primary level ranked highly in terms of importance at national level. All countries are currently prioritizing STEM curriculum reform at either primary/secondary level or both, except for Austria, Greece and Turkey. One possible explanation for secondary curriculum reform receiving a slightly more dedicated focus than primary curriculum reform, is because primary education by nature is already rather hands-on and inquiry-led, in comparison with secondary education, which has traditionally been more content-heavy and less experimental. Moreover, with research indicating that students' interest in STEM subjects decreases as they grow up (Osborne and Dillon 2008, pp. 11), there is clearly a more urgent need to change the way STEM subjects are taught and perceived by young people at secondary level, if we are to encourage them to pursue careers of this orientation. Having said this, countries recognize the importance of an excellent and motivating primary STEM curriculum, as research informs us that science teaching at primary school has a strong long-term impact, which explains why efforts are also being made at this level. Primary education covers the period of time in which pupils have a strong sense of natural curiosity allowing them to develop intrinsic motivation, associated with long-lasting effects (Rocard, 2007, pp. 11).

60% of countries claimed the promotion of context based teaching approaches focusing on socio-economic aspects of science, to be either a priority or very important (*AT*, *BE*, *BG*, *CY*, *DK*, *EE*, *ES*, *FI*, *IE*, *IL*, *LT*, *LV*, *MT*, *NL*, *NO*, *RO*, *SE*, *UK*). This aspect's similar ranking with curriculum reform is again logical as the two are strongly interlinked, as one of the most efficient ways of promoting the teaching of socio-economic aspects of science is indeed by introducing new curriculum content which links science with everyday life and current issues. Research has indicated that one of the most important factors determining students' interest in STEM subjects and careers, is the way in which they are taught at school (Rocard, 2007), hence the significance of inquiry-based learning and context-based teaching which ensure the teaching of STEM subjects at school is relevant, dynamic and engaging. Indeed, among the 15 issues countries were asked to rank in terms of priority, these are the only two issues that no country is failing to address, albeit to different extents, clearly illustrating their importance. This also reflects the finding of the recent Eurydice report, which states that debating current scientific and societal issues and self-directed project work are recommended in the steering documents of a majority of countries at secondary level, while this is the case for fewer countries at primary level (Eurydice (a), 2011, pp. 71).

The third most highly ranked STEM education issue at national level, is the integration of the effective use of ICT in STEM teaching and learning, which 72% of countries (*AT*, *BE*, *BG*, *CH*, *CY*, *CZ*, *EE*, *EL*, *ES*, *FR*, *FI*, *IE*, *IL*, *IT*, *LT*, *MT*, *PT*, *RO*, *SI*, *SE*, *UK*) declared to be a top priority or an important issue.

67% of countries (*BE*, *BG*, *CY*, *CZ*, *EE*, *FI*, *HR*, *HU*, *IE*, *IL*, *IT*, *LT*, *LV*, *MT*, *RO*, *SI*, *SE*, *UK*) declared that the development of new or revised STEM teaching resources and learning resources for students was a top priority or an important issue at national level. Again, with STEM curriculum reform being so high on the national agenda, it is natural that countries are also attaching importance to the development of new teaching and learning resources to accompany the implementation of the revised curricula. While the majority of countries are prioritizing STEM curriculum reform and the promotion of innovative pedagogies and resources to deliver it, only around 50% of all countries (*BE*, *CH*, *DK*, *EE*, *ES*, *IE*, *IL*, *MT*, *RO*, *IT*, *LT*, *LV*, *SE*, *UK*) are currently dedicating the same level of attention to the development of new assessment methods for STEM education. Indeed, as documented in the 2011 Eurydice report, traditional assessment methods still prevail in the majority of European countries, and there is no clear distinction between how STEM subjects are assessed compared to how other curriculum subjects are assessed (Eurydice (a) 2011, pp. 10). Assessment is often thought as inextricably linked to the development of the curriculum and its underpinning pedagogical methods, yet past education policies across Europe have shown that it is often taken care of at a later stage within the process of curriculum reform, partly due to its complexity. This can be detrimental however, as if new curricula are implemented before the corresponding updated assessments are introduced, the resulting poor alignment between the curricula and the assessment could undermine the innovative teaching and learning the new curricula set out to promote (KeyCoNet (a), 2014, pp. 16). Indeed, when Ireland was preparing its mathematics reform 'Project Maths', research carried out by the National Council for Curriculum and Assessment recommended that, in order for real change to happen, it was important for the syllabus, assessment and the teaching and learning of mathematics to change in tandem (KeyCoNet (b), 2014, pp. 30).

54% of all countries (*BE*, *BG*, *CY*, *CZ*, *DK*, *FI*, *FR*, *IE*, *IL*, *MT*, *NL*, *NO*, *RO*, *SE*, *UK*) surveyed state that the improvement of STEM secondary teacher education is either a priority or an important issue at national level, while 43% (*BE*, *FR*, *CY*, *CZ*, *DK*, *IL*, *MT*, *NL*, *NO*, *RO*, *SE*, *UK*) state this is also the case for STEM teacher education at primary level. This is perfectly in proportion with the priority rankings for primary and secondary curriculum reform, reflecting the fact that currently more emphasis is put on updating teacher education at secondary level, where curriculum reform is currently taking place to a larger extent.

To reflect the European Commission's focus on Responsible Research and Innovation (RRI) as a cross-cutting theme of the Horizon 2020 European Framework Programme, in this year's survey, we additionally asked countries to indicate to which extent this issue is addressed by STEM education at national level. Only 34% of all countries surveyed state that RRI (whether it be in relation to STEM curricula/teaching and learning resources/initial teacher training or in-service teacher training programmes) is addressed as a priority (*ES*, *IL*, *MT*) or as an important issue (*BE*, *CY*, *EE*, *IE*, *LT*, *SE*, *SI*) by their national school education systems. This is not surprising considering that up until now this concept has mostly been developed in the research community, and has only recently surfaced prominently at European level, explicitly being promoted by the European Commission as concerning all of society, including teachers and students, as highlighted in its new publication 'Science Education for Responsible Citizenship' (European Commission (b), 2015). Indeed, there is clear evidence that today we need to involve all citizens in the decisions about the development of science and technology so that we can all contribute to the smart, sustainable, and inclusive growth of our societies. This is the core principle behind the European Commission's focus on Responsible Research and Innovation (RRI) which is a cross-cutting issue in Horizon 2020, the current European Framework Programme for Research and Innovation. It is in this context that the project RRI Tools, funded under the European Horizon 2020 Framework Programme has been set up in order to empower all actors to contribute their share to the Responsible Research and Innovation initiative. The project's final outcome is to develop a set of digital resources (the RRI Toolkit) to advocate, train, disseminate and implement RRI for various target groups: policy makers, researchers, business and industry, civil society organizations, citizens at large, and of most interest to this report, the education community, including teachers, students and families. Countries with initiatives focusing on RRI issues are described in section 7 of this report.

Finally, the two issues considered less of a priority by most countries, following the trend also identified in the 2011 STEM report, are gender balance and career guidance. Regarding the issue of gender balance, in order to get a more precise picture, this year we asked countries to what extent at national level are they addressing not only the issue of gender balance of students studying or pursuing STEM careers, but also of STEM teachers, as some initiatives reported on in 2011 targeted fostering a female role model approach to encourage girls to engage with STEM studies and careers. Only 10% of countries (*AT*, *EE*, *LT*) stated they were prioritizing or treating with importance the issue of recruiting more female STEM teachers, while only 27% (*AT*, *BE*, *CH*, *IL*, *LT*, *NL*, *SE*, *UK*) stated this to be the case for engaging more female students to study and pursue STEM careers. Around 23% claimed to be addressing these gender balance issues to some extent, while the largest number of countries in fact declared they are not addressing either issue at national level at all (around 68% stated this to be the case for the gender balance of STEM teachers - *FR*, *BE*, *BG*, *CH*, *CZ*, *CY*, *DK*, *EL*, *FI*, *HR*, *HU*, *LV*, *NL*, *NO*, *PL*, *PT*, *RO*, *SE*, *SI*, *TK*; and around 45% for the gender balance of STEM students - *FR*, *BG*, *CY*, *EL*, *HR*, *HU*, *LV*, *PL*, *PT*, *RO*, *SI*, *TK*). The reasons given by countries with regards there is not, or at least there is no longer a focus on gender balance in relation to STEM education, are varied and nuanced. For example, in **Denmark**, the country respondent noted that as in many countries, the gender issue is usually in fact the predominance of female teachers in general. However, when it comes to STEM teachers in Denmark, the country is closer to a gender balance, meaning there is no need to take special measures on the issue. **Bulgaria** gave the following reason for the lack of focus on gender balance of STEM students at national level: in Bulgaria there are 30 'Natural Sciences and Mathematics' high schools across the country which specialize in the teaching of STEM subjects. Entrance to these specialized STEM schools is subject to passing an entrance examination at the age of 12-14. Consistently statistics have shown that at least 50%, and often more of successful applicants are girls, who after completing their school career go on to study and pursue STEM related careers. For this reason, Bulgaria is not so concerned by the gender imbalance of STEM students faced more acutely by other countries.

Regarding STEM career guidance, although only 4 countries state they are not currently addressing the issue at all (*FR*, *EL*, *HU*, *TK*), the majority (52%) state they are only addressing it to some limited extent, and only 20% as an important issue (*AT*, *CH*, *EE*, *IE*, *SE*, *UK*), and 14% as a top priority (*BE*, *ES*, *IT*, *NL*). Where countries do have specific measures or initiatives in this area, whether they are instigated by the Ministry of Education, educational institutions or industry, they often tend to emphasize the diversity of STEM career possibilities, as young people and STEM teachers themselves are often unaware of the various STEM-related opportunities available in the labour market. This is understood by some countries as one of the barriers to a larger uptake of STEM careers.

Countries were also asked to mention any other STEM education priorities they are focusing on at national level, not already listed in the survey. One priority issue mentioned by 3 countries (*BE*, *EE* and *UK*), is the collaboration of key stakeholders to ensure various actors in society support STEM education and careers, including various Ministries, industries, teacher training institutions, informal learning partners, and the wider community. In this respect, Flanders indicated that several STEM networks have emerged during the last year: one overarching STEM Network for all partners committed to supporting STEM in the broadest possible sense; two STEM Learning Networks for primary and secondary education, a Network for STEM partners in informal education and finally, the Network of the three government departments involved in STEM. The collaboration of key stakeholders is also a very well established process in **England**, on, for example, the development of the STEM curriculum and training programmes for apprenticeships, and cooperation through the National Science Learning Network. Moreover, England's Enthuse project which consists of government, employer and charitable trust funding offers bursaries for teachers to access subject-specific and leadership related continuous professional development. The government's recent 2015 autumn budget statement highlights the need for ongoing investment in this area. **Scotland** mentioned a much greater role for industry in supporting the development of skills for learning, life and work, as well as increased provision of work-based learning and the uptake of industry recognized qualifications including apprenticeships for learners of school age. **England** on the other hand mentioned a focus on improving subject-specific STEM leadership, while **Slovenia** mentioned that to some extent they are also addressing low achievers in STEM education at national level.

It is important to also take note of the five countries which do not consider STEM education as a particular current priority at national level. These include **Greece, Turkey, Finland, Slovenia** and **Slovakia**, the last three of which, also stated this to be the case in 2011 (see Kearney, 2011, pp.6). These countries explain this to be the situation due to there being no specific STEM education strategy currently in place at national level, and mostly because their countries are focusing on other education issues considered to need more urgent attention. This, however, does not mean that there are no STEM initiatives taking place in these countries, as this report illustrates.

Finland explains that the current Finnish government, appointed in May 2015, has published a Government Programme[1] in which STEM education is not mentioned. There is, however, some emphasis being placed on developing new learning environments and digital materials for comprehensive schools, as well as a more active dialogue between educational institutions and working life, which will also affect STEM education. Other than this, the current government's education objectives are related to other priority areas including decreasing early school leaving, improving the quality and effectiveness of educational research and innovation, the further internationalization of education and research and removing obstacles to education exports.

Slovenia explains that at national level there are no special objectives currently being prioritized for STEM education. Rather, the Ministry of Education, Science and Sport's more general education priorities, also apply to STEM education. One possible reason for Slovenia not needing to prioritize STEM education as much as other countries may be that at national level average basic skills proficiency is already satisfactory, especially in mathematics and science (European Commission (a), 2015, pp. 15).

Similarly in **Slovakia**, STEM education is not considered a priority area. The whole education system in Slovakia is currently in transformation, and there are many areas which need changing. The Ministry will introduce these changes through specific strategies in stages, but currently no specific STEM strategy is envisaged.

Interestingly, **Turkey** seems to be in a different situation to most other countries surveyed, as the challenge it faces on a yearly basis is the very large number of students who apply to university to study one or more of the STEM subjects. The number of STEM university applicants is each year much higher than the number of places each university is able to offer. This is one potential reason why the need to promote STEM education is not a priority in Turkey, and why there are no national initiatives aimed at encouraging students to pursue STEM studies and careers. Students are selected according to their scores in university entrance exams, mainly on the basis of their performance on specific scientific and mathematical questions. However, this focus on knowledge and comprehension skills in order to pass the multiple choice STEM questions in the university entrance exam often means that teaching and learning in these subjects at schools is often about this rather than inquiry-based methods which are very important for studying STEM subjects at university level.

2. STEM EDUCATION NATIONAL STRATEGIES

30% of countries surveyed (BE, FR, HR, IL, LT, MT, NO, NL, and UK [Scotland and Northern Ireland]) report that they currently have a national strategy or dedicated action plan devoted to STEM education. A higher percentage of 43% of countries (BG, CH, CZ, EE, EL, ES, FI, LV, PL, RO, TK, and UK [England and Wales]) reported that while at national level there is no stand-alone strategy devoted only to STEM education, other more general education strategies in which STEM education issues are highlighted, do exist. Rather than, or in addition to global strategies dealing with STEM education more holistically (due to covering more than one STEM area), 20% of countries (BG, CZ, EE, EL, IE, and NL) have specific strategies dealing with improving the profile, quality and interest in technology studies and careers in particular. 13% of countries (AT, CY, PT, and SE) state that STEM education is neither the subject of a dedicated strategy nor integrated into a broader national strategy, yet nonetheless is considered a priority at national level. Finally, Denmark and Slovenia are currently planning STEM education strategies at national level.

2.1. National strategies or action plans devoted to STEM education

30% of countries surveyed (BE, FR, HR, IL, LT, MT, NO, NL, and UK [Scotland and Northern Ireland]) report that they currently have a national strategy or dedicated action plan devoted to STEM education.

STEM education has been a priority area for the **Norwegian** Ministry of Education since 2002, starting with the strategy “Realfag naturligvis” (“STEM of course”). Since then four consecutive strategies have been launched and monitored, with the most recent being announced in August 2015. This strategy, entitled “Tett på realfag”[2] (“STEM close up”), has four main objectives: increasing the competence of children and youth in STEM through a renewal of STEM subjects, better learning and increased motivation; reducing the number of children and youths performing at the lowest level in mathematics; increasing the number of children and youths performing at the highest level in STEM; and increasing the competence of kindergarten and schoolteachers in teaching STEM subjects and skills. The strategy states that its main actions to reach its objectives are to: review and update the framework plan for kindergartens’ content and responsibilities to strengthen STEM content; review and update the curriculum for STEM subjects in primary, lower secondary and upper secondary school; evaluate the structure of the mathematical subjects in upper secondary school and simplify it; and strengthen teaching and education practices in kindergarten and school.

Similarly, the **Netherlands** has also had a clear STEM education strategy in place since 2004, starting with the Delta Plan Science and Technology (2004-2010) which aimed at promoting science and technology education to increase future skilled employees capable of contributing to innovation. This policy action plan aimed to tackle the country's shortage of scientists and engineers in the years to come. A crucial instrument of the Delta plan was the Platform Bèta Techniek (National STEM Platform) which is still running today. The Platform Bèta Techniek is commissioned by the government, education and business sectors and facilitates mutual contact between schools, universities, businesses, ministries, municipalities, regions and sectors. The objective is to ensure that the future supply of knowledge workers will meet the expected demand. The platform is also dedicated to knowledge development and sharing in the STEM field, and supports action-driven research as well as providing an online knowledge bank. Every year the Platform Bèta Techniek reports progress in this area in its publication 'Facts and Figures'. The platform s initial aim was to achieve a structural increase of 15 percent more pupils and students in scientific and technical education. This target has now been reached (Eurydice (a) 2011, pp. 28).

To continue this holistic approach beyond 2010 a Master Plan was published in November 2009 by the Platform Bèta Techniek and the Science and Technology Think Tank. The Master Plan is a response to the Manifesto 'Room for Talent! Room for Science and Technology!' published in November 2008, which called for the need to develop scientific and technological talent, not only for the benefit of every individual child, but society as a whole. It outlines a strategy for implementing the Manifesto's goals during the period 2011-2016, and aims to offer all children aged 2-14 the opportunity to develop their talents for investigation, reasoning and problem solving. This Master Plan was already reported in the 2011 STEM report (Kearney 2011, pp. 7-8), and is still being implemented. Since 2013 the overarching STEM education strategy is formed by the Technology Pact, a targeted strategy focused specifically on technology studies and careers and developing technology skills for future STEM professionals was launched (see section 2.3 below).

Following a Resolution on STEM approved by the **Flemish** Parliament in 2011, the Flemish government has developed a long-term strategy for STEM in its STEM Action Plan 2012-2020. The action plan forms the foundation of an intense STEM cooperation at strategic level between the Ministry of Education and Training, the Department of Economy, Science and Innovation, and the Department of Work and Social Economy including three of its strategic partners which are key for STEM issues at national level: the Social and Economic Council of Flanders (SERV), the Flemish Education Council (VLOR) and the Flemish Council for Science and Research (VRWI). The Policy Steering Committee which emanates from these bodies, decides on the operational policies, their collaboration at the level of the Strategic Plan and - in order to remain updated on the latest developments - receives regular in depth advice from the STEM Platform, which unites a number of high level representatives from research institutions, media, and industrial sectors. On the one hand, Flanders has a broad and continuous range of STEM-activities targeting schools, students' free time and their career choices. On the other hand, there is a permanent change-driven strategy, in order to increase the participation of girls and students from less privileged backgrounds as well as a strong focus on the societal impact of STEM. The permanent update at policy level via the operationalization of the STEM Action Plan 2012-2020 is continuously informed by PISA figures, TIMSS, international exchange of information, as well as by grass roots information, coming from strategic partners, as well as from schools. A bi-annual STEM-Monitor (baseline: 2011) regularly updates the figures, which show a steady growth.

France also launched a STEM strategy in 2011 entitled 'Primary and Secondary Education. Promotion of scientific and technological subjects. A new ambition for Science and Technology at school'[3]. At secondary school level, the aim is to better integrate sciences and technology into the curriculum, and to increase the interest of students in STEM by building and developing collective multidisciplinary and trans-disciplinary projects through dedicated portals (such as www.universciences.fr/fr/accueil), and partnerships with different science and technology organizations, including laboratories, research centres, museums etc. The French Ministry of Education has also launched the action *Sciences à l'école*[4], targeting lower and upper secondary level. The programme aims at promoting science projects in secondary school by providing schools with special equipment for experiments, training teachers how to use them, proposing interdisciplinary projects, competitions and fairs. Moreover, in 2015, the French Ministry of Education introduced new curricula for primary and lower secondary schools. In the case of the lower secondary school, the new curricula introduces interdisciplinary teaching for students aged 11 to 16; the so-called "EPI" - *Enseignements Pratiques Interdisciplinaires* (Practical Interdisciplinary Teaching)[5]. This new curriculum development comes as a follow-up to the earlier "*EIST: Enseignement Integré de Science et Technologie*" (Integrated Teaching of Science and Technology), which was put in place in 2006 and targeted students aged 11-13.

Although STEM education has since some time been high on **Malta**'s national agenda, the recent priority it has been given is illustrated by the large-scale stakeholder consultation launched in 2011 resulting in the strategic national document 'A Vision for Science Education in Malta'[6]. It was compiled by a working group comprising representatives from the three education sectors (namely State, Church and Private), the University of Malta, the Chamber of Scientists and the national MATSEC examinations board. The strategy document puts forward a revised secondary school science structure involving all students at lower secondary level to follow a Core Science Curriculum that will be offered to students at upper secondary level (who do not specialise in a science subject). Furthermore the document puts forward the proposal that in the higher levels of secondary education students who want to specialise in science subjects can choose from Materials Sciences, Physical Sciences and Life Sciences. The strategy document highlights the following objectives: an exploration of different available national science education programmes and resources; a shift in the pedagogical processes used in the science classroom; a shift towards assessment for learning methodology; a focus on learning outcomes for the Early Years, Primary and Secondary science curricula. The document also outlines the necessary requirements for effective implementation of such a process. Furthermore the strategy document lists the following key indicators: improvement of Malta's performance in the TIMSS and PISA surveys in science achievement. Malta should obtain a better placing and an improved average score mark in science achievement, among the participating countries; a significant reduction of the percentage of the student population that achieve at or are below the Low Benchmark of science achievement in the TIMSS survey – currently standing at 52% of the cohort; an increase in the number of students who take up the science option (i.e. Materials Science, Physical Sciences and Life Sciences) at secondary level; an increase in the number of students who sit for the SEC examinations in science; an increase in the number of students who study one or more science subjects as part of their Matriculation Certificate, and read for under/post-graduate degrees in science and/or science related areas; and the conducting research projects that attract more funding from local and foreign sources.

More recently, the **Croatian** government adopted a new strategy entitled Education, Science and

Technology[7] in October 2014. The strategy aims to create a society of equal opportunities based on know-how, where education and science are development priorities not only for Croatian society as a whole, but for each individual. The strategy is aligned with EU strategies within Europe 2020 and also includes goals for 2025. Its underlying principle is the 'knowledge triangle' which consists of lifelong learning, science and innovation. It aims to create conditions for research and innovation focused on excellent science, industrial leadership and society challenges, as well as conditions to provide high quality education for all and enable science to contribute to job creation and socioeconomic prosperity. The strategy highlights the need to increase the attractiveness and competitiveness of STEM studies as a particularly important area for the development of the economy. Moreover, the development of new study programmes within professional studies will be planned according to the experience of more advanced European countries in this area, while reflecting the forecasted needs of the Croatian economy. Also it is important to mention that the Croatian Employment Service made a series of recommendations[8] concerning education enrolment policy and scholarship policy for Croatian counties and cities, and the STEM related-subjects are indicated as a priority for most of them.

Lithuania has also recently launched a specific action plan in this area, but puts the focus on STEAM (Science, Technology, Engineering, Arts and Design, and Mathematics) rather than just STEM subjects. The STEAM action plan for 2015-2020 has been developed in in collaboration with business, industry, researchers, education experts and policy makers. This plan enables a systematic approach to the harmonisation of science, technology, the arts (creative activities) and mathematics in the educational process. The aim is to raise and maintain students' interest in STEAM fields through the development of competences of creativity, initiative, and entrepreneurship to help Lithuania's innovation culture grow. The action plan's objectives include modernising the curriculum in the STEAM areas aiming at better student achievement; developing in-service teachers' competence in these areas; and finally, raising the popularity of STEAM more generally in society. This dedicated action plan has come about as a result of needs and necessary measures identified in the Lithuanian national progress strategy entitled 'Lithuania 2030'[9], approved by the government in 2012, and the consequent state education strategy 2013-2022[10]. Moreover, according to national research results published in the report 'Science education in lower secondary education: achievements and attitude' (2011), the attractiveness of science is decreasing among secondary level students and there is a gap between science education and real life. Furthermore international research such as TIMSS (2011) revealed that Lithuanian primary schools either have very few or no laboratories in their schools making it difficult for students to conduct experimental scientific research tasks. According to PISA (2012) results, Lithuania is below the OECD average, and girls outperform boys in the majority of scientific disciplines – their achievements are equal only in mathematics. It is on this basis of these results that the current STEAM action plan has been put in place.

In **England**, the Roberts review[11] in 2002 about the supply of people with science, technology, engineering and mathematics skills as well as the Science and Innovation Investment Framework report[12] in 2004 – 2014, developed a cohesive approach to STEM education in England. There has been eight years of considerable funding dedicated to STEM education which has included the development of the National Science Learning Centre, the network of the nine Regional Science Learning Centres (now integrated into the 50 Science Learning Partnerships as part of the National Science Learning Network). During 1999-2011 there was also a national strategy for schools improvement across primary and secondary schools which included a programme for the development and improvement of secondary level science. Due to this commitment from the government, schools are now in a much better position to move forward with the school-led self-improving education system which the English government is currently advocating.

In 2003, the **Scottish** Science Advisory Committee's (SSAC) report Why Science Education Matters made a number of recommendations for the future improvement of science education in Scotland to meet perceived concerns and challenges. The report called for a programme of curriculum change that moved away from a cluttered, content-dominated and assessment-driven curriculum with little scope for teachers to include topical or innovative material to inspire learning. It recognised that the lack of science specialists and the absence of science infrastructure and technical support in primary schools were major obstacles to sustaining the interest of young people in science across the transition into secondary education, and the need to improve the uptake of science and the standard of science educational attainment in secondary education. The report made several recommendations regarding primary school science facilities, teacher and technician support in primary schools, and continuing professional development (CPD) to tackle this problem. It recognised the deficiencies in school careers advice around pathways into science and career opportunities for science graduates, and recommended that CPD be provided to address these deficiencies. It recognised the need to reverse the decline in public confidence in science. It called for better co-ordination of science education activities and support across Scotland, and recommended the formation of local clusters of primary and secondary schools, industry, colleges, research institutes and universities to support and improve science education. Concern was expressed about the age structure of a science teaching cohort in which, in 2000, one-third of science teachers were over 50 years old, and a half over 45. These issues all remain priority concerns in 2015 for Scotland.

Current work within Scotland seek to address the issues noted above. Also there are a number of Skills Investment Strategies[13] led by Skills Development Scotland to provide a framework for action across STEM sectors. It is also worth mentioning the establishment of a Science and Engineering Education Advisory Group (SEEAG) which in 2012 published its report 'Supporting Scotland's stem education and culture'[14]. Therefore STEM continues to be seen as a national priority and is likely to be for a number of years to come. Learning in STEM, particularly at primary school level, is listed as one of the key priorities in the current Programme for Government 2014-2015. It has also been given a high profile within the report entitled Education for All! - Commission for Developing Scotland's Young Workforce (2014). The Commission recognised that STEM has to be at the heart of all efforts to improve youth employment and promote positive destinations for Scotland's young people. Also noteworthy, is Scotland's National STEM project to pilot a cluster approach to STEM involving all key partners in providing coherent support. The pilot is currently working with five clusters in four local authorities.

In August 2010, the government of **Northern Ireland** published its report 'Government STEM Strategy'[15]. This Government STEM Strategy forms the Executive's overarching strategy for the delivery of STEM skills. The Report contains 20 recommendations grouped under four 'imperatives': Imperative 1 - Business must take the lead in promoting STEM; Imperative 2 - The key constraints in the STEM artery must be alleviated; Imperative 3 - There needs to be increased flexibility in the provision of STEM education; and Imperative 4 - Government must better coordinate its support for STEM.

STEM education is rated very high on **Israel**'s national priorities list. Israel is now highly concentrated on the development of higher technologies and in occupations requiring a STEM-rich education.

Therefore STEM education has become a focus of an intensive public discussion and debate which can be gauged from the many initiatives in place: the involvement of the National Council for Research and Development (Civil) which commissioned surveys and papers to obtain solid evidence to steer its decisions; many meetings of Parliament committees dedicated to STEM related education; background papers prepared by the Centre for Research and Information of the Parliament (Knesset); STEM projects carried out by the Israel Academy of Sciences Initiative for Applied Research in Education; the role of STEM in the ongoing reforms being implemented by the Ministry of Education in collaboration with the teachers' syndicates; a profusion of activities by the public sector involving leading foundations and high technology corporations; as well as surveys, research and papers commissioned by these initiatives. A fourth edition of the report entitled 'Science, Technology and Innovation Indicators in Israel: An International Comparison[16]' was commissioned by the National Council for Research and Development (Civil) from the Neaman Institute and published in 2013. The report summarizes some basic data concerning STEM education in Israel, including: In 2010, among the students completing their secondary education, 56% qualified for a Baccalaureate diploma and 46% obtained the minimum requirements from universities, while 14% chose to complete the maximum level of units (five) of Mathematics; Israel showed a substantial improvement in the TIMSS Mathematics survey results in 2011, arriving in seventh position among 42 (up from 17th position in the previous survey); In 2010 among new students 25.5 % chose to study subjects, representing a decrease from previous years; In the year 2008/9, 8700 students completed a first academic degree in STEM disciplines. Among them 56% study engineering and architecture; 21% Mathematics, Statistics and Computer Science; 15% Biological Sciences; and 7% Physical Sciences.

It is important to note that in Israel, the national STEM strategy should be considered in the context of ongoing, deep and comprehensive reforms in the curriculum and in the education system at large. In addition to these broader reforms, Israel has dedicated STEM strategies. In 2010, the Minister of Education designed a strategic plan to strengthen science and technology studies. "Technology and Science Excellence Student Reserve[17]" is a key project in this plan which sets the criterion for a high quality science and technology matriculation diploma. The criterion consists of three science subjects studied at five point level (the highest level possible in an Israeli high school): 5 points in Mathematics; 5 points in one scientific discipline (Biology, Physics or Chemistry); and 5 points in an additional scientific or technological discipline. While facilitating a solid knowledge base, this programme is designed to identify and to nurture excellent students with high learning capabilities and outstanding persistence. This programme presents a new approach by defining success in the Baccalaureate (matriculation) diploma in terms of high quantity and quality standards. Analysis shows, that the programme's goal of increasing the amount of students who complete high quality science and technology matriculation (Baccalaureate) diploma from 6% to 14% within 3-5 years and reach 20% within 6-9 years, appears feasible. This policy was grounded in a research paper jointly prepared by the head of the Science and Technology Administration in the Ministry and the head of the Central Bureau of Statistics: "Treading on diamonds: Israel's unrealized potential of excellence"[18], and published in 2012 in parallel with the beginning of the programme's implementation.

The programme started in 2012 in 186 classrooms in junior high schools (7th grade) and 176 classrooms in high schools (10th grade) and each subsequent year additional cohort classrooms entered the program. In 2015 the number of classrooms participating reached at Junior High Schools: 218 - 7th grade; 203 - 8th grade; 180 – 9th grade. At high schools:

221 – 10th grade; 176 – 11th grade; 148 12th grade. To achieve the programme objectives the schools received additional resources: junior high schools received additional 2 weekly hours per student in mathematics, physics, computer science in each one of the age cohorts in the 7th, 8th and 9th grades. The secondary schools (high schools) received additional teaching hours, especially in mathematics, physics and technology. These additions were intended for splitting classrooms, provision of private lessons and to increase the number of students who learn these disciplines and reduce drop outs. Both in junior as well as in high schools 'excellence coordinators' were identified in the schools, trained and deployed. The additional resources package included additional equipment for junior high schools labs (for physics and robotics, as well as for computer science); professional development courses for teachers, accompanying tutors and more.

Another programme promoted by the Ministry at national level, is the Technician and Baccalaureate – TOV programme[19]. The programme is a study path from the 9th until the 12th grade providing students with the opportunity to become qualified as a Technician as well as be eligible to gain the Baccalaureate diploma. Such students will be able to complete an additional two year study track and graduate as Practical Engineers with the possibility of continuing studies towards higher education degrees. In the 9th grade they study the regular curriculum appropriate to this level. In addition they receive eight additional weekly hours of study to strengthen their qualification in Mathematics, Science, English and Language (Hebrew or Arabic). Up until the 11th grade the students complete 14 study units. In the 12th grade the students complete the requirements to get a Baccalaureate (completion of at least 21 study units) and the requirements for a Technician Certificate. The goal of the project is to register each year at least 2,500 students who will successfully complete the entire programme and receive both the Technician Certificate and the Baccalaureate.

Finally, Israel also has a dedicated Mathematics strategy, entitled 'Mathematics First'. The purpose of this strategy is to increase the number of students studying 5 units of Mathematics from the present number of 9,000 to 18,000 in five years; the program began in school year 2014/2015 and it was expected to increase, already in the first year, the number of student by 15%. In the last six years the number of students that choose to study 5 units of Mathematics for their Baccalaureate diploma (the highest number of units) has dropped by 30%. The diminishing numbers of those who study an intensive Mathematics course of studies has a negative impact on the scientific, technological and economic capacity of the country to stand by the challenges of the 21st Century. In the school year 2014/2015 the Ministry of Education decided to encourage secondary schools to open new study groups for the intensive study of and assessment in 5 units of mathematics. The Ministry decided to incentivize new study groups in the 10th, 11th and 12th grades and to increase the budgeting for teaching hours in existing groups[20]. The activities that are supported by the increased budget are additional teaching hours for existing classes or for the splitting of a class into groups of 15 students (such groups should have a minimum of 12 students and maximum of 15). Furthermore additional budget will be provided for new groups of students in case there are students learning for 5 units in addition to the number of students who studied for 5 years in the same cohort in the previous year.

2.2 STEM education issues included in other national strategies

A higher percentage of 43% of countries (BG, CH, CZ, EE, EL, ES, FI, LV, PL, RO, TK, and UK [England and Wales]) reported that while at national level there is no stand-alone strategy devoted only to STEM education, other more general education strategies in which STEM education issues are highlighted, do exist.

Bulgaria is one such country in which STEM education is considered a priority, but is addressed through various strategies, rather than a specific one devoted to it. During 2013-2014 several strategies were adopted in Bulgaria to support the government's position that education, research, technological development and innovation serve as a basis for achieving dynamic and sustainable economic growth of the country. In each of these strategies different aspects of STEM education has been considered in terms of how they might contribute to solving more general problems facing the Bulgarian education system.

A similar situation exists in **Switzerland**, where STEM education is emphasized in the 2015 strategy statement[21] about the general educational goals and resulting political actions for the Swiss education system, issued by the Federal Department of Economic Affairs, Education and Research (EAER) and the Swiss Conference of Cantonal Ministers of Education (EDK). The 2015 strategy statement states that interest in STEM study and career paths should be stimulated and strengthened at all educational levels, and that there should be an improved coordination of the numerous existing STEM initiatives and extracurricular activities across the country. It should be noted however, that the Cantons are responsible for school education, and almost all cantons have their own STEM promotion strategies and consider this domain a priority[22]. One example is the canton of Zurich which has various STEM education measures in place, particularly concerning the promotion of natural sciences and technical sciences at upper secondary level[23], following the proposals and recommendations outlined in a research report commissioned by the canton[24]. This national and cantonal focus on STEM education came about following the publication of the Federal Council's report "Lack of STEM specialists in Switzerland[25]" in 2010, which in turn led the State Secretariat for Education, Research and Innovation (SERI) to put a clear focus on resolving the issue of a lack of qualified STEM professionals, particularly women, on the national agenda for the period 2013-2016[26].

The **Czech Republic** also has no national strategy specifically targeting STEM; the issue is rather covered by various general strategic documents, notably the Strategy for Education Policy of the Czech Republic until 2020[27]. On the basis of the strategy a document entitled 'Long-term Policy Objectives of Education and Development of the Education System in the Czech Republic for 2015-2020[28]' was prepared and adopted as a resolution in April 2015. This document contains several measures to be implemented in the next few years that focus on STEM: in particular, these include: support for craftsmanship and education in basic technology skills (in pre-school, elementary and secondary education), the development of mathematical and science literacy and ICT education (in elementary and secondary education) and the inclusion of mathematics as an obligatory subject as part of school-leaving examination for most programmes (in secondary education). It should also be noted that in accordance with these strategic documents, the year 2015 was declared the Year of Industry and Technical Education by Svaz průmyslu a dopravy České republiky (the Confederation of Industry of the Czech Republic) with the support of the Czech government. The main purpose of this nationwide campaign is to increase public interest in industry and technical education and to enforce conceptual and systemic changes in education as well as to raise interest amongst schools and industry to cooperate and share examples of good practice[29].

In **Estonia**, STEM education is included as an important component of the Estonian Lifelong Learning Strategy 2014-2020[30], which focuses on the development of basic skills, transversal skills and general competences. It is on the basis of this overarching strategy, that the government will make its decisions for educational funding for the period 2014-2020, and for the development of programmes which support the achievement of necessary changes. The following key indicators of the Lifelong Learning Strategy are clearly linked to STEM education: the percentage of top achievers in basic skills (reading, mathematics, science); the percentage of low achievers in basic skills (reading, mathematics, science); the percentage of students at ISCED levels 1 – 6 who use computers and/or other digital devices for studying every school day – (target: 100% by 2020); the percentage of 8th grade students who learn in digitally supportive schools, as defined by The Survey of Schools: ICT in Education survey[31] – (target: 100 % by 2020); the percentage of tertiary graduates in mathematics, science and technology – (target 25% by 2020).

In **Greece**, STEM education is a priority issue in the overarching ‘New School’ framework programme which aims to modernize the Greek school education system, and improve its overall quality and relevance. As a result of this framework programme, numerous STEM education actions have been designed and partially implemented, including: the introduction of experimental Physics in the first year of lower secondary school; new curricula for ICT, and the introduction of project work as a separate lesson in upper secondary school.

Spain is another country which has no dedicated STEM education strategy in place, but nevertheless has specific STEM education requirements highlighted in the Organic Law 8/2013 on the improvement of educational quality, knows as the ‘LOMCE’. This Law is in force and is currently being implemented in each of the different educational stages, with each Autonomous Community being responsible for developing its own regulations as part of this progressive implementation. This Law places special emphasis on the need to improve science teaching, as justified by the inadequate results of Spanish students in the mathematical and scientific PISA 2009 tests, which were somewhat below the average for OECD countries. The law stipulates that in primary education Natural Sciences and Mathematics should be mentioned within the block of core subjects all students are obliged to study. The Law likewise states that regional educational administrations are obliged to evaluate students individually at the end of the third year of primary education, on their level of acquisition of mathematical competence, and at the end of the sixth year, on their basic competences in science and technology. In secondary education, the Law incorporates into the curriculum an increase in the hours dedicated to Mathematics, Physics and Chemistry, and brings the teaching of Biology and Geology forward to first year and Physics and Chemistry forward into second year. It should also be noted that Spain’s Federal Ministry of Education, Culture and Sport has formal agreements with scientific bodies at national level for the development of a scientific culture in schools. These scientific entities include: the Confederation of Scientific Societies of Spain, the Scientific Research Council (CSIC), the Royal Spanish Societies of Mathematics, Physics and Chemistry, and the National Association of Chemists of Spain.

STEM education in **Finland** is also addressed within the wider national development plan for education and research in Finland (2011-2016)[32]. In 2014 a Ministry of Education and Culture-led working group on STEM education published a proposal for increasing competence and interest in STEM education and careers in children and young people[33]. The report and proposals were aimed to guide decision making at the Ministry of Education and Culture with regard to policies connected to STEM education. In addition institutes, universities and organizations often have their own strategies for STEM education, including most notably for example the LUMA Centre's (the Finnish STEM education network) strategy[34].

Likewise, **Romania** also prioritizes STEM education in its National Strategy for Education 2020. Due to the fact that in Romania the development of the IT industry is one of the goals for the durable development of the economy, STEM education is likely to remain a priority in the near future.

Although the **Turkish** Ministry of Education does not have its own specific STEM education strategy, it follows the guidelines given for STEM education in schools in the National Science, Technology and Innovation Strategy (2011-2016) produced by TUBİTAK (the Science and Technological Research Council of Turkey)[35]. According to this strategy, the Ministry of Education provides support to STEM education through the organisation of Science Fairs for primary and secondary schools, the encouragement of young people to study Space Sciences, the foundation of Science centres in all provinces and the improvement of science, technology and design, and mathematics curricula at primary and secondary level.

In **Latvia** STEM education and the development of related competences is defined as a priority area in the overarching National Development Plan of Latvia for 2014-2020 (NDP2020)[36]. One of the strategic objectives of Latvia's NDP2020 is the development of students' mathematical competence and basic competences in science and technology. Measures to be carried out within this strategic objective are: the introduction of innovative forms of curriculum content and activities in elementary and secondary education to promote students' creative and entrepreneurial competences; a digital learning environment, the improvement of the natural science curricula, and strengthening of career guidance within the education system; the creation of opportunities for students' talents to be discovered and developed, including support for youth science and technology centres, academic summer camps for students, and the provision of science workshops, competitions and research projects.

While there is no dedicated strategy as such, **Poland**'s Minister of Education has for the last two school years set STEM education issues amongst its top priorities for education policy, under the provisions of the Education System Act. One of the priorities of state educational policy in the school year 2014/2015 was to improve the quality of upper secondary education in the skills set out in the curriculum, with a particular emphasis on mathematics skills. Currently one of the top priorities for the school year 2015/2016 is improving Mathematical and Nature Education (science) in general education. The authorities in charge of pedagogical supervision and teacher education institutions are responsible for implementing these priorities.

Moreover, the development of mathematical competences and science education at all levels is highlighted in the country's main strategic documents, on the basis of which policy is being realized: the long-term national development strategy – 'DSRK -

Poland 2030. The third wave of modernity', (which defines the main trends, challenges and the concept of the country's development in the long term) and the ' SRK - National Development Strategy 2020' (which defines strategic objectives of national development until 2020 in the medium term). Furthermore, the need to develop the above mentioned competences and the dissemination of teaching methods that develop innovation and creativity in learning have also been included in two integrated strategies contributing to achieving development goals: the Human Capital Development Strategy and the Strategy of Development of Social Capital.

The **United Kingdom** is made up of four devolved nations, each of which is responsible for devising its own approach to STEM education. Therefore, within the United Kingdom, the devolved governments of England, Scotland, Wales and Northern Ireland take slightly different approaches to their STEM strategy. There is no one overarching strategic document for the United Kingdom. However, STEM education has been and remains a priority for the United Kingdom, as the country's STEM sectors need 180,000 engineers, scientists and technicians per year by 2020 to maintain the United Kingdom's future competitiveness in the global economy. Ensuring the supply of high quality STEM professionals to teach, nurture and train our future STEM talent is paramount if we are to solve the skills challenge in the United Kingdom's high tech industries. The STEM subjects in schools and colleges have received clear, particular and continuous support from the government of the United Kingdom and the devolved administrations for the last 10 years. Government support for science and technology more generally goes back generations. The adoption of the term STEM in United Kingdom public policy was brought together with the publication of the government's Science and Innovation Investment Framework 2004-2014 (HM Treasury, 2004, pp 159); "Science, technology, engineering and maths have a core role in the future health of sustainable higher value added activity in the United Kingdom. As such, the DfES (Department for Education and Skills now known as Department for Education) will play a more strategic role in the coming years towards monitoring the quality and quantity of outputs from the education system, at all levels, in STEM subjects, and acting decisively to redress emerging mismatches between supply and demand for skills." The link between STEM subjects and the economy is alive in current public policy debates to this day as the demand for most STEM occupations still exceeds supply in the United Kingdom (Greenwood et al. 2011, Harrison 2012, BIS 2013). Within the United Kingdom, the Council for Science and Technology is in place to support and inform the STEM agenda. Its role is to advise the Prime Minister on the strategic policies and framework for: sustaining and developing science, engineering, technology and mathematics (STEM) in the United Kingdom, and promoting international co-operation in STEM; encouraging the practice and perception of STEM as an integral part of the culture of the United Kingdom; promoting excellence in STEM education; making more effective use of research and scientific advice in the development and delivery of policy and public services across government; promoting STEM-based innovation in business and the public services to promote the sustainable development of the United Kingdom's economy, the health and quality of life of citizens, and global sustainable development. The council's terms of reference reflect its United Kingdom-wide remit and responsibility for looking at issues that cut across government departments. It should also be noted that the employer led body, the CBI, recently published its report Engineering our Future[37] which provides a collaborative approach to taking forward a STEM strategy involving both employers, public sector, schools and young people.

The Department for Education in **England** continues to see STEM education as a national priority, despite there being no specific STEM education strategy. This is evident in a range of policies including those aimed to recruit and train more specialist teachers in maths and science as well as funded programmes to raise the quality of teaching in these subjects and encourage more young people to pursue these subjects post-16. In order to attract top STEM graduates into teaching, bursaries and scholarships of up to £25k are available. Further investment of £67m was announced for the next five years (2015-2020) to train an extra 2,500 maths and physics teachers and upskill 15,000 existing teachers. In addition, continuing professional development for existing STEM teachers is being supported in 2015-16 through: a national network of 34 new Maths Hubs; the National Science/ STEM Learning Centre and the 50 Science Learning Partnerships as part of the National Science Learning Network; a national network of computing 'Master Teachers'; programmes focused on Maths A level (the Further Maths Support Programme) and "Core Maths" (a new Maths qualification for 16-19 year olds with a good pass at GCSE, but not taking A/AS level maths); a range of smaller programmes which provide CPD, resources and/or promote STEM participation; increasing the number of boys and girls progressing to A level Maths and Physics and beyond, through work with the Your Life campaign.

Since the first science policy for **Wales** was published (A Science Policy for Wales – The Welsh Assembly Government's Strategic Vision for Sciences, Engineering and Technology, November 2006) there has been a number of other policies and initiatives relating to STEM skills. The Welsh government's skills strategy and action plan (Skills that Work for Wales Strategy and Action Plan, Welsh Assembly Government, July 2008) for example, states that: "Science, technology, engineering and maths (STEM) graduates offer skills and knowledge that are highly valued in the labour market. Chemistry and physics graduates will earn, on average, 30% more over their working lives than A-level holders, a significantly higher premium than graduates in subjects including psychology, linguistics, and history. Employers tell us that the demand for STEM graduates is likely to grow significantly over the next few years." The Welsh government's higher education strategy and plan (For Our Future – The 21st Century Higher Education Strategy and Plan for Wales, Welsh Assembly Government, November 2009) also identifies the importance for the Welsh economy of developing stronger high-level skills and leading-edge research in science, technology, engineering and mathematics.

The three most recent developments in the STEM field are the appointment in February 2010 of Professor John Harries as the first Chief Scientific Adviser for Wales, to coordinate current and future initiatives for promoting the take-up of STEM and to overcome any barriers that discourage learners. In April 2010 the Welsh government announced the establishment of the National Science Academy (directed by the Chief Scientific Adviser) to promote the take-up of STEM at all levels to ensure Wales has a continuous stream of graduates with the appropriate qualifications and skills. In October 2010 the government announced the STEM Cymru project, led by the Engineering Education Scheme in Wales and aimed at encouraging 12 to 19-year olds to study STEM subjects and participate in industry-linked technological and engineering activities.

Although there is no specific STEM education strategy at national level in **Italy**, it is currently a priority of the new government and Ministry of Education, especially in terms of bridging the job shortage in STEM careers in Italy, which is currently behind the European Union average. STEM education is mentioned in the recent strategic circular of the Ministry of Education entitled 'The Good School: Let's help our country grow'[38].

2.3 Technology focused national strategies

Rather than, or in addition to global strategies dealing with STEM education more holistically (due to covering more than one STEM area), 20% of countries (BG, CZ, EE, EL, IE, and NL) have specific strategies dealing with improving the profile, quality and interest in technology studies and careers in particular.

This is the case for **Bulgaria**, which recently put in place a strategy for the effective implementation and integration of ICT in education and science in Bulgaria for the period 2014-2020[39].

It is also the case for the **Czech Republic** where the Strategy for Digital Education until 2020 was approved in 2014. The Strategy for Digital Education until 2020 is part of the Comprehensive Strategic Plan for Digital Education - Touch your Future, which was created on the basis of the government document entitled 'Digital Czech Republic'. The aim of this strategy is to integrate modern technology into the whole curriculum at schools, not only in specific subjects. The full integration of modern technology in the teaching of all subjects should be essential in order to ensure that the education system shifts from memorising facts to an emphasis on reading literacy, communication skills and logical thinking. The purpose of the strategy is therefore to support the development of pupils´ competence in handling information and digital technologies, as well as the development of computational thinking of pupils to enable them to take a position in the information society throughout their lives. It is also essential to support head teachers and teachers in schools, and to help link up school education with learning outside school.

In **Estonia**, one of the main objectives of the Lifelong Learning Strategy 2014-2020 (mentioned previously) is a strong digital focus in lifelong learning. Modern digital technology is to be used to ensure learning and teaching is effective and efficient. The strategy also highlights the importance of improving the digital skills of the total population and ensuring access to the new generation of digital infrastructure.

In **Greece**, 'Digital School' is the name of the large scale initiative of the Greek Ministry of Education dedicated to improving Greek schools' infrastructure, digital educational content, teacher training and the digital management of education. It is one of the major action lines of the 'New School' Framework Programme, described earlier. Digital educational content is a priority of the Greek digital education policy for primary and secondary education. The 'Digital School Platform, Interactive Books, and Learning Object Repository[40]' (2010-2015) is a flagship project within the Digital School initiative for digital educational content for schools, which is being implemented by the Computer Technology Institute and Press (CTI). Within this project, more than 3.000 interactive digital learning objects (experiments, simulations, interactive labs, etc.) for Physics, Mathematics, Chemistry, Biology, Geography, Environmental Education, Technology, and Informatics, have been developed and are freely available via the "Photodentro" National Learning Object Repository[41] and National Aggregator of Educational Content[42]. The majority of these learning objects promote an inquiry- and problem-based approach, a constructivist approach, and experimental learning. According to the current strategic plans of the Greek Ministry of Education, the Digital School programme for digital educational content is expected to be continued in the context of the new National Strategic Reference Framework. Teacher-training programmes on the pedagogical exploitation of digital content and services will be included as well.

In 2013, the **Netherlands** launched the Technology Pact[43] at national level. The main aim of the Pact is to find solutions for the estimated annual shortage of 30.000 STEM workers in the Netherlands. On this basis the Netherlands needs to grow from ‘2 out of 10 people working in STEM’ towards ‘4 out 10 people working in STEM’. In force since 2013, the Technology Pact aims to reach a set of 22 goals (directed towards primary, secondary and tertiary education, the labour market and workforce) by 2020. Each goal is directed to one of the following ‘lines of action’: Choosing for STEM, Learning in STEM, and Working in STEM. The Technology Pact, an initiative of three Ministries working together, was signed by 60 government, education and industry stakeholders and focuses on three lines of action: Choosing for STEM, Learning in STEM and Working in STEM. There are 22 concrete goals that have been jointly agreed will be pursued until 2020. One of the goals of the Technology Pact is that by 2020 it will be obligatory for all primary schools to have incorporated Science and Technology in their curricula. This goal was the result in particular of the advice given in the report produced by the Committee on Science and Technology in Primary Education[44], which stated that if pupils do not have a positive experience of learning Science and Technology before their seventh year of age, their natural interest in STEM will fade and it will be very hard to regain interest for STEM subjects later in life.

The activities planned in the Technology Pact are intended to take place across the country’s five regions (existing of combined Dutch provinces). Indeed, regional action plans are at the core of the Technology Pact, with the aim of ensuring that issues and solutions concerning STEM shortages are addressed in in a way that best suits the local and regional situation. The Platform Bèta Techniek described earlier has both an initiating and supporting role in the execution of the Technology Pact and also supports the Pact’s special envoy and ambassador. In June 2015 the Technology Pact Monitor[45] was published, providing an overview in numbers concerning the current state of STEM studies and professions in the Netherlands, including the successes of the Pact as well as challenges ahead.

Similarly, the **Irish** Minister for Jobs, Enterprise and Innovation and Minister for Education and Skills recently published the ICT Skills Action Plan 2014[46]. Under the Plan, it is aimed to meet 74% of industry demands domestically for ICT professionals by 2018 – up from 45% in 2011 and 60% now. In order to meet this target, the Minister for Jobs, Enterprise and Innovation announced a series of reforms aimed at dramatically increasing the availability of graduates: the provision of an additional 1,250 undergraduate ICT places per year in higher education institutions; an increase in the retention rate of students on ICT related courses; the launching of a further round of ICT Skills Conversion courses; the promotion of careers in ICT to primary and second level students with industry support; and the roll-out of courses in digital media literacy, programming and coding in the new Junior Cycle Student Awards. The Minister for Education and Skills outlined further reforms aimed at ensuring that there is a strong ICT talent pool and promoting Ireland as a centre for high-level ICT skills: the promotion of STEM and ICT careers through SFI Discover Smart Futures and training of 450+ volunteers to give career talks in schools; the organisation of career fairs abroad with the participation of companies who have vacancies; the facilitation of issuing of up to 2,000 employment permits per year to experienced ICT professionals with skills in high demand; the increase of efficiency in the employment permits process and the introduction of new legislation to enhance the application process.

2.4 Countries in which STEM education is considered a priority outside of any strategy

13% of countries (AT, CY, PT, and SE) state that STEM education is neither the subject of a dedicated strategy nor integrated into a broader national strategy, yet nonetheless is considered a priority at national level.

Austria's approach to STEM education issues continues to be delivered through its large-scale main STEM initiative at national level - IMST (Innovation Makes Schools Top)[47], which has been running since 1998. This initiative is complemented by the Ministry for Education and Women's efit21 initiative as well as the more recent initiative, Sparkling Science[48], established by the Ministry of Science, Research and Economy.

Cyprus does not have a specific strategy dedicated to STEM education, but still considers it a priority area at national level because of the need to improve students' learning outcomes in these subjects.

Similarly, **Sweden** also highlights STEM education as a priority due to falling results of Swedish students in PISA and TIMMS surveys. PISA 2012 and TIMSS 2011 results revealed Swedish students aged 15 to be performing below the OECD average. Indeed, Sweden's performance in PISA mathematics and science tests has been consistently getting worse since 2003.

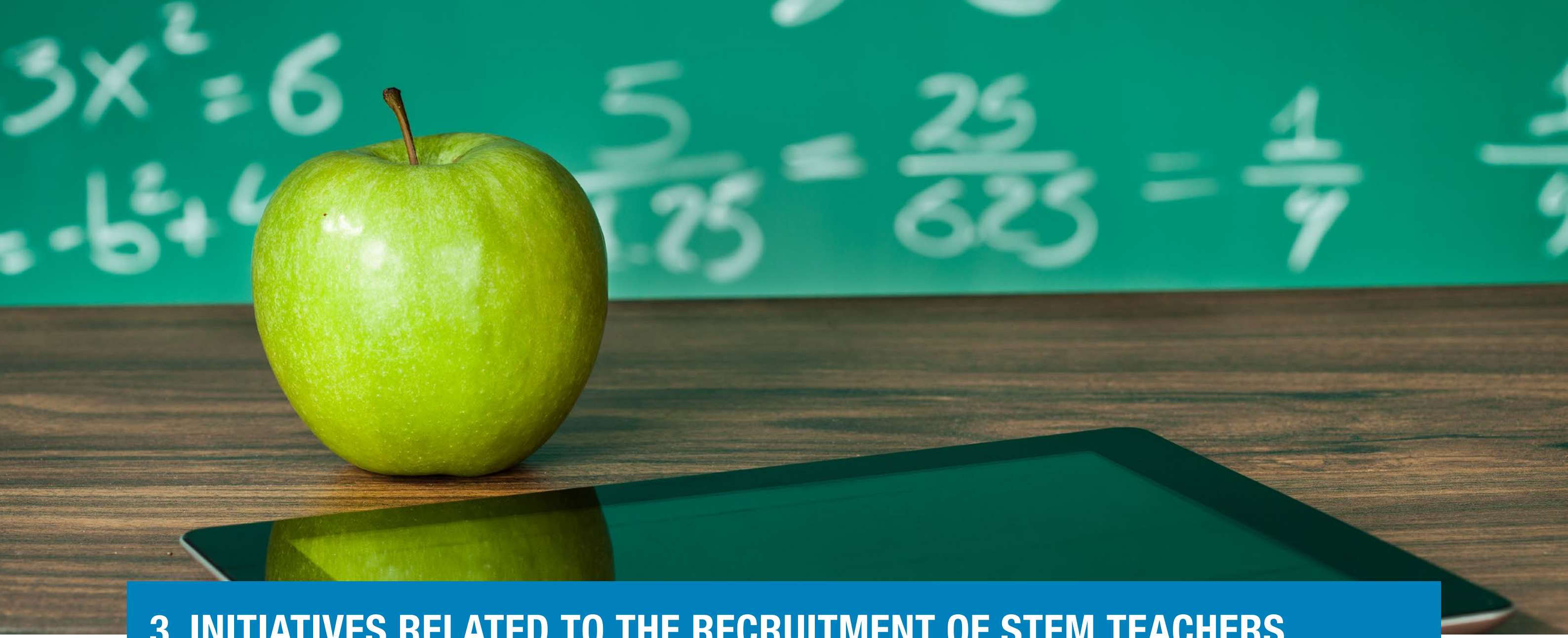
Finally, **Portugal** is another country which falls under this category, as STEM-related curriculum reform and various projects at national and local levels testify to the importance of the issue at national level, despite its absence in strategic documents.

2.5 Countries planning strategies

Denmark and Slovenia are currently planning STEM education strategies at national level.

Denmark does not currently have a STEM education strategy in place, however plans to develop one are currently being considered by the National Centre for Science Education. Inspiration will be taken from the Dutch Technology Pact (see above) – especially concerning the importance of gathering all stakeholders around a common set of initiatives instead of today's situation with a tendency to have less coordinated efforts through projects and individual initiatives.

Slovenia is another example of a country which does not currently have a specific STEM education strategy in place, but is planning one in the near future. The Ministry of Education, Science and Sport plans to develop guidelines for the future development of STEM education in the context of new development projects planned between 2015–2020. The planned national strategy for STEM education will place emphasis on scientific and mathematical literacy, the development of STEM didactics (including learning approaches such as Inquiry-Based Learning and formative assessment etc.), teacher training, school leadership, the flexible organisation of lessons and activities, vertical and horizontal intra- and inter disciplinary connections, and the promotion of STEM careers.



3. INITIATIVES RELATED TO THE RECRUITMENT OF STEM TEACHERS

37% of countries (BG, CH, DK, FR, HU, IL, LV, NL, SK, SE, and UK) report that initiatives are planned or in place to address the issue of recruiting more STEM teachers in schools, particularly at secondary level. In the United Kingdom, Israel, the Netherlands, Bulgaria and Denmark several initiatives are being implemented concurrently as part of a concerted effort at national level. In Hungary, Switzerland, France, Israel, and Latvia a general lack of teachers of all subjects (including STEM) is reported, along with accompanying initiatives to address this via various actions. Initiatives range from scholarships and loans, to programmes facilitating students and professionals from non-teaching backgrounds to become STEM teachers, and in some cases allowing participants to combine working as a STEM professional and teaching in the classroom. Often these initiatives target high achieving students with a proven academic record. Additionally, Finland and Sweden report there is evidence available at national level supporting the need to invest further in the recruitment of STEM teachers.

3.1 Countries with several initiatives in place to recruit STEM teachers

In the United Kingdom, Israel, the Netherlands, Bulgaria and Denmark several initiatives are being implemented concurrently as part of a concerted effort at national level.

In 2015, the government of the **United Kingdom** has launched a massive investment to increase the number of maths and physics teachers, and raise the status of STEM teaching as a profession. With £67 million invested over 5 years to open up routes into maths and physics teaching, there will be financial incentives and fast track courses to get former teachers, high quality career changers and top graduates into the classroom. Included are plans to boost the skills of 15,000 existing non-specialist teachers and attract up to 2,500 additional specialist maths and physics teachers over the next 5 years. In the near future, one-to-one support will be available to all trained maths and physics teachers seeking to return to the profession. Around 30,000 teachers leave the profession every year, often to start a family or pursue other avenues of work. The support on offer will include: access to specialist subject training courses to update their curriculum knowledge; help with applications and interview preparation; and support to access recent classroom experience to make sure they are classroom ready. Grant funding of up to £20,000 will be available to school partnerships to allow them to develop pilot training programmes, with the first trainees entering the classroom as early as January 2016.

In addition to this significant investment at national level, the United Kingdom has specific initiatives planned to bolster this targeted effort. One such initiative is to get maths and physics specialists into the classroom. Up to £15,000 will be available to top maths and science undergraduates while at university. To receive this funding, students are required to commit to teach for three years after graduating, and are entitled to a salary of up to £18,500 while training. The government also plans to expand its successful Maths and Physics Chairs programme. The programme will recruit experts with PhDs in these subjects to teach in schools and train those around them. More than 100 university fellows will benefit from a salary package in the region of £40,000 a year for two years. This will be targeted to schools that are struggling with maths and physics results, as well as areas where they are facing a shortage of high quality teachers in these subjects. Paid internships will also be available to maths and physics undergraduates from summer 2016 to give them the opportunity to experience teaching before they commit to it as a career. This will be a useful tool in persuading some to train as teachers who may otherwise not have considered it as an option. It will also enable them to begin training as a teacher while they complete their degree, getting them into the classroom more quickly.

Another initiative involves the up-skilling of 15,000 existing non-specialist maths and physics teachers over the next five years, with a dedicated budget of £24 million. This will enable every secondary school in England to up-skill at least one of their staff in these specialist subjects each year. The training will be developed and delivered by outstanding and good schools across the country and will help drive up the quality of maths and physics teaching nationwide. Lastly, Subject knowledge enhancement (SKE) courses, funded by the National College for Teaching and Leadership, have been provided for some time in England for qualified teachers who are teaching in a subject they did not qualify in. For the academic year 2014 to 2015, the government provided support to improve teacher capacity in shortage subjects. Forty-five teaching school alliances are taking part in a 'test and learn' project to develop and offer SKE training in shortage subjects (including maths, physics, chemistry, computing and design and technology) to meet their local challenges. The teacher subject specialism training programme for the academic year 2015 to 2016 builds on the post initial teacher training SKE test and learn project to improve the maths and physics subject knowledge of non-specialist teachers.

Israel also has several initiatives in place specifically targeting the recruitment of STEM teachers. One example is the programme for retraining engineers as secondary school teachers in the STEM disciplines[49]. This programme of the Ministry of Education is implemented jointly by the Teacher Education College Seminar HaKibutzim and the Academic Technological College ORT Braude, and takes place in Tel Aviv. It is intended for academic diploma holders in Mechanical Engineering, Electrical Engineering, Electronics Engineering, and allows for these diplomas to be recognized by the Israel Council of Higher Education or by a recognized academic institution from abroad. Another programme, also targeting engineers from specific areas seeking employment in teaching as a second career (as well as Hi Tech personnel) is a cooperative programme involving the Ministry of Education, Ministry of Finances, the Employment Service, the Ministry of Economy and the Council for Higher Education. The training programme includes all the elements required for regular teacher training, only the programme's length is shorter than usual, due to the high cost of the programme, and also to make it more suitable for adult students who already have families. The HOTAM programme aims at engaging excellent STEM graduates for teaching. The programme is coordinated in partnership between the Ministry of Education, JDC Israel and the movement "HaKol Hinuch" (Everything Education). It seeks to stimulate students with outstanding achievements to begin their professional career in teaching in roles demanding leadership capabilities in addition to a feeling of social mission. Graduates of the programme are eventually deployed in periphery towns and in city quarters in which there is a need for educational and social strengthening.

Moreover, Israel also has an initiative called the 'Academic rewards basket', which is aimed at stimulating the Teacher Training Colleges to develop programmes of studies for those disciplines in high demand, including STEM, and to choose candidates that stand up to high quality criteria. There is an effort to attract highly qualified students through this programme of scholarships and conditional loans. **Slovakia** also has a STEM-specific scholarship scheme in place to motivate students to study the teaching of STEM subjects. In 2014 and 2015, universities provided motivational scholarships for students choosing to follow the pedagogical study of Physics, Chemistry, Geography, Biology, Informatics and Mathematics, allowing them to teach these subjects in schools in the future. 15% of students received scholarships at an average rate of € 1,000 in 2014. The selection procedure for granting the motivational scholarships depends on the individual college's own rules.

Like the United Kingdom and Israel, the **Netherlands** also has several programmes in place aimed at recruiting more and high quality STEM teachers. 'Education Traineeship[50]' is a two-year programme in which trainees work as a teacher in secondary education and get their teaching qualification at the same time. The additional programme within the Education Traineeship focuses on didactics and other education related themes and a personal development element. The Education Traineeship programme focuses on recruiting more highly skilled teachers, especially for subjects which face a shortage of teachers at national level, including amongst others, physics, chemistry and maths. Inspired by the successful programmes in England and the US, the Netherlands has been running the intensive traineeship programme, *Eerst De Klas*[51], since 2009. In a two-year traineeship, talented university graduates (of any subject) work several days a week as secondary school teachers. In addition to earning a teaching qualification, they take part in an intensive business leadership programme. *Eerst De Klas* strives to get more highly educated teachers into the classrooms.

Two further programmes exist in the Netherlands, which both interestingly allow participants to combine working as a professional in the STEM industry and teaching their STEM area of expertise in general secondary or vocational education. The first of these programmes is 'Teach and Tech[52]', in which professionals get the opportunity to teach in lower vocational education. Participants follow an adapted programme to gain an official teaching qualification, in order to make it easier for STEM professionals to combine working in STEM with teaching (often very practical) courses within lower vocational education. 'Teach and Tech' is currently a collaboration between secondary education schools and the lower and higher vocational institutes in Rotterdam, and is supported by the local government of Rotterdam. The plan is for programme to spread to other regions of the country in the future. Finally, the 'Hybrid Teachers[53]' initiative involves teachers who, from their own passion or choice, combine working in education and industry at the same time in a structural manner. This makes their lessons up-to-date, their work more diverse and challenging and the subject more relevant to their students. In 2015 a pilot is being run in which teachers and professionals from companies (also STEM related) are linked to each other in order to exchange ideas about their shared field of work, get acquainted with one another's jobs and get inspired to combine the two worlds of education and industry, or even start their own company.

Like the United Kingdom and Israel, the Netherlands also has several programmes in place aimed at recruiting more and high quality STEM teachers. 'Education Traineeship ' is a two-year programme in which trainees work as a teacher in secondary education and get their teaching qualification at the same time. The additional programme within the Education Traineeship focuses on didactics and other education related themes and a personal development element. The Education Traineeship programme focuses on recruiting more highly skilled teachers, especially for subjects which face a shortage of teachers at national level, including amongst others, physics, chemistry and maths. Inspired by the successful programmes in England and the US, the Netherlands has been running the intensive traineeship programme, Eerst De Klas, since 2009. In a two-year traineeship, talented university graduates (of any subject) work several days a week as secondary school teachers. In addition to earning a teaching qualification, they take part in an intensive business leadership programme. Eerst De Klas strives to get more highly educated teachers into the classrooms.

Two further programmes exist in the Netherlands, which both interestingly allow participants to combine working as a professional in the STEM industry and teaching their STEM area of expertise in general secondary or vocational education. The first of these programmes is 'Teach and Tech ', in which professionals get the opportunity to teach in lower vocational education. Participants follow an adapted programme to gain an official teaching qualification, in order to make it easier for STEM professionals to combine working in STEM with teaching (often very practical) courses within lower vocational education. 'Teach and Tech' is currently a collaboration between secondary education schools and the lower and higher vocational institutes in Rotterdam, and is supported by the local government of Rotterdam. The plan is for programme to spread to other regions of the country in the future. Finally, the 'Hybrid Teachers ' initiative involves teachers who, from their own passion or choice, combine working in education and industry at the same time in a structural manner. This makes their lessons up-to-date, their work more diverse and challenging and the subject more relevant to their students. In 2015 a pilot is being run in which teachers and professionals from companies (also STEM related) are linked to each other in order to exchange ideas about their shared field of work, get acquainted with one another's jobs and get inspired to combine the two worlds of education and industry, or even start their own company.

In **Bulgaria**, the main problem with promoting STEM careers (especially in mathematics, physics and chemistry) is the limited number of higher education candidates who choose to study these fields at university. As a result, various national strategies currently in place each have objectives which aim to address the need to recruit more STEM teachers at all levels. These include: Strategy for the Development of Higher Education (2014-2020); Strategy for the Development of Professional Education (2015-2020); Strategy for the Development of Educational Staff; and the National Strategy for Lifelong Learning (2014-2020)[54]. Each of these strategies contains a corresponding Action Plan reflecting the recommendations of public discussions on the issue, as well as the position of the Ministry of Education and the National Council for Science and Innovation. A concrete example, is the Faculty of Physics and Engineering Technology, at the University of Plovdiv which has its own career centre, offering a wide variety of internships[55]. Students graduating from the Faculty of Physics and Engineering Technologies enter the job market as professional engineers and specialists in the fields of physics, electronics, communications, laser technologies, nuclear physics etc. Many graduates following these internship programmes also become Physics teachers. The faculty's career centre has recently started offering the possibility to receive a teaching qualification to students graduating and doing internships in relation to newer fields, including integrating physics with engineering, informatics, and telematics. The result has been a significant increase in the number of students in the Faculty.

In **Denmark**, there is a currently a specific approach used to attract more students to study to become STEM teachers. Most of the university colleges have designed specific STEM teacher training profiles, which are advertised on their teacher training web pages and include arguments for why students should choose a STEM teaching career. For example, University College South Denmark, mentions the following benefits for students who choose to follow their 'science teacher' course[56]: while normally in Denmark initial teacher training covers at most three subjects, this course allows you within the same time, to get qualified in teaching mathematics as well as three other science-related subjects from the following: physics chemistry, natural sciences, geography and biology; students on the 'science teacher' course are linked to science projects in the municipalities, and through this come into very close with the latest research in the field. Via the research projects students acquire unique knowledge that makes them extremely attractive and in demand as teachers in primary and secondary schools; finally prospective students are reminded that there is a great shortage of teachers in science subjects and there are relatively few trained teachers which specialize in a science related or technology subject, which therefore means students on this course will be particularly attractive to schools, and are very likely to gain employment quickly. Other universities are now offering prospective teachers the opportunity to follow the 'outdoor profile' based course, which allows you to become an expert in teaching outside of the classroom and in nature[57]. This specific profile-based course tries to motivate students to apply by including a study period abroad (either 6 months or one year) at the National Centre for Pedagogy, at Linköping University in Sweden, internationally recognized for its teaching and research in outdoor education. Following the other 33 member countries, Denmark has also recently joined the Teach First initiative, which focuses on recruiting the best graduates (including from STEM subjects) to teach in state schools.

3.2 Initiatives targeting the general lack of teachers in all subject areas including STEM

Hungary, Switzerland, France, Israel and Latvia report a general lack of students choosing to follow teaching careers, and mention initiatives to recruit teachers of any subject, including in the STEM area, particularly high quality students with proven excellent academic achievement.

Hungary is currently facing a lack of students interested in pursuing teaching as a career, in general. For this reason, as an incentive, the 'Klebelsberg Scholarschip' has been especially developed and is open to university students who undertake to teach in the public education system upon graduation for at least as long as the duration of their scholarship. The amount available is 25,000, 50,000 or 75,000 forints per student per month, depending on the level of demand for the student's chosen studies. The scholarship is aimed at encouraging students to enrol into courses for teaching degrees that are in high demand, making future staff planning in public education more predictable. Although the scholarship is open to any student wishing to become a teacher of any subject, the Minister of State for Public Education stated that in autumn 2014, teachers of natural sciences were in particular demand, so students applying for this subject are likely to get priority[58].

Similarly, in **Switzerland**, there is also currently a general lack of teachers at both primary and secondary levels. The precise situation of course varies from one Canton to another and so different measures are taken accordingly at this level to address the problem. It is important to note that the measures taken however are not STEM specific and therefore apply to recruiting teachers of every discipline. An example of one measure which has been adopted is the possibility for "professional transfer", whereby professionals from non-teaching backgrounds can become teachers subject to the conditions set by the Swiss Conference of Cantonal Ministers of Education (EDK)[59].

France is another country in which there is a need to attract more students to study to become teachers of any subject. For this reason in 2016, the Ministry of National Education has set a target to recruit 25,000 teachers, of all disciplines at all levels. The campaign is advertised on the Ministry's website[60].

Israel also has various programmes to increase the number of teachers in all subject areas, including STEM, at national level. These include: a Masters degree in Teaching called 'M.Teach', which provides scholars with a post-graduate degree including a teaching license - a two year programme focused on preparing candidates to teach any of the subjects taught at secondary schools; and the programme 'second career for IDF army officers' which allows army officers with a degree to study a course leading to a teaching license in a specialization that corresponds to their academic field. Another Israeli initiative which has been put in place, this time with a focus more on attracting high quality candidates for teaching, is the 'Excellence in Teaching' programme. The programme is focussed on student candidates with very high qualifications with a combined grade of 630 points (while in the regular programmes only 525 points are required). This is an intensive training programme of three years. The participants are exempt from paying the tuition and get a living allowance of 5,000 *NL*I a year. They assume a commitment to work as teachers for at least for three years.

Likewise, **Latvia** also has a specific programme in place to attract and select the most promising students to become teachers of any subject, including the STEM disciplines. The programme is called 'Mission Possible' (IM)[61] and began in 2008. More than 40% of teachers in Latvia are older than 50, and therefore there is a need to recruit high quality university graduates to become inspiring teachers and future leaders. Each year IM attracts, selects, and prepares university graduates with leadership potential and good academic achievement for school careers. Their mission is to help schools establish a positive and progressive environment, as well as raise students' interest and motivation to learn. By participating in the IM programme, participants work full-time as teachers and also spend 2 years studying to acquire pedagogy and management skills within the Leadership Development Programme. After a two-year cycle in the programme the participants get involved in the Ambassador Movement of IM which aims to further the programme's goals of recruiting as many top quality teachers as possible. The 'Mission Possible' programme is a partner within the global network, 'Teach for All'[62], which unites 35 organizations worldwide, aiming at expanding educational opportunity around the world by increasing and accelerating the impact of national organizations that are cultivating the leadership necessary for change. While all the organizations which are part of the network share common values around the principle that everyone has the right to an excellent education, each organization works on the basis of their own national context, as well as their priorities and needs.

3.3 Recent national evidence revealing a lack of STEM teachers

In Finland there is evidence at national level concerning a lack of STEM teachers, but currently no initiatives are in place to address the problem. Sweden also has recently published national statistics illustrating the problem, and has joined the 'Teach for All' global network to help address the issue.

In **Finland** a recent large-scale national survey (carried out by Statistics Finland every two to three years) called 'Teachers in Finland 2013'[63] reported there to be problems concerning the recruitment of STEM teachers at national level. The report published in 2014 states that there is a lack of qualified mathematics teachers. Moreover, many STEM teachers will retire in the following years. Universities are currently facing difficulties to get enough students to join their STEM teacher programmes. Currently no specific initiatives are in place to address this issue.

Sweden has even more recent and substantial evidence concerning the lack of STEM teachers at national level. In June 2015 the Swedish National Agency for Education published an extensive forecast of the need of various categories of teachers[64]. A diagram illustrating Sweden's recruitment and assessment needs for science and mathematics teachers at upper secondary level shows that these categories of teachers are of particular concern. Over the forecast period between 2015 and 2029, the report calculates that approximately 800 biology teachers, 1,000 physics teachers, more than 700 chemistry teachers, just over 1,000 general science teachers and more than 3,200 mathematics teachers will be needed. Currently, echoing the situation in Finland, 40-45% of science teachers in Sweden are 50 years old or older, and so will retire in the not so far off future. To help address this growing issue of concern, in 2013 the country launched the organization 'Teach for Sweden[65]', which is a member of the global network 'Teach for All' (see section 3.2). Teach for Sweden is a non-profit, politically and religiously independent organization that works for every child's right to an equal education. All children regardless of socioeconomic background should have the same educational opportunities and the ability to choose their own future. Unfortunately however, the results of several studies show that is not the case. Teach for Sweden's 2-year programme recruits future leaders with a degree in any STEM subject or in foreign languages, and places them as teachers in schools with challenges. They work at a school while at the same time studying for their teacher degree part-time at a distance. Teach for Sweden aims to contribute to a more equitable school and believes the key is to simultaneously engage the civil, private and public sectors. In 2014 there were 35 participants took part in the Teach for Sweden programme specialized in Technology, Science or Mathematics, and were placed 29 schools in 10 municipalities across the country.

4. STEM RELATED INITIAL TEACHER EDUCATION INITIATIVES

50% of countries (AT, BE, BG, CZ, DK, EE, FI, FR, IL, LT, LV, MT, NL, NO, UK) mentioned that specific STEM-related initial teacher training has recently been or is currently available for prospective teachers, and/or that there is a specific initiative related to this in place.

4.1 New courses and special programmes for the provision of STEM initial teacher education

Malta and the United Kingdom are developing new degree programmes to facilitate and enhance the studying of sciences for prospective science teachers, while Lithuania, Latvia and the Netherlands have updated and modernized their initial teacher training courses to reflect STEM curriculum reforms in their countries and to introduce innovative content and methods. Israel has introduced special programmes to train future STEM teachers, including a school residency programme.

In **Malta**, a new Bachelor of Science Education is currently being developed for the first time. In the coming years initial teacher education provided by the University of Malta will no longer be through the Bachelor of Education or Bachelor plus Postgraduate Certificate in Education (PGCE) routes. In the forthcoming years the route will be through a Masters in Teaching and Learning, following a first Bachelor degree. The Masters programme that is currently in development will be available to students in possession of a Bachelor of Science in the Natural Sciences or a Bachelor of Science in Science Education. The new Bachelor of Science in Science Education is intended to provide a sound background in scientific knowledge, familiarity with current science related debates and discourse and an opportunity to experience interdisciplinary approaches to science in the community.

The **United Kingdom** has also launched a new initiative to develop completely new physics degrees, to be piloted in ten top United Kingdom universities. This will enable students to get a teaching qualification alongside their degree course. The universities have been offered grant funding of up to £10,000 to develop the specialised physics degrees. These courses will be accredited by the Institute of Physics and will allow students to directly become qualified teachers, rather than having to do an additional year's teacher training on top of their degree. The specialised courses will be developed ready to begin in 2016 and 2017.

In **Lithuania**, new study programmes for initial teacher training courses in Chemistry and Physics have been developed by the Lithuanian University of Educational Sciences[66]. It is the only university which offers a course covering pedagogy, chemistry and physics resulting in a Bachelor's Degree and also a valid teacher qualification. The course focuses on innovative methods and the use of laboratory practices. The course involves group work as well as independent work, and puts an emphasis on critical thinking and creative methods.

The University of **Latvia** has also developed a new course on the Methodology of Teaching Sciences which was approved in 2013. This course has an increased emphasis on teaching approaches that encourage students' acquisition of scientific inquiry skills, and the possibilities of using various study methods and cooperation models to teach sciences at school. Also noteworthy, is that since Latvia's curriculum reform of science and mathematics education at both primary and secondary level, the study programmes for initial teacher training in science and mathematics have been adjusted accordingly, incorporating a special focus on inquiry based teaching and learning.

Similarly, in the **Netherlands**, initial teacher education courses have also been updated as a result of curriculum reform. Since 2014, Science and Technology is one of the main subjects studied by all prospective primary school teachers, to reflect one of the goals of the Dutch Technology Pact, which declares that all primary schools must incorporate the teaching of Science and Technology into their curriculum by 2020.

In addition to the regular teacher training programmes for STEM teachers at secondary level, **Israel** ran a special programme to train Science graduates as teachers of Science and Technology in junior high school in 2013. Moreover, three special programmes for training engineers as teachers in secondary education were also run in 2012. The subjects covered were electricity/electronics; machines; and computer science. Following the success of this programme, a similar programme is being run in 2015. The results of an ongoing research project concerning these special programmes are expected to be published at the end of 2015. The research project has been carried out over the last three years and in addition to evaluating the special programmes mentioned above, it also evaluates an earlier programme from 2010 which trained teachers of Mathematics and Sciences. The evaluation report will be made available through the Ministry of Education's Division for Initial Teacher Training, who initiated the programmes.

Additionally, Israel's Weizmann Institute of Science has a programme for training tutors and accompanying instructors for newly appointed teachers of Mathematics and Sciences[67]. Moreover at national level several programmes are being implemented in cooperation with the Trump Foundation to train teachers of Mathematics in a special residency programme in which teachers are mainly trained directly in schools. This innovative programme provides teachers with a larger exposure to the practical experience of teaching in school during their initial teacher training. These programmes also make extensive use of observation, video recording and constructive feedback. Team work, simulations and experimentations using project-based approaches are also emphasized. The rationale for introducing this programme is linked to the fact that about half of Israeli teachers leave the profession during their first five years of teaching. These teachers have reported that the reasons for this are to a large extent associated to the overly theoretical initial teacher training they received, which did not sufficiently prepare them for the realities of teaching in the classroom and school life. This residency programme aims to address this issue.

4.2 STEM related initial teacher training developments arising from collaboration in national or European projects

Flanders, Estonia and Austria have reported that through collaboration in national or European projects (involving universities, teacher training colleges, teacher networks and other partners), new encouraging developments are entering STEM related initial teacher education at national level. These developments have included the incorporation of innovative pedagogies and resources into teacher training programmes, and have also given rise in parallel to the building of professional development networks.

In **Flanders**, the teacher training colleges at university level are currently jointly developing new STEM didactics, within the project 'STEM for the Basis'[68] launched in May 2014. The project is coordinated by the Teacher Expertise Network (ENW) of the Ghent University Association (in collaboration with other ENWs). The objective is to develop teaching methods to improve STEM teaching in particular in relation to technology, and to improve teachers' perception and attitudes towards technology. The project which will run until December 2015 also aims to develop a network for the professional development of STEM teachers within and outside the school. The same joint effort is being made by teacher training colleges and partners to develop new didactics for the second and third grade of STEM secondary education in Flanders, through the project STEM@SCHOOL[69]. The STEM@SCHOOL project, which is coordinated by the University of Leuven and will run until 2018, consists of three major phases. The first phase involves developing the new STEM didactics; the second stage will involve the validation of the new didactics with the help of teachers, and the final stage will involve embedding the new didactics in the curriculum and providing the necessary training for STEM teachers. Both these initiatives targeting teachers of primary and secondary STEM education, have also set up Communities of Practice for the development and validation of the new didactics. In these Communities of Practice, schools meet at regular intervals to exchange good practices. In this way, the teachers have a large ownership of the STEM activities in their classrooms. They take charge of their own quality control as well as their continuous development in the teaching profession. Currently there are about 100 primary schools who are a partner in the STEM Learning Network for primary education and about 12 local networks for STEM in secondary education (each ranging between 10 and 40 partner schools). Most networks meet on a bi-monthly basis.

During 2008-2014, **Estonia** developed a project, EDUKO[70], to strengthen initial science teacher training, and to also raise the level of qualification for general education teachers. The project involved various Estonian universities and Academies, and was funded by the European Union Structural Funds. The overall objective of the program was to strengthen science education by designing a flexible and coherent teacher education system with Estonian educational researchers and teacher training staff. The project encouraged the use of self-assessment methods by all teachers and supported the development of their knowledge, professional skills and career opportunities. One of the project's goals was to create active cooperation environments (web-based or other) for the development and exchange of teaching and learning methods and materials.

In **Austria**, the Colleges of Education in Vienna, Salzburg and Graz are making use of the outputs developed within the European project PRI-SCI-NET[71], to improve initial teacher training in science education. The aim of the project, which finished in 2014, was to develop training courses and materials and provide professional support to teachers to help them use Inquiry based learning in Science teaching in primary schools. Among the project's outputs were three international teacher-training courses as well as 45 science teaching activities using IBSE (Inquiry Based Science Education) produced in 15 different languages. The Colleges of Education of Vienna, Salzburg and Graz are incorporating these courses and activities into their teacher training programmes, so that when teachers enter the profession they are well equipped and capable of teaching science in an engaging and dynamic way to primary pupils. At policy level more generally, there are plans for the various teacher training institutions in the country to become more closely aligned with the universities which also provide initial teacher education. This change is planned to take place by the latest in 2018.

4.3 General reforms in initial teacher training also impacting on future STEM teachers

In the United Kingdom, there has been a shift to greater levels of school-based teacher training which has brought about a significant change. This change has meant that schools now have considerable autonomy to drive school improvement at a very local level. In 2013, both Denmark and France introduced general reforms to their national initial teacher training systems, which interestingly share various commonalities. In both cases the reforms emphasize the strengthening of a common core covering psychology, pedagogy and didactics as well as subject-specific competences; more opportunities for specialization; a flexible module structure; and an international perspective. Additionally in France, worthy of note, are the research and practical components and an emphasis on innovative tools and methods (particularly with a digital focus), as well as a high level of collaboration between the various educational professionals providing the training. Israel, the Netherlands, and Norway have ongoing system wide reforms which share the specific objectives of raising the quality of students that choose to enter the profession, as well as the effectiveness, attractiveness and flexibility of the initial training they receive. In Israel, as in France, there is a strong focus on increasing the practical element of getting experience of teaching in the classroom, through pairing student teachers with experienced teachers. These encouraging reforms in Denmark, France, Israel, the Netherlands, and Norway apply to all prospective teachers of any subject, and as such will also have a significant impact on the content, format, and methods used and promoted for STEM teaching and learning.

In **Denmark**, a general reform of initial teacher training took effect in 2013, the main characteristics of which were: an increased focus on students' competencies – core teacher skills; subject-specific skills covered in three subjects (it being compulsory for one subject to be Danish or Mathematics); the strengthening of teachers' basic knowledge by bringing together the disciplines of psychology, didactics and pedagogy; greater choice and opportunities for specialization; facilitations made for studying one semester abroad; and more flexibility thanks to the course's modular structure. One direct consequence has been that most University Colleges have now developed specific profiles and/or modules targeting different aspects of STEM education (e.g. outdoor teaching; school-industry-collaboration, inquiry based science teaching etc.).

In September 2013, **France** also reformed its initial teacher education by opening a new umbrella organization, ESPE[72] (Écoles supérieures du professorat et de l'éducation), mainly focused on providing innovative initial teacher education for primary and secondary levels, but also offering professional development for in-service teachers. This new network is composed of teacher training providers in various universities across France. ESPE offers students wishing to become teachers a 2-year Masters degree (further to having completed any Bachelor degree), on teaching, education and training, known as MEEF (Métiers de l'enseignement, de l'éducation et de la formation). The Masters degree is made up of several modules, with a focus on innovative teaching tools and methods, an introduction to research, an international perspective, and a digital component. The four main dimensions are: a common core involving pedagogy and didactics as well as lessons relating to school life (e.g. team work, relations with the educational community, crisis management etc.); subject-specific teaching; opportunities for specialization; and a practical component involving school placements. The organization, structure and teaching modules of the Masters degree are flexible and involve a high level of ongoing collaboration between students and practitioners on the ground. Teachers, teacher trainers, managerial staff, inspectors, and representatives of school partner associations are all involved in the training offered. With the creation of ESPE new modalities for the evaluation of teachers' initial education have also been introduced, to ensure they are aligned with the new content and format of the initial teacher training courses proposed[73]. While this reform does not target STEM focused initial teacher training in particular, it nevertheless will have a significant impact on the way in which STEM teachers are prepared to teach their subjects in the classroom, thanks particularly to the emphasis on innovative tools and methods, the research and digital components and the high level of collaboration.

In **Israel**, there is an ongoing system wide reform in the initial training of teachers with deep implications for teacher education in STEM. Several policies and initiatives are being carried out to significantly improve the quality of those that choose teaching as their profession and of those that complete their professional training in the teacher education institutions, comprising universities and teacher training colleges. Since 2013, the Division for Teacher Training in consultation with the heads of the Teacher Training Colleges decided on the gradual increase in the grades required for acceptance of a candidate to participate in initial teacher training programmes across the country. The aim is to introduce selection processes that will assess the adequacy of the candidate for teaching. The hope is that such a process will increase the professional prestige of the profession.

The reform also includes the establishment of common obligatory criteria for initial teacher training programmes (see section 4.4 below) and various measures to attract high quality candidates for the teaching profession (as described in section 3). An important programme within this reform, is the 'Academy/Classroom[74]' programme of the Ministry of Education, which, like the French reform described above, aims to advance the practical component of the teacher training process through a focus on 'pair teaching' in the classroom. In the upcoming school year (2015/2016) a pilot will start in which three days in the week a thousand teacher students (in the third year of their teaching training programme) will be placed in 250 classrooms in kindergartens and schools for 12-16 hours weekly. They will join experienced teachers to teach together in a joint challenging experience in the classroom. In December 2014 a paper was published about the introduction of the new programme by the Ministry of Education and the Administration for Teaching Personnel, entitled 'Academy/Classroom' – a partnership for strengthening teaching: a policy paper summarizing the conclusions of the thinking team'[75].

In the **Netherlands**, following an intensive start-up phase, a vision and action plan for the development of initial and in-service teacher training has been formulated in the Teachers' Agenda 2013-2020. The Teachers' Agenda is based on a broadly supported vision, jointly developed by teachers, school leaders, teacher trainers, directors and the Ministry of Education, Culture and Science. The Agenda impacts on all prospective teachers, including future STEM teachers. There are seven action points of which three are specifically focused on initial teacher training: recruiting better students to join teacher education institutes[76]; the provision of better education for teachers-in-training[77]; and developing attractive and flexible learning routes for teacher education[78].

Norway is also undergoing a reform of its initial teacher education system through the programme 'Promotion of the status and quality of teachers'[79]. The curricula for the initial teacher education programmes are currently being reviewed and updated. At the same time the length of the initial teacher training programmes are being increased from four to five years, and will result in a Masters degree. The 'Promotion of the status and quality of teachers' also introduces a requirement for all teachers to have at least 30 credits to teach mathematics in primary school and 60 credits to teach in lower secondary school, with the aim of improving standards.

4.4 Autonomous teacher training providers and the development of quality standards

Estonia, Switzerland, the Czech Republic, Israel, the United Kingdom and Finland, all emphasized the autonomy with which their initial teacher training providers operate, resulting in it being difficult to provide a national overview of STEM related initiatives at this level. However, what is known is reported below. Interestingly, while this freedom and independence has its benefits, the Czech Republic, Israel, the United Kingdom and Finland are realizing the need for teacher education institutions and experts from the sector to work together in order to develop a common initial teacher training framework (for general use, and STEM-specific use in the case of Finland) to ensure quality and consistency in the content and methods taught.

In **Estonia** universities are free in the way they organize initial teacher training courses. Initial teacher training courses for prospective STEM teachers do provide training in the application of inquiry-based approaches as well as scientific method in teaching practices.

In the case of **Switzerland**, there are 17 universities[80] providing initial and in-service teacher education which all operate independently from one another. There are therefore no national guidelines about the content of initial teacher training or continuous professional development, and no nation-wide initiatives concerning STEM-related initial or in-service teacher education. The cantons, which manage the universities providing teacher education, are the ones who set the conditions and modality for the training of prospective and in-service teachers. However, the national conditions for the recognition of teaching degrees are set by the Swiss Conference of Cantonal Ministers of Education (EDK)[81]. The quality of initial teacher education and professional development provided by the Swiss universities, including related to STEM teaching, can generally be said to be considered of good quality and not currently in need of reforming at national level.

Like in Switzerland and Estonia, teacher training at universities in the **Czech Republic** is largely decentralised, and the individual universities are characterised by a high degree of autonomy. As a teacher training course (in general, not only STEM subjects) can now be taken at 37 faculties in a total of 761 study fields, it is very difficult to make any kind of generalisation. Every programme (including those for future teachers) must be accredited by Akreditační komise (the Accreditation Commission);

however, there are great differences in not only the content but also the mode and format of study at the individual universities. Nevertheless, it is worth mentioning that some universities have already introduced new methods into initial teacher education in order to strengthen the inquiry-based approach. In particular, attention is paid to the so-called 'Hejný method' related to primary school mathematics[82]. This method, which aims at enabling children to discover mathematics themselves and to enjoy the process has been incorporated into initial teacher training courses at the Faculty of Education at Charles University in Prague and at the University of Ostrava. At national level, there have been recent discussions about the usefulness of developing a standard for the content of initial teacher training, to at least partially ensure consistency[83]. However, no such initiative has been prepared so far in regards to STEM-related initial teacher training.

A similar discussion concerning the need for uniform quality requirements has taken place in **Israel**. Initial teacher training which is provided by universities and the Teacher Training Colleges have traditionally been regulated by two different bodies – the Council for Higher Education and the Division for Teacher Training at the Ministry of Education. Much effort is being applied in raising and making uniform the quality requirements of both kinds of institutions. This has been concretely achieved first and foremost through the 'Ariav road map outline' which has been approved by the Council of Higher Education and the Ministry of Education. It sets common obligatory criteria for all courses by provided by teacher training institutions and awards them with an academic status. The outline defines a core of subject areas to be covered and stresses the importance of practical experience. The importance of integrating educational studies, subject teaching content and methods and practical experience is stressed. Following the Ariav outline the programme of studies were updated and a common professional infrastructure has been established with the purpose of bringing quality human resources to the profession.

In the **United Kingdom**, each nation (England, Scotland, Wales and Northern Ireland) has clear national standards which teachers are required to meet, including those entering the teaching profession, although the standards vary slightly across the nations. The English government has commissioned an independent working group made up of expert representatives from the sector to develop a core initial teacher training framework - to support those who deliver teacher education as well as to provide applicants and trainees with a better understanding of the essential elements of good quality core content. The government has commissioned the Teaching Schools Council to develop a new set of aspirational standards for school-based initial teacher training mentors - to help promote the importance of the role and create a better shared understanding of the characteristics of effective mentoring across the sector. The independent expert group and the Teaching Schools Council are expected to report to Ministers by the end of 2015. These measures come as a consequence of a review of the quality and effectiveness of initial teacher education courses in England[84]. The report highlighted that the system in England is performing well but that more needs to be done to ensure all trainees receive some core grounding in the basics of classroom management and subject knowledge. The report made 18 recommendations to government and the initial teacher training sector. The two specific measures described above are in response to these recommendations.

Interestingly, **Finland** is also developing a framework and standards for initial teacher training, but unlike the countries above, these are being specifically designed for STEM teacher education. In the autumn of 2014, representatives of STEM teacher education in Finnish universities founded a "STEM teachers education forum"[85]. The aim of this forum is to promote discussions and cooperation between STEM teacher education units in different universities. The ultimate goal is to establish quality standards for STEM teacher education in Finland. It is intended for the quality standards to serve as a set of guidelines for developing teacher education at national level. Finnish universities, just like in the countries described above, are also autonomous and therefore independently decide how to organize the initial teacher training they provide.

4.5 Adequacy of initial teacher education available for prospective STEM teachers

A striking 15 out of 16 knowledge and competence areas for STEM teachers are not adequately covered by the initial teacher training available at national level, according to at least 68% of countries (and more depending on the area in question). The only exception, unsurprisingly, is the most basic and traditional aspect of initial teacher training - professional content knowledge, which almost half of all countries (48%; AT, BG, EE, ES, FI, HR, HU, IL, MT, NO, PL, SI) stated was sufficiently covered. Strikingly, all countries (except Lithuania) stated that teaching the principles and practices of Responsible Research and Innovation (RRI) needs to be more thoroughly addressed in initial teacher training, which matches the findings in section 7 of this report, underlining that this concept in the context of STEM school education is not yet known or established at national level.

Moreover, 80% of countries agreed that two areas closely related to one another; namely: knowledge and ability to analyze students' beliefs and attitudes towards STEM (AT, BE, BG, CY, EE, EL, FR, HR, HU, IE, IL, IT, LV, MT, NL, NO, PL, RO, SI, TK), and, Knowledge and ability to teach STEM taking into account the different interests of boys and girls (BE, CY, DK, EE, EL, ES, FI, FR, HR, HU, IE, IL, IT, NL, NO, PL, RO, SI, TK), are not addressed sufficiently in initial teacher education programmes. This reflects the fact that at present, and since many years, STEM teaching often does not adequately take into account students' STEM-related beliefs and attitudes or their gender-specific interests (Rocard 2007, Osborne 2008, OECD 2015). Prospective teachers not only need to be made aware of the importance of attitudes and gender in impacting on students' motivation to study and pursue STEM careers, but also need to be guided in pedagogical methods and specific resources targeted at addressing this issue (European Parliament 2015).

This section explores the adequacy of training provided at national level, with regards specific knowledge and competence areas identified as relevant for STEM teachers, and therefore worthy of inclusion in initial teacher education programmes. Respondents were asked to indicate whether training provided at national level is sufficient or lacking with respect to 16 knowledge and competence areas specifically relevant to STEM teachers. The list of 16 knowledge and competence areas was proposed by the author of this report and approved by all participating National Contact Points during the design phase of the survey. Countries were invited to propose other areas which they considered relevant to their national context, not mentioned in the list, but no country made use of this option, so the list was considered exhaustive and fit for purpose for this report.

It should be noted that some countries (*CH*, *CZ*, *PT*, *SE*, and *SK*) were unable or preferred not to answer this part of the survey. This was the case for Switzerland as it has 17 education universities which operate independently and so it is not straightforward to make generalizations at national level. This was also the case for the Czech Republic, as initial teacher training is not centralised meaning that the content and modality varies greatly from faculty to faculty. Similar reasons concerning the autonomy of initial teacher training providers were mentioned by Portugal and Sweden.

A number of countries also noted that due to a lack of official documents and research reports, national respondents based their answers to this set of questions on their own professional experience of working with teachers, together with input from colleagues, and related information available from relevant conferences, seminars and other teacher-focused activities.

Strikingly, 15 out of 16 knowledge and competence areas for STEM teachers, were rated by at least 68% of countries as not adequately covered by the initial teacher training available at national level. The only exception, unsurprisingly, was the most basic and traditional aspect of initial teacher training - *professional content knowledge (teacher's mastery of subject-matter knowledge and the ability to teach it in a way that makes it possible for their students to learn)*, which almost half of all countries (48%; *AT*, *BG*, *EE*, *ES*, *FI*, *HR*, *HU*, *IL*, *MT*, *NO*, *PL*, *SI*) stated was sufficiently covered. Only two other areas were considered by around one third (32%) of countries as sufficiently addressed in initial teacher training programmes; these included: *Knowledge and ability to teach scientific modelling skills* (*AT*, *DK*, *FI*, *HU*, *LT*, *LV*, *NL*, *UK*), and, *Knowledge and ability to teach argumentation skills (i.e. the ability to persuade others of the validity of a specific idea/theory using well-supported arguments) e.g. through facilitating small group discussions etc.* (*AT*, *DK*, *IT*, *LT*, *MT*, *NL*, *PL*, *UK*). However, even in these three areas, the majority of countries reported that more initial teacher training was needed in order for it to be considered sufficient.

All other areas were considered by a significant majority as not adequately addressed by the initial teacher training on offer in their countries. This was most strikingly the case for *Knowledge and ability to participate in Responsible Research and Innovation (RRI) processes, as well as teach the principles and practices of this approach to their students and help them become actively engaged in all stages*, which all countries (with the exception of Lithuania) stated needs to be more thoroughly addressed in initial teacher training. This matches the findings in section 7 of this report, which underline that the concept of Responsible Research and Innovation (RRI) in the specific context of STEM education is not known or established at national level, resulting in the education community not being familiar with the principles and practices of this approach and how it can involve them.

Other areas of particular concern included two strictly STEM-related areas, as well as three areas which while very important for STEM teachers, are also of relevance to teachers of other subjects. 80% of countries agreed that two STEM-specific areas closely related to one another, are not addressed sufficiently in initial teacher education programmes; namely: *knowledge and ability to analyze students' beliefs and attitudes towards STEM* (*AT*, *BE*, *BG*, *CY*, *EE*, *EL*, *FR*, *HR*, *HU*, *IE*, *IL*, *IT*, *LV*, *MT*, *NL*, *NO*, *PL*, *RO*, *SI*, *TK*), and, *Knowledge and ability to teach STEM taking into account the different interests of boys and girls* (*BE*, *CY*, *DK*, *EE*, *EL*, *ES*, *FI*, *FR*, *HR*, *HU*, *IE*, *IL*, *IT*, *NL*, *NO*, *PL*, *RO*, *SI*, *TK*). This is very interesting as it may well partly explain why students, particularly at secondary level, get 'turned off' by STEM teaching and learning. At present, and since many years, STEM teaching often does not adequately take into account students' STEM-related beliefs and attitudes or their gender-specific interests (Rocard 2007, Osborne 2008), and from the results of this survey, it can be argued that it is at least in part due to newly qualified teachers not having received any specific training in this regard. Prospective teachers not only need to be made aware of the importance of attitudes and gender in impacting on students' motivation to study and pursue STEM careers, but also need to be guided in pedagogical methods and specific resources targeted at addressing this issue (European Parliament 2015). For example, the recent OECD report on gender equality, based on the findings of PISA

2012, suggests that teachers should use teaching strategies that demand more of their students, since all students, but particularly girls, perform better in mathematics when their teachers ask them to try to solve mathematical problems independently (OECD, 2015, pp. 15). It would therefore be useful for initial teacher training programmes targeting future STEM teachers to incorporate such teaching strategies into their courses.

The other areas where a considerable 80% of countries agreed there was a serious lack of initial teacher training were: *Knowledge and ability to effectively collaborate with external professionals (e.g. to update their own professional content knowledge and skills, as well as to cooperate with them to directly contribute to classroom teaching or out-of-school visits to STEM places of work etc.)* (AT, BE, BG, CY, DK, EE, EL, ES, FI, FR, HR, HU, NL, NO, PL, RO, SI, TK, UK)[IV]; *Knowledge and ability to use ICT effectively to teach STEM (e.g. using simulations of experiments, video conferences for demonstrations etc.)* (AT, BE, BG, DK, EE, EL, ES, FR, HR, HU, IE, IL, IT, LT, NO, PL, RO, SI, TK, UK); and, *Knowledge and ability to plan and facilitate individual and collaborative science project work (project-based learning)* (BE, BG, CY, DK, EE, EL, ES, FI, FR, HR, HU, IE, IT, LV, NL, PL, RO, SI, TK, UK).

Following closely, with 76% of countries expressing more initial teacher training would be beneficial in these areas were: *Inquiry/problem-based teaching and learning methods, including the use of practical laboratory experiments* (AT, BE, BG, CY, EE, EL, ES, FR, HR, HU, IE, IT, LT, LV, NL, PL, RO, SI, TK); and, *Knowledge and ability to teach a diverse range of pupils with different abilities and motivation to study STEM* (BE, BG, CY, DK, EE, EL, FI, FR, HR, HU, IE, IT, LT, LV, MT, RO, SI, TK, UK).

Finally, a slightly lower proportion of 72% of countries reported that initial teacher training in their countries did not sufficiently cover the following areas: *Context-based science teaching emphasizing the philosophical, historical, cultural and societal aspects of science and technology, as well as connecting scientific understanding with students' everyday experiences* (BE, BG, CY, EE, EL, ES, FI, FR, HR, HU, IE, LV, MT, NL, PL, RO, SI, TK); *Knowledge and ability to teach the 'Nature of Science' (i.e. the key principles and ideas behind scientific knowledge)* (BE, BG, CY, EE, EL, ES, FI, FR, HR, HU, IE, IL, LV, PL, RO, SI, TK, UK); *Knowledge and ability to use diagnostic tools for early detection of students' learning difficulties in STEM* (AT, BE, BG, CY, EE, EL, ES, FR, HR, HU, IE, IL, IT, PL, RO, SI, TK); *Knowledge and ability to critically analyze and eliminate gender stereotypes which may be portrayed in teaching materials, and be careful to avoid such stereotyping when interacting with students as well as ensuring students do not encourage them amongst themselves* (BE, CY, EE, EL, ES, FI, FR, HR, HU, IE, IL, IT, NL, PL, RO, SI, TK); and, *Knowledge and ability to identify, locate, adapt and develop relevant and motivating STEM related learning resources* (AT, BE, BG, CY, DK, EE, EL, ES, HR, HU, IE, IT, LT, LV, NL, PL, RO, SI, TK).

[IV] To be noted: Ireland did not answer this question, stating that it was not applicable in the Irish context, so the percentage of countries for this question was divided by 29 instead of 30 countries.

5. STEM RELATED IN-SERVICE TEACHER EDUCATION INITIATIVES

97% of countries (representing all countries except for Hungary) mentioned that specific STEM-related professional development has recently been or is currently available for in-service teachers, and/or that there is a specific initiative related to this in place.

5.1 STEM in-service teacher education initiatives led by the Ministry of Education or the national teacher training institution

30% of countries (PT, RO, PL, TK, MT, HR, CY, SI, and UK [Scotland]) have STEM in-service teacher education initiatives which have been implemented or are currently being led at central level, either directly through the Ministry of Education, or the national institution responsible for teacher training, often affiliated to the Ministry. Some of the initiatives reported are directly related to national curriculum reform or educational priorities leading to the need to update teachers' STEM knowledge and competences, enabling them to implement the changes in the classroom.

In the context of the **Portuguese** national curriculum reform that came into force in 2012, the Ministry of Education developed a new national training programme to prepare in-service teachers to work with the new national STEM syllabi and learning outcomes. The training programme involved 2,650 primary and lower secondary education teachers of Mathematics and 474 upper secondary teachers of Mathematics, from 2013 until 2014. The materials used in the national training programme are now available online for all STEM teachers[86].

Similarly, in **Romania**, to accompany the national curriculum reform for primary education, the Ministry of Education put a training programme in place for in-service teachers working at this level[87]. The training programme covered all areas, including the teaching of STEM at primary level.

Poland is another country in which curriculum reform and national education priorities has determined recent developments in teachers' professional development. One of the goals of the Polish state educational policy, set out by the Minister of Education in the school year 2014/2015, was to improve the quality of upper secondary education, with particular emphasis on skills in mathematics. In the current school year 2015/2016, one of the goals emphasized again in national education policy, is mathematical and science education in general education. The Centre for the Development of Education[88] has therefore responded to these STEM related educational priorities by designing and organizing various STEM in-service teacher training programmes and related support for teachers. As part of the implementation of the recent core curriculum introduced in 2009/2010, a series of in-service teacher trainings have been conducted. These have included: three trainings in May 2015 on the planning of teaching, care and educational work of teachers in the first level of education (and also the fourth level in the case of science) in mathematics, natural science, and ICT (as well as other subjects), targeting consultants, methodological advisors and teachers; a general training in March 2015 for mathematics teachers, consultants and advisors; and a specific training on the organization of work of mathematics teachers in the fourth grade. This final training aimed to support teachers, consultants and advisors by providing them with the methodological knowledge and skills necessary for the effective preparation of students for the matriculation examination. A series of training programmes and conferences for mathematics teachers have also been organized, which aim to support secondary school mathematics teachers and technicians in preparing students for the new matriculation examination.

The Ministry of Education in collaboration with the Copernicus Science Centre also worked on a project from February 2013 until June 2015 called the “Copernican Revolution”[89]. The project aimed at training teachers in active learning methods. The goal was to transform Polish schools in places where student curiosity is stimulated and engaged and students are motivated to explore the world. The project aimed to develop and disseminate innovative tools that allow science teachers to effectively use the best methods of working with their students, based on experimentation, making and verifying hypotheses, and exploring phenomena through direct experience. Within the project’s two years, workshops took place for teachers in the Copernicus Science Centre and all Polish regions. Participants received educational kits enabling them to conduct experiments in the classroom. New laboratories for natural science classes for grades 4-6 of primary school were developed and tested within the project. The most effective equipment was recommended to the Ministry of Education for wider implementation.

In **Turkey**, the Ministry of National Education’s Directorate General for Teacher Education and Development is responsible for in-service training of teachers. Concerning STEM in-service teacher education, the Ministry has designed standard training programmes for in-service science teachers[90]. These programmes are aimed at training teachers about new teaching approaches in science teaching and how to effectively use innovative science and mathematics materials in lessons. These courses include educational objectives for lesson activities concerning scientific research, and the use of experiments, etc. A simiar programme has been designed for in-service mathematics teachers.

In **Malta**, professional development for STEM teachers is mostly focused on inquiry based pedagogical approaches. This has been partly developed and delivered through the FP7 EU funded PRIMAS project[91], which began in 2010 and finished in 2013. The European PRIMAS project aimed to support and foster the use of inquiry-based teaching strategies in maths and science subjects by providing teaching materials, teacher training and other supporting actions. Since the end of the project, the Maltese Ministry of Education has further developed and continued this inquiry-based professional development through its annual in-service teacher training courses designed and organised by Education Officers of specific STEM subjects.

The **Croatian** Education and Teacher Training Agency is responsible for the provision of professional and advisory support in the area of general education in Croatia. It coordinates the work of all County Teacher Councils which also involves the organization of workshops for the Councils’ in-service STEM teachers[92]. The Agency is also very active in the pilot project 'Croatian Teachers' Programme – CERN[93]', which in part involves training teachers to have the knowledge and ability to effectively collaborate with external STEM professionals. This allows in-service STEM teachers to update their own professional content knowledge and skills, as well as feel confident in cooperating with STEM professionals in the classroom or when involved in out-of-school visits to STEM places of work. The Agency also participates in various projects which it encourages STEM teachers to get involved in, as they are targeted at making science more motivating for students[94]. One example is the recently launched '365 experiments in 365 days' project[95] in which a physicist from Split records each day a new experiment which he broadcasts to increase the availability of high quality digital content for teachers to use in their physics lessons. The first video was recorded on 1 July 2015 and new experiments will be recorded and made available each day until 1 July 2016.

In **Cyprus**, since 2007, the University of Cyprus has overall responsibility for the initial preparation of secondary education teachers at national level offering a compulsory introductory training programme for newly appointed secondary level teachers of all subjects, including STEM. It provides a series of courses for all teacher specializations in secondary education in order to improve the effectiveness of their teaching. Part of this programme involves supervised school teaching experience supported by a mentoring programme. Candidate teachers participating in the school teaching experience are guided and assessed by university staff.

Teacher preparation in primary education involves a four-year degree in Pedagogy and is offered by four universities in Cyprus. These programmes include specialization courses in Mathematics and Science for the subset of teachers who choose to specialize in these subject areas.

Additionally, the Cyprus Pedagogical Institute runs an induction programme for first year teachers and an optional professional development programme for in-service teachers. These include a series of seminars targeting newly appointed and experienced teachers in primary, secondary and technical education, open to any serving teacher who wishes to exchange knowledge, ideas and experiences with colleagues and experts.

Slovenia's National Education Institute has organized several national conferences during the last five years, specifically aimed at the professional development of STEM teachers. Examples include a national STEM conference 'Pathways to quality of knowledge in STEM[96]' in 2012; three conferences for science teachers in 2011, 2013 and 2015: 'From life to technological processes[97]', 'From observation and research to knowledge[98]', and 'We connect knowledge to improve literacy and Scientix[99]'; and two conferences on teaching and learning mathematics in 2012[100] and 2014[101].

Education Scotland (the national body in **Scotland** for supporting quality and improvement in learning and teaching) has run a large amount of networking support events, training events and courses and materials for teachers on the national educational intranet, Glow. For instance, Education Scotland organised 12 events bringing teachers from all local authorities together to co-develop classroom resources, including for STEM teaching. There are now 3,000 resources available on the Glow online community. Four professional learning resources have also been published since April 2014. These professional learning resources are based on an in-depth analysis of children and young people's responses to tasks in a national survey. Each resource helps practitioners use the survey findings to understand areas of strength and areas for development. They support practitioners with teaching advice and signpost career long professional learning opportunities. Professional learning resources have been published on Estimation and Rounding (published in April 2014); Numeracy and Mathematics Skills (published June 2014); Time (Published in September 2014); and Number and Number Processes (published in March 2015)[102].

5.2 Countries in which various providers deliver teacher continuous professional development in the STEM area

30% of countries report that various providers, including dedicated teacher training agencies, universities and private organizations (sometimes in collaboration) are responsible for the provision of teachers' continuous professional development in STEM teaching.

In **Flanders**, teacher education providers provide a wide range of STEM in-service teacher training[103]. In addition to their own offer of training, these education providers work in partnership to develop innovative STEM didactics. Moreover, a special initiative will take place in the year 2015-2016, which will involve all education providers providing an in-depth STEM teacher training course for an extra 150 primary schools, in some cases spread over eight weeks.

A remarkable share of teachers belong to professional teacher associations in **Estonia**, which aim to increase the quality of teaching, and share teaching materials and experiences related to educational innovation. Most of the teacher associations organize subject-specific meetings (such as 'Mathematics Teachers' Day' or 'Chemistry Teachers' Day') and annual events, where educators and teachers have the opportunity to discuss the latest research and ideas about good practice.

The situation is similar in **England** where the government funds professional development in science and mathematics and a number of science, technology, engineering and mathematics professional bodies and subject associations offer professional development opportunities. However, interestingly, England reports that it is witnessing a move away from a national and regional delivery model for continuous professional development in science education, to a school-led model. 50 Science Learning Partnerships to this effect have now been put in place, with 75% of lead partners being schools themselves.

Since 2004, there is extensive support for teacher's professional development in England, particularly in science, through the National Science Learning Centre (NSLC)[104] and the National Science Learning Network (NSLN). Both the Centre and Network offer bursaries that are funded by the Department for Education and the Wellcome Trust. There are a large number of evaluation reports on the impact of the professional development support provided by NSLC and NSLN[105]. There is also support for teachers' professional development in mathematics through the National College for the Excellence in teaching of Mathematics which also coordinates the recently established Mathematics hubs to support school-led professional development. Central to the Mathematics Hubs is the Mathematics Teacher Exchange Programme between England and China. In September 2014, 71 primary teachers travelled to Shanghai, with a similar number from Shanghai primary schools returning to England, in two waves: November 2014, and February/March 2015.This programme is spearheading changes at primary level in the first year, by implementing real change in the way mathematics is taught in the participant schools. A similar pattern of exchanges involving secondary school teachers will take place in 2015/2016. Finally, there is some limited support for computing through the Computing at School[106] initiative, which aims to promote and support excellence in computer science education, through its community of professional practice.

In **Italy**, there are various continuous professional development teacher training courses organized at national level, specifically for in-service STEM teachers. These include: PON educazione scientifica (targeting science teachers); Mat@abel (targeting mathematics teachers); PON didatec (targeting all STEM teachers aiming to use ICT in teaching); Master level II: Training Physics Teachers (this course is provided by the Physics department of the University of Udine); and Master level II: Training Maths Teachers. This latter course (this course is provided by the Maths departments of the universities of Torino, Pisa, and Bologna).

In **Bulgaria**, there are three professional development centres which are affiliated to the universities in the corresponding towns (Sofia, Stara Zagora, Varna (Shumen)). The Bulgarian Academy of Sciences and some universities are also involved in the professional development of teachers by providing specialized courses directed towards the implementation of the national programmes and strategies. A good example is a course aimed at educating mathematics and informatics teachers on Inquiry Based Learning in Mathematics, organized and delivered by a team in IMI-BAS (the Institute of Mathematics and Informatics - Bulgarian Academy of Sciences) as part of the National programme 'Qualification 2014'. It is also part of the Action plan of the National programme 'Development of the teaching staff 2015', accepted by the Council of the Ministers in April 2015 within the measure 'Assuring conditions for the continuous qualification of teachers in priority directions'. Other concrete examples include one week intensive STEM in-service training courses which were organized by the Ministry of Education and Science in the summer and autumn of 2015 in Switzerland: one was the National Teacher Programme for ICT and Informatics teachers, and the other was the National Teacher Programme for Physics and Astronomy teachers[107].

In **Spain**, there are several institutions providing professional development for STEM teachers. INTEF offers in-service teacher training for STEM teachers annually through its summer courses, examples of which include 'Bang goes Science!' and 'Connect the physical and digital world through programming'. INTEF also organizes congresses and working days whose objective is to spread, deepen and exchange knowledge and skills in different subjects and on various educational topics. Some of the subjects related to STEM teaching addressed this year have been: Models for Integrating ICT into Education; and Digital Educational Content[108]. Spain's Autonomous Regions also provide professional development courses for teachers in different areas, including STEM.

In **Lithuania**, STEM related professional development services are organized by the Education Development Centre[109] or by Education centres located in cities and districts[110]. These include seminars on the use of digital educational content, the use of mobile devices in education, new assessment methods, the organization of research projects, etc. Teachers also have access to information relevant to their professional development via the country's Teachers' TV[111].

In **Switzerland**, each of the 17 universities providing initial and in-service teacher education operate independently and therefore decide autonomously about the nature of the STEM-related professional development services they offer. It is therefore not possible to make any generalizations at national level. However, the education universities do have courses in place for in-service STEM teachers. One example is the course on Natural and Technical Sciences Didactics offered by the Education University FHNW (FH Nordwestschweiz)[112]. Moreover, the university of Zurich has its own Centre for Natural Sciences Didactics[113]. The task of the centre is the development and promotion of science education in compulsory education (in nursery, primary, secondary education) through science-didactic research. The centre supports teachers, pupils and schools concerning the teaching and learning of science at all school levels. Also worth noting is that the Swiss Conference of Cantonal Ministers of Education (EDK) provides general recommendations about teachers' professional development, which also covers STEM teachers[114].

Romania has benefited from many projects funded by the European Social Fund, which have directly targeted in-service teacher education. These projects involving various partners at national level have produced a wide range of courses for teachers on different educational topics. One STEM-specific example is the course 'Professional development of Mathematics teachers in a knowledge-based society[115]'. Moreover, the Ministry of Education has approved several optional courses arising from these projects funded by the European Social Fund, which are now taught in primary, lower and upper secondary schools.

In the **Czech Republic**, there have not been any recent significant changes in the teacher education landscape with a particular impact on STEM teachers. In addition to the Ministry of Education's provision, professional teacher training has continued to be supported by European or privately funded projects which mostly take place at regional level. The range of fee paying and free of charge professional development opportunities for teachers remains relatively extensive in the Czech Republic.

5.3 Countries where general developments in teacher professional development have also impacted STEM teachers

20% of countries (IL, CZ, EE, MT, FI, and NL) report that reform has recently or is currently transforming their teacher professional development systems at national level. These general reforms in in-service teacher education have impacted STEM professional development in various ways.

Teacher professional development in **Israel** is currently undergoing deep changes as a result of major reforms of the education system at primary (the Ofek Hadash reform) and secondary (the Oz LeTmura reform) level. Ofek Hadash is the result of an agreement between the Ministry of Education and the Teachers' Syndicate covering primary education and lower secondary schools, and Oz LeTmura is the result of a later agreement between the Ministry and the Organization of Teachers in Secondary Schools. These reforms are being introduced gradually; while Ofek Hadash is well advanced in its implementation, the deployment of Oz LeTmura reform is slower, requiring the agreement of at least 50% of the teachers in a given school for its implementation. The professional development policy of the Oz LeTmura reform highlights the following issues: Career long learning stressing professional specialization in teaching; School based professional development intended to establish an institutional culture of a learning organization; Training in preparation to assume a new role while exercising it; and Improvement in the quality of the processes of teaching, learning, and evaluation. The Division for Professional Development involved all other relevant units in the Ministry and the Organization of Teachers in establishing the principles for professional development of the teachers. The main pedagogical principles are the following: the professional development for teachers will be grounded in programmes prepared by the professional units of the Ministry; these courses will serve as the outline for professional development. Such professional development course templates exist for the following STEM subjects: Mathematics[116], Biology[117], Chemistry[118]; Phsyics[119]; Science and Technology in Society[120], and Technology discplines[121]'. Every graded course will include an operational task requiring documentation on the reflection and application of the relevant process of learning and teaching. The head teacher will dialogue and build with each teacher an appropriate professional development track. The professional development will be carried out by recognized academic institutions and specified bodies. As a rule, teachers who attend courses regularly and complete tasks successfully will receive a salary bonus each year after completing a course/courses of 112 hours.

The professional development policy of the Ofek Hadash reform at primary level is to enable teachers to engage in a reflective learning process concerning teaching and learning. Moreover, there is a focus on improving peer teaching and learning, as well as the school/team organizational climate, while also developing teachers' professional identity. The principles of the teacher professional development programme at this level include: flexibility in the learning conditions and range of tasks required; the development of a cooperative professional learning community; the integration of practice, theory and experience; learning in context; the development of learners' capabilities (emotional, cognitive, and behavioural); establishing the conditions for a shared dialogue that bridges the personal collective dimensions; and learning and tutoring guided by practical outputs. Equivalent professional development course templates are also available at primary level for the following STEM subjects: Mathematics[122]; Science and Technology[123]; Computer Science[124]; 21st Century Competencies (ICT – Information and Communication Technologies)[125]; and Environment, Sustainability, Agriculture[126].

In the **Czech Republic** there are two recent developments which have already or will impact teachers of any subject, including STEM. The first is the amendment to the Act on Educational Staff which came into effect on 1 January 2015. The amendment states that as of this date to become a teacher requires a professional qualification for direct educational activity. This has resulted in the need for serving teachers who are now deemed unqualified by the amended law, to study for the required qualification should they wish to continue teaching, or alternatively, leave the profession. It is hoped that the long term impact of this legal change will be the increased quality of teaching in schools. A second development in Czech teacher education, is the so-called 'career system', which aims to support the lifelong professional development of all teachers and will be linked to teachers' remuneration. The career system will therefore impact on all teachers, including STEM teachers. The initiative strives to improve the quality of professional development available to teachers, and to increase their motivation to engage with it. The draft system, including the legislative and financial aspects, has now been completed and published as the outcome of the project 'Kariérní systém', which was initiated by the Ministry of Education Youth and Sport and carried out by Národní ústav pro další vzdělávání in 2012- 2015[127].

In **Estonia**, a programme for teacher´s professional development was implemented in 2009-2014. This included the development of new standards for the teacher profession, applicable to teachers of all subjects. The programme also supported the professional networking of teachers. This year, a new programme for professional development of teachers and school leaders was launched in 2015 and will operate until 2018. In preparation of this new programme a needs analysis for in-service teacher trainings was conducted. The analysis of teachers' skills was compiled based on the data from the OECD's survey of adult skills - PIAAC. The goal of the programme is to re-organize in-service teacher training for teachers of all subjects, to better take into account the requirements of an innovative teaching approach as well as the time teachers have available to participate in such training.

Malta is also currently reviewing the process of its in-service teacher training. To this purpose, the Directorate for Quality & Standards in Education is presently holding talks with the Malta Union of Teachers (MUT). Moreover, the Professional Training Department within the Directorate for Quality and Standards in Education is being re-structured and will form a new, autonomous entity; namely the Institute for Education. The Institute will carry out functions related to teachers' professional development and will serve as the main driver in this area. The main duties of the Institute will include the provision of training in relation to teachers' knowledge, skills, attitudes and practices for practical use in their daily professional lives, and the implementation of continuous professional development activities consistent with or in support of the government policies and educational frameworks.

Finland is also in the process of evaluating teacher professional development in general, at the national level. The Ministry of Education and Culture recognizes the need for further developing and providing in-service teacher training for all teachers. In 2015 the Ministry published an analysis of the situation and proposals for the future of continued professional development in the report 'Paths to Continuing Professional Development - The challenges and future of state-funded professional development of education personnel'[128]. These proposals will of course also impact on the future professional development of STEM teachers.

In the **Netherlands**, a vision and action plan for the development of initial and in-service teacher training has been formulated in the Teachers' Agenda 2013-2020 (see also section 4.3). Four specific action points target in-service teacher education, and therefore impact on STEM teachers' professional development. These include 'A good start for new teachers[129]'(providing guidance for new teachers to do their job as part of a professional team); 'Schools as learning organizations' (promoting a learning culture in schools); 'Competent and qualified teachers' (promoting teachers' self-assessment and the continuous updating of their knowledge and skills); and 'A strong professional association' (connecting teachers to ensure continuous and long lasting improvement of the profession). Since 2013, the Netherlands also has the 'Teachers' Register[130]in place. Through this Register teachers can collect information on all the extra activities they undertake with regard to professional development. This could be a masterclass, participating in a conference, but also following a course or participating in a study. By means of the Register, teachers can demonstrate their qualifications and competences through a record of their professional development achievements. Currently, registration is voluntary, but the government is intending to make registration obligatory by 2017.

5.4 Investing in the professional development of STEM teachers through creating new initiatives, expanding existing ones, or providing dedicated funding

The Netherlands has launched a STEM Teacher Academy which provides professional development in cooperation with industry, while France has expanded the reach of its existing La main à la pâte Foundation, by creating a national network of "Houses for science". Finland and Norway on the other hand have received dedicated funding from their governments to invest in STEM specific teacher professional development programmes.

The **Dutch** STEM Teacher Academy[131] is a new initiative launched in 2014 and run by the Platform Bèta Techniek. The Academy provides initial and in-service teacher education through the provision of internships, master classes and courses organised in cooperation with industry. The activities of the STEM Teacher Academy are available to all secondary education STEM teachers throughout the Netherlands.

Rather than create a new dedicated initiative as in the Netherlands, **France** has expanded the reach of its existing La main à la pâte Foundation, by creating a national network of "Houses for science". These Houses are centres for promoting science education in primary and lower secondary school, through the professional development of teachers and the production of pedagogical resources that support teachers' actions[132]. The aim of the Houses for Science is to help teachers bring innovation to their science teaching practices. Each House caters for its own region, offering professional development courses to teachers from kindergarten to the final year of lower secondary school who teach science and technology to their classes. As of September 2015, the network is made up of nine Houses for Science and is coordinated by the La main à la pâte Foundation, which is its national centre. This central foundation also offers professional development courses that are specifically targeted towards primary and secondary level teacher educators (education advisors, inspectors, academics, etc.) across all of France. This initiative has been supported and partially funded by the French Governement, through a plan for 'Investments for the future[133]'.

In recent years, the **Finnish** National Board of Education has supported and financed numerous training courses held by different organizations providing STEM related professional development for both primary and secondary level teachers. In 2014 the LUMA Centre (Finland's national STEM education network) received state funding from the Ministry of Education and Culture and the National Board of Education to implement its development programme which includes developing new, research-based teaching methods, tools, resources and teacher training, all targeted at in-service STEM teachers. The target groups include primary and secondary level teachers as well as early childhood educators such as kindergarten teachers. The pilot phase of the six-year development programme is currently underway (2014-2016), and the implementation phase will take place in 2016-2019. The LUMA Centre's development programme has a wide scope and is split into three themes: 1) Mathematics and mathematics education 2) Natural sciences and science education and 3) Technology and technology education. The programme consists of over 30 individual projects[134] which cooperate with schools and train teachers. The programme will be evaluated throughout its duration by the head of the department of teacher education at the University of Helsinki, who is also a Professor of didactics in Physics and Chemistry. The first diagnostic evaluation has been completed and the next is due by the end of 2015.

Norway has also received dedicated funding from the government, but unlike in Finland, this funding is specifically for in-service training in Mathematics, rather than all STEM areas. Mathematics is one of the three (along with Norwegian and English) prioritized subjects in the Norwegian strategy for in-service training – 'Competence for Quality[135]'. The Norwegian Parliament recently introduced a regulation stating that to teach mathematics, primary school teachers will need at least 30 credits, while secondary school teachers will need at least 60. To help teachers obtain the new qualification requirements, the government is increasing the funding for in-service training in this area.

5.5 Professional development with a focus on teacher collaboration and peer learning

Flanders, Denmark, Latvia and Sweden have specific in-service teacher education initiatives in place for STEM teachers, which have a special focus on teacher collaboration and peer learning. This innovative approach to professional development is intended to have a lasting impact through the network of teachers established and the continuation of such collaborative learning within their schools and beyond, once the programmes have ended.

Currently in **Flanders** there is one STEM Learning Network working in the area of primary education in Flanders. Within the network teachers create their own in-service training through constant peer learning and conducting their own quality control. As from 2016 onwards, this network will specifically focus on schools, particularly those with children from challenging socio-economic backgrounds. A second STEM Learning Network will be established in 2016 for secondary schools. Teacher training providers at Bachelor and Masters level, as well as STEM-professionals and providers of informal education in STEM are all partners within both networks. However, crucially, schools take centre stage, as it is the teachers who decide the network's agenda, the actual programmes for the teacher training courses as well as the selection of the modules.

In **Denmark**, one of the most prominent continuous professional development activities during recent years, specifically targeting STEM teachers, is QUEST (Qualifying In-service Education of Science Teachers). QUEST is coordinated by the Danish Centre for Science Education, and started in 2012 and will finish at the end of 2015. It involves 43 schools and 450 teachers from 5 Danish municipalities. The project activities will take place in the 5 Jutlandic municipalities: Holstebro, Horsens, Randers, Silkeborg and Aarhus. The main outcomes of the project are to build up and support structured networks of science teachers, science teacher groups (PLCs), schools and municipalities. The most innovative aspect of the model used in QUEST is that skills development is based on collaboration within the school's team of science teachers. The teachers participating in the project receive inspiration from specially organized courses and from discussions about science education in networks across schools. The courses allow teachers to work independently on improving their own teaching practice while at the same time giving them the opportunity to collaborate in subject teams and networks within and across schools. This innovative in-service teacher education programme, is being carefully monitored by ongoing research. Preliminary results are already available. After two years of working on QUEST, participants were asked if the project had changed their teaching, and 90% answered positively. An almost equally high percentage of teachers (88%) reported that the project had also improved cooperation in school subject teams.

In **Latvia**, the National Network for Schools with Innovative Experience was established in 2011 by the National Centre for Education in cooperation with The Centre for Science and Mathematics Education (DZM) of the University of Latvia. The Network is an additional form of professional development which complements the existing in-service teacher training courses, and has been specifically created to facilitate the implementation of change in schools. The Network is composed of 22 schools in Latvia. Under the DZM's expert guidance, school teams (including teachers and school administrators) meet on a regular basis in order to share their innovative experience and to raise students' interest in science and mathematics.

The Network's school teams are currently working on three specific dimensions. The first is the improvement of teaching involving 13 of the Networks' schools which meet once a month together in order to share experience. They observe and analyse science and math lessons, and cooperate to develop content and methodologies for competence based learning. The second dimension is the focused learning group for action research[136]. This is used as a teacher professional learning tool to improve individual teaching practice and the self-reflection of science teachers. Teachers work individually in their own schools, and then also meet all together once a month for a workshop lead by DZM's experts. Every workshop includes the following structure: individual reflection, group reflection and discussion about the work done between the workshops; a focused input from the group leader according to teachers' needs; planning of next steps; and the identification of independent research work. The guidelines under which the group operated, were developed together with teachers. The third dimension is teachers and leaders professional development groups, which involves around 40 Physics, Biology, Chemistry and Mathematics teachers of the Network which work in groups. Teachers are engaged in training on a regular basis together with experts from the DZM in order to become specialists in their subjects. In the groups' meetings participants share their ideas, gain new knowledge, discuss and reflect on how to build students' knowledge and skills, how to teach specific topics, and how to gain higher attainment. Each of the groups are formed by 5 to 8 teachers, united by the desire to collaborate with colleagues and motivated to explore their subject's content and related methodological problems and possible solutions.

The **Swedish** National Agency for Education is currently running a three-year initiative "NT-satsningen", with a focus on teacher training through peer learning, which began in 2013 and will continue until 2016. 'N' is for Naturvetenskap (Science) and 'T' is for Teknik (Technology). Schools (and preschools) are offered different kinds of support to improve the quality of teaching in these subjects. The target groups are teachers, preschool-teachers, headmasters and principals. Like in the Danish and Latvian initiatives described above, there is a specific emphasis on teacher collaboration, through the programme's focus on peer learning. The programme is structured around collaborative learning where the structured collaboration of teachers allows them to assimilate new knowledge into daily teaching practices. In short, teachers learn with and from one another, guided by a colleague that leads the collaborative learning, the so-called 'NT-developer'. This guiding teacher facilitates the learning process between the group of colleagues collaborating together. This peer learning programme was introduced as a consequence of several observations: an increase in the need for STEM specialists; the decline in students' interest in STEM subjects; and a decrease, at national level, of students' performance in international assessment (PISA).

The focus of the programme has been on in-service teacher training; two programmes were put in place (for pre-school and compulsory school, and for upper secondary school). The programme for pre-school and compulsory school focuses on collaborative learning (teachers support each other through the learning process, guided by a coordinating teacher) and it aims to move away from the concept of professional development, towards professional learning. Teachers evaluate together the processes of problem-solving approaches, conveying information to students, and define what they need to know in order to teach students effectively. A three-year in-service teacher training was put in place for all coordinating teachers who support collaborative learning activities and a network of 270 teachers was established. The programme for upper secondary school teachers includes the organization of conferences for teachers and principals, as well as a dedicated website for learning support, lectures and workshops. Teachers and principals are given access to materials, up-to-date developments in research and have the possibility of learning from their peers and finding inspiration for their classrooms. The programme has been allocated a budget of €300,000 per year, between 2013-2016.

The Swedish National Agency for Education is also running another large-scale mathematics initiative during the period 2012-2016. The in-service teacher training programme addresses innovative didactics in the teaching of mathematics, and also includes a focus on peer learning. It is the largest training initiative in one subject area ever to have taken place in Sweden. The initiative aims to strengthen and develop the quality of mathematics teaching and consequently to increase student achievement.

These Danish, Latvian and Swedish initiatives focusing on teacher collaboration and peer learning, are particularly interesting in the light of recent research concerning the lack of these practices throughout Europe. We know from recent international research from TIMMS and PIRLS that across the 17 EU countries surveyed, on average, only around one third (36%) of fourth graders are taught by teachers reporting a high degree of collaboration with other teachers, aimed at improving teaching and learning. When analysing the nature of this collaboration we find that on average, not much more than half of students are taught by teachers who share what they have learned about their teaching experiences (57.45%) and discuss how to teach a particular topic (51.24%) with others on a weekly basis. A lower share of students still (42.42%, on average) are taught by teachers collaborating weekly in planning and preparing instructional materials. Practices that require closer collaboration, such as working together to try out new ideas and visiting another teacher's classroom, are even less frequent (European Commission (c) 2015).

5.6 ICT-focused professional development courses

Greece, Slovakia, Ireland and Croatia report professional development courses/conferences, specifically aimed at training in-service teachers in the effective use of technology for teaching and learning.

In **Greece**, within the framework of the professional development programme of teachers, the on-going programme "B-Level ICT Teacher Training" focuses on the design of educational activities using digital media and resources. This is provided to in-service teachers of STEM domains and primary education. Inquiry and problem-based teaching and learning methods is a significant element of the course curriculum for STEM domains, with respect to digital labs. The course is significantly supported by the Photodentro learning resources[137] (learning objects, learning scenarios, educational software, open educational practices, etc.) and interactive textbooks[138]. Learning scenarios developed by teachers and trainers during the B-Level course are made available through the IFIGENEIA portal[139]. To date, around 25% of in-service teachers have taken the course. The programme includes 96 hours (in 3-hour lessons) of theory and practice as well as a 3-hour exam in which teachers have to design their own scenario on a given subject. The programme is managed by the Computer Technology Institute and Press (CTI) 'Diophantus'.

In **Slovakia**, as a result of ongoing curriculum reform, digital competence is underlined as a key competence for all pupils since 2008. To make this a reality, there is a need to ensure that ICT teaching is up to standard. To meet this need the Ministry of Education in cooperation with 5 faculties of different higher education institutions implemented the DVUI national in-service training for 1,500 informatics teachers during the period 2008-2011, involving each teacher receiving a notebook for learning purposes. This programme has now come to an end but is being followed up by the MVP training initiative which has enlarged its scope to teachers coming from a large breadth of subjects at lower and upper secondary level, including all STEM subjects. As in the previous training programme, each teacher involved in the MVP training initiative receives a notebook, and is trained to integrate the use of ICT into their subject teaching effectively.

Ireland currently provides a full in-service teacher education programme for Design and Communication Graphics, delivered by the Professional Development Service for Teachers (PDST). The programme involves blended support through online components and then follow-up face to face support. The programme provides participants with updates on CAD software (see section 6.1). The first phase of support involves the development of a series of online tutorials and supporting web resources. Phase two of the programme will include half days (2.5 hours) of practical workshops to be held nationally in various education centres.

In **Croatia**, the annual 'Modern Technologies in Education' conference targets all serving and future teachers interested in introducing new approaches to teaching with the support of technology[140].

5.7 Completed, ongoing or planned evaluations of teachers' continuous professional development

A few countries have invested in carrying out large scale evaluations of the professional development available for STEM teachers at national level. In the case of the United Kingdom, Italy, and Portugal, evaluation results are already published and available online. Some of the evaluations mentioned focus not only on the impact of the programme/s on teachers' skill development, but also on the learning of students. Ireland and Slovenia mention the routine implementation of evaluations of all the in-service teacher training they conduct at national level, while Finland reports the opening of a new Education Evaluation Centre.

In the **United Kingdom**, there are a large number of evaluation reports on the impact of the continuous professional development provided by the National Science Learning Centre and National Science Learning Network. In particular there is evidence of impact from a survey of participants in the National Science Learning Network Regional Programme, which took place in March 2015, which revealed that: 88.4% reported impact on personal knowledge and skills, 76.9% reported impact on their ability to use evidence and research, and more than 90% of respondents identified a positive impact on their colleagues' practice, on science teaching in the school more broadly, and on demonstrating the value of science-specific professional development as a tool for improving and sustaining the quality of science teaching and learning[141]. There are also various other evaluations and related research concerning the impact of continuous professional development in the area of STEM education in the United Kingdom carried out by other training providers and research institutions.

During July 2013 until April 2014, a team of external evaluators investigated the effectiveness of all in-service teacher training initiatives at national level in

Italy, which took place within the framework of the National Operation Programme 2007-2013 called 'PON'. This included training initiatives focused on STEM. The evaluation has taken stock of the current situation, highlighting strengths, weaknesses, threats and opportunities. The executive summary[142] and full report[143] are available in Italian.

The **Portuguese** Ministry of Education commissioned the Educational Research Centre at the University of Aveiro to conduct an evaluation study to assess the impact of the in-service primary teacher training programme aimed at increasing teachers' use of experimental work in teaching. This in-service teacher training programme was implemented during 2006-2010, and involved more than 5,000 teachers. The aims of the evaluation study which was published online[144] in 2012 were to: compare science teaching practices before and after the training programme, to identify changes which have taken place; assess the training programme's impact on students' scientific knowledge and skills; analyse the impact of collaborative environments within and between schools; evaluate the use and management of laboratory equipment and materials in schools; and evaluate the impact of the Science Education Guides produced as part of the programme to complement the use of science textbooks in primary schools.

Similarly, in **France**, the National Research Agency (ANR) launched a research project, 'FORMSCIENCES[145]', in 2013, with the objective of evaluating the impact of teachers' professional development in Inquiry Based Science Education on students' understanding of science and scientific literacy. The research project aims to understand, through quantitative and qualitative analyses, what the impact of this professional development on Inquiry Based Science Education has been on teachers' teaching practices as well as on students' skills. France has long invested in Inquiry Based Learning through the various professional development actions for primary and lower secondary school teachers available through the *La main à la pâte* initiative (Kearney 2011), and is now taking the time to evaluate the actual impact these actions are having on the all-important indirect beneficiaries: the students themselves.

Ireland is committed to ongoing evaluation of the teacher training it provides for Maths, Science and Technology subjects, as well as Physics, Chemistry Agricultural Science and Biology, delivered by the Professional Development Service for Teachers (PDST).

Slovenia's National Education Institute also reports that all the in-service teacher education it provides, whether through courses, conferences or seminars etc. is routinely evaluated.

An important recent development in **Finland**, has been the opening of the new Finnish Education Evaluation Centre (abbreviated to KARVI in Finnish and FINEEC in English)[146] in May 2014. It was formed by combining the evaluation activities of the Finnish Higher Education Evaluation Council, the Finnish Education Evaluation Council and the Finnish National Board of Education. The aim was to collect tasks and competences related to evaluation under a single entity and to consolidate evaluation activities crossing educational level boundaries. The new Evaluation Centre creates improved preconditions for the development of evaluation methods, as well as further international evaluation cooperation. The centre has not as of yet conducted any STEM specific evaluations on the quality of professional development for teachers for example, but this is possible in the future.

5.8 Adequacy of professional development available for in-service STEM teachers

According to at least 56% of countries (and often more), 15 out of 16 knowledge and competence areas identified as relevant for STEM teachers are not adequately covered by the professional development courses available for in-service teachers at national level. The only exception is for the area of professional content knowledge, which a significant majority of 72% of countries (AT, BG, CZ, DK, EE, ES, FI, FR, HU, IL, IT, LV, MT, NL, NO, PL, SI, UK) state is adequately covered by professional development available in their countries. Strikingly, as many as 88% countries (a large majority, even if not as many when compared to the results of the same question with regards initial teacher training) stated that teaching the principles and practices of Responsible Research and Innovation (RRI) needs to be more thoroughly addressed in in-service teacher education, underlining that this concept in the context of STEM school education is not yet known or established at national level (see section 7 of this report).

Moreover, mirroring the situation at initial teacher training level, a large majority of 80% of countries agreed that two areas closely related to one another are not addressed sufficiently in in-service teacher education programmes; namely: knowledge and ability to analyze students' beliefs and attitudes towards STEM (AT, BE, BG, CY, CZ, EE, EL, ES, FR, HR, HU, IT, LT, LV, MT, NL, NO, RO, SI, TK), and, Knowledge and ability to teach STEM taking into account the different interests of boys and girls (BE, BG, CY, CZ, EE, EL, ES, FI, FR, HR, HU, IL, IT, LT, LV, NL, NO, RO, SI, TK). This reflects the fact that at present, and since many years, STEM teaching often does not adequately take into account students' STEM-related beliefs and attitudes or their gender-specific interests (Rocard 2007, Osborne 2008, OECD 2015). In-service teachers (as well as prospective teachers) not only need to be made aware of the importance of attitudes and gender in impacting on students' motivation to study and pursue STEM careers, but also need to be guided in pedagogical methods and specific resources targeted at addressing this issue (European Parliament 2015).

The section below explores the adequacy of continuous professional development provided at national level, with regards specific knowledge and competence areas identified as relevant for STEM teachers. Respondents were asked to indicate whether continuous professional development provided at national level is sufficient or lacking with respect to 16 knowledge and competence areas (the same list of areas described in section 4.5 in relation to initial teacher training). The list of 16 knowledge and competence areas was proposed by the author of this report and approved by all participating National Contact Points during the design phase of the survey. Countries were invited to propose other areas which they considered relevant to their national context, not mentioned in the list, but no country made use of this option, so the list was considered exhaustive and fit for purpose for this report.

It should be noted that some countries (*CH*, *IE*, *PT*, *SE*, and *SK*) were unable or preferred not to answer this part of the survey. Where a reason was given this was mostly concerned with the autonomy of professional development providers at local level, making it difficult for respondents to generalize and provide answers which could be said to accurately reflect the situation at national level.

A number of countries also noted that due to a lack of official documents and research reports, national respondents based their answers to these questions on their own professional experience of working with teachers, together with input from colleagues, and related information available from relevant conferences, seminars and other teacher-focused activities.

Strikingly, 15 out of the 16 knowledge and competence areas for STEM teachers, were rated by at least 56% of countries (and often more) as not adequately covered by in-service teacher education available at national level. The only exception is for the area of *professional content knowledge (teacher's mastery of subject-matter knowledge and the ability to teach it in a way that makes it possible for their students to learn)* which a significant majority of 72% of countries (*AT*, *BG*, *CZ*, *DK*, *EE*, *ES*, *FI*, *FR*, *HU*, *IL*, *IT*, *LV*, *MT*, *NL*, *NO*, *PL*, *SI*, *UK*) state is adequately covered by professional development available in their countries. Only 28% (*BE*, *CY*, *EL*, *HR*, *LT*, *RO*, *TK*) state that more professional development is needed in this area. Interestingly this is in contrast to the situation in initial teacher training, where the majority of respondents (52%) reported that more training was needed. Once again, we see that it is in this most traditional area of subject-matter knowledge that countries report the most adequate training (whether for prospective or in-service teachers) to be available.

Just like it was the case for initial teacher training, all other areas were considered by a significant majority as not adequately addressed by the professional development opportunities available in their countries. It is worth mentioning that there are however some areas where a little more than a third of all countries consider there is sufficient coverage in the professional development available. These include the following areas: *Knowledge and ability to identify, locate, adapt and develop relevant and motivating STEM related learning resources* (44%; *AT*, *BG*, *CZ*, *FI*, *FR*, *IL*, *IT*, *MT*, *PL*, *SI*, *UK*); *Knowledge and ability to effectively collaborate with external STEM professionals (e.g. to update their own professional content knowledge and skills, as well as to cooperate with them to directly contribute to classroom teaching or out-of-school visits to STEM places of work etc.)* (40%; *FI*, *FR*, *IL*, *IT*, *LT*, *MT*, *NO*, *PL*, *SI*, *UK*); *Knowledge and ability to teach the 'Nature of Science' (i.e. the key principles and ideas behind scientific knowledge)* (36%; *AT*, *CZ*, *FI*, *IT*, *LT*, *MT*, *NL*, *NO*, *UK*); and *Knowledge and ability to teach scientific modelling skills* (36%; *AT*, *CZ*, *FI*, *FR*, *IT*, *NL*, *NO*, *PL*, *UK*). Interestingly, in the case of providing training on how to effectively collaborate with external STEM professionals, twice as many countries reported this to be sufficiently covered in in-service teacher education, as compared to the lower extent to which it is addressed in initial teacher training.

On the other hand, there is one area where a significant number of more countries reported initial teacher education programmes to cover it more sufficiently compared to professional development, and that is: *Knowledge and ability to critically analyze and eliminate gender stereotypes which may be portrayed in teaching materials, and be careful to avoid such stereotyping when interacting with students as well as ensuring students do not encourage them amongst themselves*. Only 12% (*AT*, *DK*, *PL*) of countries stated this area is sufficiently covered in professional development offered to in-service teachers, compared to more than double the number of countries (28%) who stated this to be the case in initial teacher training (see section 4.5).

Most striking, and similar to the situation in initial teacher training, is that 88% of countries (*AT*, *BE*, *BG*, *CY*, *CZ*, *EE*, *EL*, *ES*, *FI*, *FR*, *HR*, *HU*, *IL*, *IT*, *LT*, *LV*, *PL*, *RO*, *SI*, *TK*, *UK*) stated that *Knowledge and ability to participate in Responsible Research and Innovation (RRI) processes, as well as teach the principles and practices of this approach to their students and help them become actively engaged in all stages*, needs to be more thoroughly addressed in in-service teacher education. Only 12% of countries (DK, MT, NO) stated that this issue was well covered by the professional development opportunities offered within their countries, reflecting once again the newness of this concept within the school education arena, as reported in more detail in section 7 of this report[V]. Also in perfect line with the situation in initial teacher training, a large majority of 80% of countries agreed that two areas closely related to one another, are not addressed sufficiently in in-service teacher education programmes; namely: *knowledge and ability to analyze students' beliefs and attitudes towards STEM* (AT, BE, BG, CY, CZ, EE, EL, ES, FR, HR, HU, IT, LT, LV, MT, NL, NO, RO, SI, TK), and, *Knowledge and ability to teach STEM taking into account the different interests of boys and girls* (BE, BG, CY, CZ, EE, EL, ES, FI, FR, HR, HU, IL, IT, LT, LV, NL, NO, RO, SI, TK).

Finally, a lower percentage of countries (between 68 and 76%) stated that more professional development was needed in the following areas: *Knowledge and ability to use diagnostic tools for early detection of students' learning difficulties in STEM* (76%; AT, BE, BG, CY, DK, EE, EL, ES, FI, FR, HR, HU, IL, IT, LV, NO, RO, SI, TK); *Inquiry/problem-based teaching and learning methods, including the use of practical laboratory experiments* (72%; AT, BE, BG, CY, DK, EE, EL, ES, HR, HU, IL, LT, LV, NL, PL, RO, SI, TK); *Knowledge and ability to teach argumentation skills (i.e. the ability to persuade others of the validity of a specific idea/theory using well-supported arguments) e.g. through facilitating small group discussions etc.* (72%; AT, BE, BG, CY, CZ, DK, EE, EL, ES, HR, HU, IL, IT, LT, LV, RO, SI, TK); *Knowledge and ability to use ICT effectively to teach STEM (e.g. using simulations of experiments, video conferences for demonstrations etc.)* (72%; AT, BE, BG, CY, DK, EE, EL, ES, FR, HR, HU, IL, LT, NL, NO, PL, RO, TK); *Context-based science teaching emphasizing the philosophical, historical, cultural and societal aspects of science and technology, as well as connecting scientific understanding with students' everyday experiences* (68%; BE, BG, CY, DK, EE, EL, ES, HR, HU, IL, IT, LV, MT, NL, RO, SI, TK); *Knowledge and ability to plan and facilitate individual and collaborative science project work (project-based learning)* (68%; BE, BG, CY, DK, EE, EL, ES, FI, FR, HR, HU, IL, LV, NL, PL, RO, SI, TK); and *Knowledge and ability to teach a diverse range of pupils with different abilities and motivation to study STEM* (68%; BE, BG, CY, CZ, DK, EE, EL, ES, FI, HR, HU, IT, LT, LV, RO, SI, TK).

[V] To be noted: The Netherlands did not answer this question, stating that it was not applicable in the Dutch context, so the percentage of countries for this question was divided by 29 instead of 30 countries.

6. ONLINE PROFESSIONAL DEVELOPMENT FOR STEM TEACHERS

70% of countries (AT, BE, BG, DK, EE, EL, ES, FI, FR, HR, IE, IL, IT, LT, NL, NO, PL, PT, RO, SI, UK) report that they either have implemented, currently have or plan online professional development for STEM teachers, testifying to the increasing popularity and acknowledged usefulness of this mode of training. The format of online professional development offered by different countries ranges from short one-off webinars, to activities on e-learning platforms (such as Moodle) to full Massive Open Online Courses (MOOCs). Some countries also mention the use of blended approaches, involving online and offline activities. The STEM areas and topics covered by online professional development activities are varied, with the pedagogical use of ICT in STEM teaching and learning being particularly prominent. The online services mentioned mainly target in-service teachers. The use of a common platform which collects all the online professional development available at national level making it easier for teachers to access, is mentioned by France, Italy, Austria and Bulgaria. Currently, the Czech Republic and Lithuania report that there is no systematic support for online professional development of teachers at national level, but that this is either taking place independently at local level, or planned at national level.

6.1 STEM-specific online professional development

Some countries report STEM specific online professional development courses for teachers, which are often delivered through webinars or via e-learning platforms such as Moodle. Often the courses mentioned specifically aim to support teachers in the pedagogical use of ICT in STEM, as well as other areas of teaching and learning.

The **Dutch** STEM Teacher Academy, which provides initial and in-service teacher education, (see also section 5), organised its first webinar for teachers (in cooperation with the European funded Scientix project) in June 2015. During this webinar a Technical Leader from IBM was interviewed by a STEM teacher, informing participants about his job and IBM's Watson computer. The STEM Teacher Academy aims to broadcast three more webinars in the school year 2015-2016. These webinars will focus on one of the teaching materials developed during the first year of the Academy and instruct teachers throughout the country on how to use it effectively in the classroom. The first webcast is available in Dutch on demand[147].

In **France**, the La main à la pâte Foundation (see section 5.4) also organized its first webinar in December 2015, on its latest lesson plan about the oceans and the climate, targeting French teachers and teacher trainers[148].

In **Estonia**, HITSA[149] (the Information Technology Foundation for Education) provides teacher training courses on the effective use of ICT in teaching. The major part of these training sessions are conducted via webinars. HITSA also offers, along with universities, Moodle courses for teachers, including, amongst others, courses on how to teach in the Moodle environment. Since 2014 HITSA has provided six webinars on various topics in STEM teaching, with an average number of 30 participant teachers per webinar. Each of the webinars were recorded and publicly available on HITSA's Youtube channel[150] so that other teachers can benefit from them in their own time. In March 2015 a one day long online seminar entitled "Nature is wonderful" took place involving more than 300 teachers from all educational levels[151]. The seminar introduced teachers to the different options available to them to integrate ICT into STEM teaching.

The **Slovenian** National Education Institute[152] also runs webinars specifically focused on ICT didactics within STEM subjects, as part of its professional development offer to teachers.

Like in Estonia, the professional development courses provided by the **Bulgarian** Faculty of Mathematics and Informatics at Sofia University, for mathematics and ICT teachers, are partly delivered on the Moodle platform. Likewise, in **Slovenia**, all teachers, including STEM teachers have the habit of working on the Moodle platform, through the virtual classrooms available for each subject on the SiO portal[153].

The **Irish** organization T4[154] is a full time support service under the auspices of the Teacher Education Section within the Department of Education and Science. The primary function of T4 is to prepare and support teachers to implement the revised syllabuses Architectural Technology, Design and Communication Graphics and Engineering Technology and the new subject Technology at Leaving Certificate level. T4 provides continued professional development in CAD software, which includes an online component that must be distance learned and completed in order for teachers to qualify for face to face support. The software used by many schools in Ireland is a powerful design and communication tool and has many applications across the all the technology subjects including Construction Studies, Engineering, LC Technology, Materials Technology (Wood), Metalwork, Technical Graphics and JC Technology.

In **Poland**, the Centre of Education Development provides online professional development of teachers[155]. One example of relevance to STEM and other teaching, is a course dedicated to "Using e-books and e-resources in teaching and learning". These courses are designed for employees wishing to continue their education, for teachers and school support units, psychological and pedagogical units as well as educational libraries. The Centre also invites School Education Development coordinators, school leaders and other groups who want to expand their knowledge and skills in the use of ICT for pedagogical purposes.

Within the framework of sustaining the results of European pilot projects, such as Creative Classroom Lab (CCL)[156], Living Schools Labs (LSL)[157], and Innovative Technologies for an Engaging Classroom (ITEC)[158], **Portugal** has established a network of five regional ambassadors to promote the effective use of mobile devices in schools. The CCL and iTEC projects both have online professional development materials and targeted MOOCs addressing this issue, so Portugal intends to make use of these at national level. The 92 national in service teacher training centres are involved in this initiative and a course to train teacher trainers has already taken place in each of the centres. It is foreseen to continue expanding this community during 2015-2016, in the hope the initiative will eventually achieve its goal to provide nationwide support.

In **Israel**, there are two hubs that deploy online professional development programmes for teachers. The Division for Information Technologies at the Administration for ICT, Technology and Information Systems in the Ministry of Education provides technology focused online courses for teachers[159]. The Centre for Educational Technology (CET) operates the programme "The Virtual Campus for Israel's Teachers[160]" whose purpose is the professional development of teachers through distance learning. Within this programme, several online STEM related courses for professional development are offered for 2015/2016 on Mathematics, Sciences, Problem Based Learning, and Inquiry Based Learning[161].

In **Spain**, there is a wide range of online courses provided by INTEF, the National Institute of Educational Technologies and Teacher Training[162]. These range from courses on mobile learning and augmented reality, to digital storytelling for teachers and courses dedicated to the effective use of open educational resources in Mathematics and Science. The National Centre for Curricular Development in Non-proprietary Systems (CeDeC)[163] also provides numerous applications and digital resources for STEM teachers to use in their classrooms. The materials provided promote the design and development of digital educational materials using open-source software.

Lithuania also has STEM specific webinars and online courses. Examples include, a webinar about the use of digital laboratories in science teaching[164], and online courses about good teaching practice in developing student competences in science classes[165].

In **England**, the National Science Learning Centre has ten years of experience of running STEM specific webinars for teachers across a range of systems, including Adobe Connect, Livestream and Google Hangouts on Air.

In **Flanders**, online STEM-specific professional development is available to the members of the Communities of Practice, set up by the 'STEM for the Basis' and 'STEM@SCHOOL' projects (see section 4.2), which are developing new didactics for STEM teaching at primary and secondary level. Moreover, KlasCement (Flanders' educational portal for teachers managed by the Department of Education), provides a multitude of STEM-practices and resources designed by teachers, which are freely available to all.

In **Romania**, all the teacher training programmes that have been funded through the European Social Fund have had an online component covering about 30% of their activities. These training activities have taken place on e-learning platforms. STEM specific examples include the e-learning platform associated to the training programme "MaST Networking, quality in the development of key competencies for Mathematics, Science and Technology[166]", and "Professional development of Mathematics teachers in a knowledge-based society[167]".

To date, in the **Czech Republic**, online teacher training has not yet received any systematic support at national level. However, teachers are beginning to be more interested in this form of training and therefore the scope and range of professional development available online is gradually increasing. These typically include webinars and Moodle courses.

6.2 Massive Open Online Courses (MOOCs) targeting STEM teachers

Various countries have already or currently provide full and interactive Massive Open Online Courses (MOOCs) specifically on STEM teaching (FI, SI, UK, DK, and IL), while others are in the process of planning or designing them (ES, HR, and EL).

In **Finland**, organizations, including the Finnish STEM teacher associations and the LUMA Centre, organize webinars and other online training sessions for in-service teachers. One concrete example, echoing Estonia's focus on courses related to the integration of ICT in teaching, is the professional development MOOC that the LUMA Centre ran in the spring and autumn of 2015. This MOOC focused on the meaningful pedagogical use of ICT in STEM teaching. The MOOC was funded by the National Board of Education.

The **Slovenian** Arnes Institute has also recently developed a MOOC on the safe use of the internet and digital devices[168], which ran for three weeks in November 2015. The free MOOC is open to all teachers in primary and secondary education. ICT is an integral part of primary and secondary schools, colleges and kindergartens whether through the use of e-diaries/journals, or using modern technologies in the classroom. However, teachers often lack the knowledge of how to use this technology safely. For example, many do not know how to protect against theft of passwords for their own e-journals. The course therefore trains teachers in digital skills (based on the European competence framework DIGCOMP[169]) related specifically to the safe use of the internet and new technologies.

England is also increasingly experimenting and developing MOOCs, thanks to recent national research in this area[170], including a government commissioned report on opportunities for the use of MOOCs in compulsory-age education[171], published in 2014. While there is interest in the possibilities around using MOOCs in the education of 11 to 19-year-olds, current developments in the United Kingdom, like in other countries, focus on MOOCs for teachers. The National Science Learning Centre has recently piloted MOOCs on two different platforms. The first pilot was deployed on the Canvas Network platform. The MOOC focused on managing behaviour for learning[172], and specifically addressed the issue from the perspective of STEM teachers, at whom the MOOC was targeted. Topics covered included managing your own behaviour to influence your students'; using rules and routines to achieve consistency; intelligent use of recognition to motivate students; reducing friction when students behave badly; and reparation and restorative practice. This 5 week course ran twice in November 2014 (3000+ enrolments, 300+ completion certificates) and June 2015 (2000+ enrolments, 200+ completion certificates). It is next scheduled for November 2015. The second pilot was run on the FutureLearn platform. This MOOC focused on Assessment for Learning in STEM teaching[173]. This free online course was designed for STEM teachers in primary and secondary schools, and sixth form and further education colleges. The course covered the following topics: the theory and science behind effective Assessment for Learning; how to use Assessment for Learning to elicit evidence about what's going on in your learners' minds; how to use this evidence formatively with your learners in your laboratory and classroom; and how to write, judge and use the 'hinge questions' that are central to Assessment for Learning in STEM. This 6 week course ran in April 2015 (10000+ enrolments, 700+

reached last week of course). It is next scheduled for February 2016. Additionally the National Science Learning Centre has hosted all or part of fee-paying courses on the National STEM Centre website, an example of which is the course 'Inspiring science learning through demonstrations[174]'. In Scotland, the Department for Education and Education Scotland are liaising with various partners to develop online resources and professional learning videos to support the teaching and learning of sciences in school[175]. In the near future, such resources and videos are planned to be developed on the topic of food science, linked to teaching and learning in chemistry.

Denmark is also active in producing MOOCs for STEM teachers. One example includes the cooperation between University College and the Teacher Training College which resulted in the design of two complementary MOOCs for primary teachers interested in integrating ICT into their teaching[176]; the first focused on digital literacy in the 21st century and the other on robotics and coding in school. Teachers are recommended to follow both courses as they complement one another. Both MOOCs provide resources that can be used directly by teachers. The courses are continually reviewed and updated to ensure they include the most current knowledge and recent resources available. There are also examples of MOOCs in Denmark targeted at teachers of other STEM disciplines. One such example is the MOOC aimed at science and technology teachers[177], where the lack of proficient teachers is most pronounced at national level. This MOOC designed by a private non-profit foundation aims to strengthen teachers' skills through interviews and presentations of innovative methods and tools. Participants are advised to work with colleagues jointly on the course, to maximize the spread of knowledge and contribute to increased cooperation between teachers working on STEM in schools.

The Division for Information Technologies at the **Israeli** Ministry of Education has recently developed technology-focused MOOCs for teacher professional development, the first of which started in the school year 2015/2016[178].

Also very recently implemented in autumn 2015, is a MOOC for the professional development of mathematics teachers, which has been developed by the **Norwegian** Centre for ICT in Education, in cooperation with the University of Tromsø and Sør-Trøndelag University College, on behalf of the Norwegian Ministry of Education[179].

In **Spain**, four training platforms for MOOCs are currently under development[180], and courses are being designed, including some specifically targeting STEM teachers.

The **Croatian** Academic and Research Network (CARNet) developed its first MOOC in January 2015 which took place over six weeks, during which participants learned how to independently design and develop an online course in Moodle. The second MOOC was launched in September 2015 and aimed at popularizing science and technology via the use of available e-resources. Moreover, there is a plan to introduce some webinars as well as MOOCs specifically for STEM teachers arising from the European funded e-School project[181], in which the Croatian Education and Teacher Training Agency is one of the main partners.

Greece also plans to introduce MOOCs for the professional development of teachers, including teachers of sciences and mathematics. However these plans have not yet been concretized and no further information is available at this stage.

6.3 Centralized platforms providing access to all online teacher professional development at national level

Some countries have one centralized platform where online teacher professional development related to all subjects and educational topics takes place.

In **France**, the M@gistère Platform[182] was launched in 2013. The platform provides teacher professional development through tutored online learning, covering a wide range of subject areas, including STEM, as well as teaching and learning topics. The online training aims to be an innovative and interactive supplement to the existing professional development courses available at national level. There is a strong focus on the collaboration of teachers to improve their knowledge and practice through learning together on the platform.

In **Italy**, all STEM professional development is offered through a blended approach, with a significant part of the training conducted online, on the national platform of INDIRE[183], the National Institute for Educational Documentation, Innovation, and Research. **Slovenia** also reports the regular use of blended learning for courses related to the teaching and learning of STEM, where face-to-face training is complemented by e-learning.

In **Austria**, the 14 Colleges of Education offer online professional development courses for in-service teachers. Just like in the countries described above, the courses are however all made available through one centralized platform[184], facilitating access for teachers. Professional development courses specifically in relation to STEM subjects are covered. This initiative was put in place by the Ministry of Education and Women's Affairs some years ago.

In **Bulgaria**, the Ministry of Education and Science also has an educational e-portal where online professional development in various subjects is offered. Moreover, several platforms (Virmathlab, Vivacognita, and *BG* Mascil) providing e-resources related to mathematics and its connection with science and the arts, as well as new forms of contests including work on research topics, are currently being developed at IMI-BAS (the Institute of Mathematics and Informatics - Bulgarian Academy of Sciences).

7. RESPONSIBLE RESEARCH AND INNOVATION AT NATIONAL LEVEL

Responsible Research and Innovation (RRI) is a process where all societal actors (researchers, citizens, policy makers, business) work together during the entire research and innovation process in order to align outcomes with the values, needs and expectations of society. As the world becomes more inter-connected and globally competitive, new economic opportunities often come hand in hand with complex societal challenges. Overcoming these challenges will require all citizens to have a better understanding of science and technology if they are to participate actively and responsibly in science-informed decision-making and knowledge-based innovation. Practising Responsible Research and Innovation allows us to provide the space for open, inclusive and informed discussions on the research and technology decisions that will impact all of our lives. Science education has a very important role to play in the promotion of Responsible Research and Innovation.

7.1 RRI as a new concept in STEM education

A significant majority of 80% of countries stated that the concept of Responsible Research and Innovation (RRI) in the specific context of STEM education is not known or established at national level, and that the education community is not familiar with the principles and practices of this approach and how it involves them.

Some countries remarked that this concept is starting to be discussed at the level of their national education systems, but only very marginally, as it is still mostly understood in relation to, and addressed within, research and higher education. Other countries such as **Switzerland** and **Denmark** mentioned that while RRI as such is not well known at national level, the concept is familiar within the school education community to some extent, only the terms used to describe it are different.

Most of the Nordic countries state that RRI is indeed a familiar concept in STEM education, to the extent that it is either currently, or planned to be, incorporated into the school curriculum. In **Denmark**, the recent curriculum reform has put considerable emphasis on sustainability issues and ethical choices related to innovation processes. These issues have been highlighted in various subjects. Examples include discussing the impact of environmental changes on biodiversity in Biology lessons; discussing developments concerning society's energy supply in Physics and Chemistry lessons; and discussing options for the development of a sustainable society in Geography lessons. **Sweden** has also put emphasis on ethics in science education in its curriculum, where the issue of responsible research and innovation is addressed. For example, in Sweden's most recent curriculum for compulsory schooling, published in 2011[185], one of the aims of technology teaching is described in the following way: 'Through teaching, pupils should be given the opportunity to develop their understanding of the importance of technology and its impact on people, society and the environment. In addition, teaching should give pupils the preconditions to develop confidence in their own ability to assess technical solutions and relate these to questions concerning aesthetics, ethics, gender roles, the economy and sustainable development'. An example of how this aim is concretely declined into core curriculum content that is to be studied by students in years 7-9 is the following: 'students should learn about the consequences of technology choices from the ecological, economic, ethical and social perspectives, such as in questions about the development and use of biofuels and munitions'. Another illustrative example from the biology section of the curriculum is that students of the same age should 'learn about genetic engineering, and the opportunities, risks and ethical questions arising from its application'.

Similarly, **Finland** has also recently incorporated RRI principles into the new core curriculum, which is currently being finalized and will be implemented as of August 2016. At upper secondary level, schools will be required to take into account six cross-curricular themes in the teaching of every subject. One of these key cross-curricular themes is entitled 'technology and society' and comprises the relationship to technology at home, in working life and leisure time, as well as trends and alternatives of technological development from different viewpoints, including from the ethical, economical, wellbeing and safety perspectives.

The **United Kingdom** is an example of a country where the term 'RRI' is well known in the academic world[186], but is less familiar in the school community. However, its key principles (including open access and governance, public accountability and public engagement, ethical considerations and equality, impact evaluation and dissemination, etc.) have been long incorporated in the United Kingdom approach to research, innovation and education. For example, one of the high priority issues for the government is the use of personal and public data in an innovative, yet secure and responsible way. The government is working closely with a range of partners and organisations to promote the importance of digital skills, including data science skills, and to promote the value of digital skills careers for the current and future workforce. There have been, and continue to be, many conversations between government, citizens, business and civil society organisations on how the use of data can provide direct benefits to citizens.

The leading United Kingdom champion of the RRI is the Engineering and Physical Sciences Research Council (EPSRC)[187], which is the main agency for funding STEM academic research. The EPSRC has institutionalised RRI into its strategic thinking and funding programmes and developed an expectation that STEM researchers need demonstrate a commitment to RRI and integrate social scientists and public engagement in their research and innovation projects. As a result of this framework, academic researchers and institutions in the United Kingdom which compete for EU and EPSRC funding have a high awareness of RRI principles. Similarly, the **Czech Republic**, also notes that its academic community which applies for European Structural Funds (ESF) is also very familiar with the RRI concept because of its importance in the ESF's Operational Programme Research, Development and Education. Also noteworthy is a recent initiative of the government of the **United Kingdom** Office for Science, Horizon Scanning Programme Team[188], which is about exploring what the future might look like to understand uncertainties better, and systematically investigating evidence about future trends.

Another aspect of RRI that is of high priority for the government of the United Kingdom is the promotion of evidence-based approach in all areas of public policy, including education. Schools are encouraged to develop stronger links between research and STEM education. Schools and teachers are expected to be engaged with research both as knowledgeable users of external academic research (education and cutting edge science) and as research practitioners who use their own educational and STEM subject research for improving STEM teaching. Furthermore, research-based teaching which involves students in real research projects is an important area of development. While this is currently more used in universities it is nonetheless being advocated as a useful approach for schools as well. Also contributing to development in this area, is the United Kingdom's National College for Teaching and Leadership's, national research and development network. The national research and development network makes research more accessible to schools. It supports teaching school alliances to engage in research and development activities with their higher education institution partners and in regional and national networks. It undertakes research with schools on priority topics and themes agreed by teaching schools, with the aim of providing a practical understanding of how to address the important issues facing teaching schools, as well as an evidence base which can contribute to school improvement and practice.

Although **Austria** does not rate RRI in relation to STEM education as a top priority, it should be noted that the concept is known within the education community, and RRI principles are promoted through the national initiative of the Federal Ministry of Science, Research and Economy, Sparkling Science[189] in which scientists work side by side with young people in current scientific research projects. Also, the Austrian Federal Ministry of Education is a partner in the European project Ark of Inquiry[190] which aims to raise young people's awareness (especially those aged between 7 and 18) of the principles and practices of Responsible Research and Innovation.

Although RRI is not yet an established concept in **Estonia**, it is an example of a country where developments in this area are starting to take place. Some institutions in Higher Education are currently planning the development of their own RRI plans and it is hoped that as a consequence, the understanding of the concept will spread also to other levels of education. Moreover, Estonia's Science Centre AHHAA is also a partner in the European Ark of Inquiry project described above, as well as the RRI Tools project (described below), and has been given the responsibility of introducing the RRI toolkit, once available, to all Estonian stakeholders, including the school community.

Portugal also reports that the concept of RRI is not well established and that the education community is not yet familiar with its principles and practices. It also has no recent, ongoing or planned initiatives targeting the promotion of Responsible Research and Innovation (RRI) principles and practices in STEM education. However, some of the country's STEM measures and initiatives include decision making, research design, implementation, evaluation and communication of research projects by various STEM stakeholders. Currently in the Portuguese context these are considered as methodologies for the promotion of cognitive skills in the STEM area, but are not yet understood as steps in the Research & Innovation process.

Indeed, it is precisely because RRI is not yet an established concept in most countries (particularly in relation to the school sector) that a project called RRI Tools[191], funded under the European Horizon 2020 Framework Programme has been set up in order to empower all actors to contribute their share to the Responsible Research and Innovation initiative. The project's final outcome is to develop a set of digital resources (the RRI Toolkit) to advocate, train, disseminate and implement RRI for various target groups: policy makers, researchers, business and industry, civil society organizations, citizens at large, and of most interest to this report, the education community, including teachers, students and families. It should be noted that while most respondents to this survey remarked that nothing or little is being done in relation to RRI issues at school level, 16 countries do in fact feature as partners in the European RRI Tools project, which will eventually produce resources specifically for teachers, students and parents as well as online community of practice where the educational community can discuss and exchange experiences. The partners include four universities/research organizations (from *AT*, *EL*, *NL*, and *UK*), four cultural foundations (from *BE*, *ES*, *IT*, and *PL*), and 8 science centres (from *CZ*, *DK*, *EE*, *FR*, *IE*, *HU*, *PT*, and *SE*). The involvement of these 16 countries in this European project not only shows support for the initiative at national level, but is also encouraging as these countries will benefit from their national partners' involvement through the dissemination of the tools and resources it will produce for schools. This is therefore an encouraging step towards better integrating the concept of RRI at school level in countries across Europe.

7.2 Examples of countries where RRI is already established to some extent in STEM school education and considered as a priority at national level

Just under 15% of countries (ES, IE, IL, SE, and Flanders) stated that RRI is either to some extent or well established as a concept within the specific context of STEM education in their countries, and that it is addressed as a top priority or important issue at national level. Information regarding specific initiatives illustrating this is provided below.

Spain is one of only two countries which considers RRI in relation to school education as a top priority at national level. Spain's involvement in work on this issue is evident through the various projects it leads or is involved in at European and national level, each dealing with specific areas relative to RRI. One example is the European Xplore Health[192] project coordinated by the Spanish IrsiCaixa and "la Caixa" Foundation which develops participative multimedia and hands-on resources with the aim of decreasing the gap between health research and education. The programme promotes Inquiry Based Science Education (IBSE) and the interaction of students with different social actors for them to become active citizens in the knowledge society. It is run through the internet, schools, research centres and science museums. The project clearly promotes important aspects of RRI by developing teaching and learning resources for ethical debates, promoting the engagement and interaction of different stakeholders, and ensuring research results are communicated effectively to them. Spain's Institute for Biocomputation and Physics of Complex Systems also leads the European project Socientize[193], which is based on the innovative concept of 'citizen science' which involves the general public in scientific processes. The project helps citizens, including teachers, students and parents, to understand science by letting them participate in scientific research and experiments. One concrete example involved 400 students from fourteen Aragonese institutes which took part in a European investigation about tumor cells to advance cancer treatments. The initiative took place in collaboration between the Department of Education, University, Culture and Sports of the government of Aragon and the Institute for Biocomputation and Physics of Complex Systems (BIFI) of the University of Zaragoza, with the support of the Foundation Ibercivis[194].

Another relevant project, funded by the Spanish Foundation for Science and Technology (FECYT) – '¡OJO A LAS INVASORAS!'[195] concerns the identification and monitoring of the current state of invasive species in the Mediterranean Balearic. The principles of RRI are once again strongly promoted as the project encourages citizen participation in the scientific process by inviting them to collect and analyze data. The University of Barcelona is also a partner in the European project Engaging Science[196], which has as one of its explicit main aims to develop teachers' beliefs, knowledge and classroom practice for RRI. The focus is on helping teachers address contemporary science issues and applications relevant to students, as well as provide students with a strong foundation to engage in science issues they will encounter during their lives.

Israel is another other country which considers RRI in relation to STEM education as a top priority issue, demonstrated by the various initiatives it is conducting in this area. The main school educational project promoting RRI at national level is ASAM[197]. ASAM is a network of school-based research units and academic institutions in Israel, set up in 2008. Schools are transformed into long-term monitoring stations on climate, ecological and social processes for student-led research projects. The ASAM project aims at engaging up to 18 schools from South Israel. It consists of a joint community of students, teachers and scientists from diverse academic institutions. They collaborate with a view to developing healthy and robust socio-ecological systems at local, regional and global level. Each school operates as an active monitoring and research station on the climate and the local socio-ecological systems. The school stations are linked up with other regions of Israel, a country diverse both in terms of climate and population. This configuration enables joint learning and scientific ecological collaboration. The project is funded by the Ministry of Science, Technology and Space and is carried out by the Dead Sea and Arava Science Centre in close collaboration with Long Term Ecological Research (LTER) Israel/MAARAG – the programme of the Israel Academy of Sciences for monitoring nature. The Ministry of Education has recently announced that the ASAM project has merged with the related GLOBE project[198].

The above project collaborates closely with the MAARAG initiative[199] of the Israel Academy of Sciences. MAARAG (the Hebrew acronym for studying ecological eystems as a network) is a consortium of organizations responsible for managing open spaces. Its objective is to support open space management with emphasis on biodiversity management and nature conservation in Israel. Since its establishment in 2007 the MAARAG has established monitoring and research activities at permanent sites throughout Israel. It also provides a national monitoring programme for the regular and continuous tracking of ecological changes in open spaces. The Arava RTD Centre of the Ministry of Science, Technology and Space is a main partner in the Maarag initiative. It leads the establishment of a network of schools that are integral functional partners in the process of nature monitoring in Israel in cooperation with the MAARAG. This network has adopted and continues to disseminate Responsible Research and Innovation principles.

Finally, just like in Spain, Israel's universities also promote Responsible Research and Innovation principles and practices through participating in European projects devoted to this. One relevant and current example is the University of Haifa's participation in the ASSET project (Action plan on Science in Society related issues in Epidemics and Total pandemics)[200]. The project aims to effectively address scientific and societal challenges raised by pandemics and their associated crisis management. ASSET combines public health, vaccine and epidemiological research, social and political sciences, law and ethics, gender studies, science communication and media, in order to develop an integrated, transdisciplinary strategy, which will take place at different stages of the research cycle, combining local, regional and national levels.

In **Sweden**, the 'NT-satsning' (the Science and Technology Investment Programme) promotes

RRI principles and practices in the professional development services it provides for in-service Science and Technology teachers.

Flanders decided, as a key result of the mid-term evaluation of its STEM Action Plan 2012-2020, to make the societal impact of STEM the leading focal point for the next 5 years of the strategy's roll out.

7.3 Science education for responsible citizenship

As this section illustrates, a few countries either have the concept of RRI incorporated into the curriculum, or are actively involved in projects which promote young people's direct involvement in scientific research for the benefit of society. However, in the majority of countries surveyed the concept is still not well established, particularly in the area of school education, despite this domain's crucial role. To help countries identify ways in which education might best contribute, the European Commission's Directorate-General for Research and Innovation recently commissioned a report from its expert group on Science Education, entitled 'Science Education for Responsible Citizenship' published in the summer of 2015 (European Commission (b), 2015). The report identifies the main issues involved in helping all citizens acquire the necessary knowledge, skills and attitudes concerning science to be able to participate actively and responsibly in, with and for society, successfully throughout their lives. It identifies ways in which science education can help Europe meet its goals and equip citizens, enterprise and industry with the skills and competences needed to provide sustainable and competitive solutions to the challenges we face. The report provides a useful Framework for Science Education for Responsible Citizenship, which identifies six key objectives and associated recommendations as well as indicative actions at European and national level.

The six key objectives include:

> *1. Science education should be an essential component of a learning continuum for all, from pre-school to active engaged citizenship;*
>
> *2. Science education should focus on competences with an emphasis on learning through science and shifting from STEM to STEAM by linking science with other subjects and disciplines;*
>
> *3. The quality of teaching, from induction through pre-service preparation and in-service professional development, should be enhanced to improve the depth and quality of learning outcomes;*
>
> *4. Collaboration between formal, non-formal and informal educational providers, enterprise and civil society should be enhanced to ensure relevant and meaningful engagement of all societal actors with science and increase uptake of science studies and science-based careers to improve employability and competitiveness;*
>
> *5. Greater attention should be given to promoting Responsible Research and Innovation (RRI) and enhancing public understanding of scientific findings and the capabilities to discuss their benefits and consequences;*
>
> *6. Emphasis should be placed on connecting innovation and science education strategies, at local, regional, national, European and international levels, taking into account societal needs and global developments.*

In combination, these objectives together with their accompanying recommendations and actions have the potential to bring about systemic and sustainable changes for collective impact.

CONCLUSIONS

High quality STEM education has a vital role to play in contributing to society's sustainable development through R&D, innovation, productivity and competitiveness. However, **recent evidence illustrates that in both mathematics and science, underachievement of 15-year-olds remains above the ET 2020 benchmark of 15%, and most countries across Europe continue to face a low number of students interested in studying or pursuing a career in the STEM field.** As illustrated in this report, it is for these reasons, that **not only do we observe ongoing strategies, policies and initiatives continuing to receive political and financial support, but also the creation of new ones**, many of which have been launched within the last year. It is therefore no surprise that around **80% of the 30 countries surveyed describe STEM education as currently a priority area at national level, at least to some degree.** Moreover, **the continued commitment to improving STEM education is testified by the majority of countries who either currently have dedicated strategies, or broader strategies with an emphasis on STEM education in place, or are currently planning their development.** Aligned with the findings of the previous edition of this publication, **promoting inquiry-based learning still remains the top priority for STEM related education policy and practice for the large majority of countries surveyed**. Moreover, **almost all countries are currently prioritizing STEM curriculum reform at either or both primary and secondary level, which is often linked to incorporating inquiry-based methods and teaching socio-economic aspects of science**.

A significant proportion of initiatives at national as well as European level contributing to the effort to improve STEM education are related to initial teacher training and continuous professional development. On the basis of the evidence in this report, **more is being done at national level to improve STEM related professional development for teachers, in comparison to initial teacher training in this area.** This means that **countries are currently prioritizing the short-term need to update the skills of in-service teachers to better ensure they are equipped with the latest pedagogical methods and resources available to motivate learners and improve their attainment in STEM subjects**. However, if the teaching of STEM subjects as well as students' achievement and interest in pursuing STEM related studies and careers is to be significantly improved, **it will also be necessary for countries to invest further in modernizing STEM initial teacher training programmes to ensure new teachers entering the profession are sufficiently prepared to teach and inspire the future scientific generation.** A small group of countries are dedicating efforts to this, and this report describes current examples of initiatives which other countries might be inspired by, including: the development of new dedicated degree programmes (*MT*, *UK*); the updating of initial teacher training courses to reflect national STEM student curriculum reforms (*LT*, *LV*, *NL*); a school residency programme (*IL*); and the setting up of a STEM teachers education forum to promote cooperation between teachers and universities to jointly establish national quality standards for STEM initial teacher education (*FI*). Moreover, **it is the recommendation of this report that more countries get involved in or further exploit the results of national or European STEM-related projects, to usefully fuel developments in initial teacher training.** A few countries (*BE*, *EE*, *AT*) have already benefitted in this way from the outputs of such projects, which have led to developments such as the incorporation of innovative pedagogies and resources into existing teacher training programmes, as well as the building of professional development networks.

The analysis in this report strikingly shows that 80% of countries agree that two closely related areas (namely: knowledge and ability to analyze students' beliefs and attitudes towards STEM and, knowledge and ability to teach STEM taking into account the different interests of boys and girls), are not addressed sufficiently in initial teacher education programmes or continuous professional development courses. This may help explain why at present, and since many years, STEM teaching often does not adequately take into account students' STEM-related beliefs and attitudes or their gender-specific interests (Rocard 2007, Osborne 2008, OECD 2015). This report recommends that national and European policies and initiatives enabling prospective and in-service teachers to be made aware of the importance of attitudes and gender in impacting on students' motivation to study and pursue STEM careers, be developed, including the provision of specific guidance on pedagogical methods and resources available to address the issue in the classroom.

Particularly innovative approaches to teacher professional development reported by countries include a special emphasis on peer learning and collaboration between teachers. The focus of these initiatives in Flanders, Denmark, Latvia and Sweden is on the individual and joint reflective practice of teachers, and the active co-development of teaching methods and resources by peers. In these innovative approaches to in-service education, the teachers themselves become jointly responsible for their own professional development.

The advent of sophisticated online teacher professional development, including through Massive Open Online Courses (MOOCs), is also noteworthy in comparison to the limited STEM e-learning initiatives for teachers reported on by a minority of countries in the 2011 edition of this report. **Five years since the publication of that last report, 70% of countries now report that they either have implemented, currently have or plan online professional development for STEM teachers, testifying to the increasing popularity and acknowledged usefulness of this mode of training. Online professional development provides an excellent platform for the creation of professional teaching communities, allowing participants to continue to collaborate and learn from one another beyond the end of a specific online course. It is the reason why Scientix, the project within the framework of which this report has been produced, provides online communities of practice, Moodle courses and webinars allowing teachers all over Europe to engage in online professional development bringing them in direct contact with the latest innovations to STEM teaching and learning. These diverse online learning opportunities allowing**

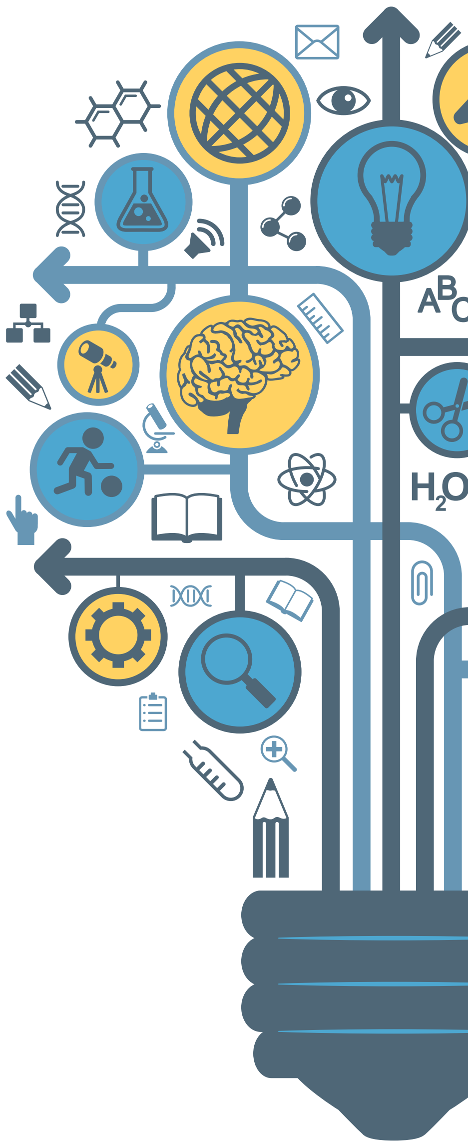
for flexible learning on selected topics can be followed so as to best suit teachers' schedules, and often include discussion forums where teachers can learn and exchange with peers from across Europe, involving them actively in an online learning community. Moreover, the Scientix community offers a bottom-up approach allowing any STEM related project registered on the Scientix repository to schedule an online meeting, webinar or workshop for up to 200 participants, using the online tools available.

When the Scientix community was recently asked (through various online fora and face-to-face events involving STEM teachers and experts) what Scientix could most usefully provide for the STEM education community in the future, the overwhelming majority suggested a concentrated focus on providing more teacher training and professional development. It was felt that such training, whether online or face-to-face, should particularly target student teachers and recently qualified STEM educators, encouraging them to engage with the latest STEM education resources and learning communities within Scientix – assumed perhaps by some teachers as an expert community for advanced STEM teachers, rather than an inclusive one also open to less experienced teachers like themselves (Baldursson, R. H. & Stone, M. J. 2015). This finding fits perfectly with the survey results analysed in this report which illustrate that more could be done particularly to enhance STEM initial teacher education. In view of certain countries being currently unable to invest in updating STEM initial teacher education at national level (whether for political, financial or other reasons), they might be well advised to focus their efforts in a first step on promoting the rich resources and innovative online communities readily available within Scientix to their future STEM teachers.

The Responsible Research and Innovation (RRI) agenda has recently gained prominence at European level, and could play a role in motivating students to pursue STEM studies and careers, by bringing the societal aspects of STEM to the forefront. However, currently, RRI mostly remains the concern of academia and has yet to be fully embedded within national school education systems. More awareness raising is needed, and countries would benefit from examples of how school education might best contribute to the RRI agenda. It will be interesting to monitor in the future how countries respond to the recommendations and actions suggested by the recent report 'Science Education for Responsible Citizenship' commissioned by the European Commission, and to observe how their implementation might contribute to firmly embedding Responsible Research and Innovation practices into the education system and lifelong learning process, for the long-term benefit of society.

This report has focused on national STEM education strategies and priorities, and particularly on initiatives aimed at improving STEM related initial teacher education and professional development. It is needless to say however, that improving STEM teacher education is only one way of contributing to increasing young peoples' interest in pursuing STEM studies and careers. Various national and European initiatives are in place which target other important and influential dimensions, including: updating STEM student curricula; modernizing STEM pedagogy and resources; maintaining dedicated centres for STEM teaching and the popularization of science for all citizens; conducting competitions and campaigns to attract talented students; providing STEM career guidance; and addressing the gender balance of STEM students and professionals. More information regarding initiatives in these areas can be accessed in the national survey responses associated to this report, available on the Scientix portal[201]. One example of an encouraging and ongoing successful initiative at European level which aims to contribute to increasing young peoples' uptake of STEM studies and careers, is the European Union Contest for Young Scientists (EUCYS)[202]. Through this contest which began in 1989, the European Commission continues to support member states in their efforts to attract young people to STEM careers. The contest annually invites young scientists aged between 14 and 20 years of age to take part in a project-based STEM challenge. Projects related to all STEM disciplines can be submitted to the contest, including biology, chemistry, physics, mathematics, engineering, computer science, environmental science, medicine and social sciences. The continued aim of the contest is to promote collaboration and exchange between young scientists, to showcase the best of European student scientific achievement and attract widespread media attention.

Finally, many of the strategies, policies and initiatives described in this report have only very recently been launched. It will therefore be useful for the national and European research and policy making communities to closely follow their development and monitor their impact to inform STEM education progress in the future.



CONTRIBUTORS

AUSTRIA

From the Scientix National Contact Point:

Karl Lehner
Education Consultant and Head of Department IT/3
Federal Ministry of Education and Women's affairs

Axel Zahlut
Education Consultant and Head of Department IT/3
Federal Ministry of Education and Women's affairs

BELGIUM / FLANDERS

Other contributors:

Rita Dunon
Policy Advisor
Department of Education and Training Flanders

Christel Op De Beeck
Policy Assistant
Department of Education and Training Flanders

BULGARIA

From the Scientix National Contact Point:

Evgenia Sendova
Assoc. Professor
Institute of Mathematics and Informatics, Bulgarian Academy of Sciences (IMI-BAS)

Toni Chehlarova
Associ. Prof., Chair of the Education of Mathematics and Informatics Department
Institute of Mathematics and Informatics, Bulgarian Academy of Sciences (IMI-BAS)

Todor Branzov
PhD Student, coordinator of Viva Cognita
Institute of Mathematics and Informatics, Bulgarian Academy of Sciences (IMI-BAS)

Konstantin Delchev
Fair Director of INNOFAIR
CYS, IMI-BAS

CROATIA

From the Scientix National Contact Point:

Tina Marković
Specialist for EU projects
Croatian Academic and Research Network - CARNet

Jurica Vratarić
Head of Support Centers
Croatian Academic and Research Network - CARNet

Other contributors:

Ivana Katavić
Senior Adviser of Physics and Technical Education
Croatian Education and Teacher Training Agency

CYPRUS

From the Scientix National Contact Point:

Christina Mappouridou
Scientific Researcher, Learning in Science Group
Department of Educational Science
University of Cyprus

Other contributors:

Andreas Papastylianou
Physics Inspector
Cyprus Ministry of Education and Culture

CZECH REPUBLIC

From the Scientix National Contact Point:

Vladimíra Pavlicová
Consultant
Centre for International Cooperation in Education

Barbora Grečnerová
Manager
Centre for International Cooperation in Education

DENMARK

From the Scientix National Contact Point:

Tommy Byskov Lund
Strategic ICT Consultant
National Centre for Science Education (NTS-centeret)

ESTONIA

From the Scientix National Contact Point:

Reet Rannik
Coordinator
Estonian Research Council

Other contributors:

Ülle Kikas
Advisor on Mst Education
Ministry of Education and Research

FINLAND

From the Scientix National Contact Point:

Maija Pollari
Communications Coordinator
Luma Centre Finland

Lauri Vihma
Coordinator
Luma Centre Finland

Other contributors:

Tiina Tähkä
Counsellor of Education
Finnish National Board of Education

Jukka Tulivuori
Counsellor of Education
Finnish National Board of Education

FRANCE

From the Scientix National Contact Point:

Elena Pasquinelli
Project Officer
La main à la pâte Foundation

Laurence Constantini
Head of International Relations
t à la pâte Foundation

Other contributors:

Nathalie Terrades
Officer at DGESCO
Ministry of National Education, Higher Education and Research

With the Support of a Group of Experts: Samuel Gouyet, Christine Trabado, Dominique Rojat and Patrick David

GREECE

From the Scientix National Contact Point:

Prof. Christos Kaklamanis
Acting President of Cti "Diophantus"
Computer Technology Institute and Press (Cti) "Diophantus"

Other contributors:

Dr Sofoklis Sotiriou
Head of the Research and Development Department of Ellinogermaniki Agogi
Computer Technology Institute and Press (Cti) "Diophantus" & Ellinogermaniki Agogi

Dr Elina Megalou
Deputy Director of Strategy & Digital Educational Content
Computer Technology Institute and Press (Cti) "Diophantus"

Prof. Chronis Kynigos
Professor at the N.k. University of Athens, Educational Technology Lab, School of Philosophy.
N.k. University of Athens & Computer Technology Institute and Press (Cti) "Diophantus"

Prof. Anastasios Mikropoulos
Professor at the University of Ioannina, Department of Primary Education
University of Ioannina & Computer Technology Institute and Press (Cti) "Diophantus"

Demetra Egarchou
Training & Certification Directorate of Cti
Computer Technology Institute and Press (Cti) "Diophantus"

HUNGARY

From the Scientix National Contact Point:

Attila László Főző (PhD)
Head of the ICT Methodology Office - Department of Digital Pedagogy
Educatio Public Services Nonprofit LLC

Bertalan Péter Farkas
ICT Methodology Consultant - Department of Digital Pedagogy
Educatio Public Services Nonprofit LLC

IRELAND

From the Scientix National Contact Point:

Barry O Higgins
Subject Advisor
Professional Development Service for Teachers (PDST)

Caroline Mchale
Team Leader
Professional Development Service for Teachers (PDST)

Anne O Brien
Team Leader
Professional Development Service for Teachers (PDST)

ISRAEL

From the Scientix National Contact Point:

Dov Winer
In House Consultant
Makash – Advancing ICT Applications in Education

ITALY

From the Scientix National Contact Point:

Silvia Panzavolta
Researcher
Istituto Nazionale di Documentazione, Innovazione e Ricerca Educativa (Indire)

Massimiliano Naldini
Researcher
Istituto Nazionale di Documentazione, Innovazione e Ricerca Educativa (Indire)

LATVIA

From the Scientix National Contact Point:

Santa Margeviča
Coordinator of projects
Centre for Science and Mathematics Education of the University of Latvia

Ilze France
Senior Researcher
Centre for Science and Mathematics Education of the University of Latvia

Other contributors:

Velga Kakse
Deputy Head of Department of Curriculum Development
National Centre for Education (Directly Subordinated To the Minister of Education and Science)

LITHUANIA

From the Scientix National Contact Point:

Ausra Gutauskaite
Supervisor
Education Development Centre

MALTA

From the Scientix National Contact Point:

Ms Desiree Scicluna Bugeja
Assistant Director
Department of Curriculum Management, Ministry for Education & Employment (MEDE)

NETHERLANDS

From the Scientix National Contact Point:

Emilie De Vries Schultink
Project Manager
National STEM Platform (Bèta Techniek)

Sebastiaan Smit
Senior Project Manager
National STEM Platform (Bèta Techniek)

NORWAY

From the Scientix National Contact Point:

Jostein Kvisterøy
Senior Adviser
Norwegian Centre for ICT in Education

POLAND

From the Scientix National Contact Point:

Agata Goździk
Head of International Cooperation and Project Management Department
Institute of Geophysics Polish Academy of Sciences

Other contributors:

Małgorzata Szybalska
Director of the Department of Quality of Education
Ministry of National Education

Agnieszka Pietryka
Head of Pedagogical Information Team
Centre of Education Development

Elżbieta Kawecka
Teacher Trainer
Centre for Education and Information Technology of Computers

PORTUGAL

From the Scientix National Contact Point:

Eulália Alexandre
Deputy Director
Direction General of Education, Ministry of Education and Science

Sílvia Castro
Senior Technician
Direction General of Education, Ministry of Education and Science

Isaura Vieira
Teacher
Direction General of Education, Ministry of Education and Science

ROMANIA

From the Scientix National Contact Point:

Anca-Elena Popovici
Lecturer, Faculty of Psychology and Educational Sciences
University of Bucharest

Roxana Zus
Lecturer, Faculty of Physics
University of Bucharest

Other contributors:

Gabriela Streinu-Cercel
Superior Counsellor
National Assessment and Evaluation Centre

Bogdan Cristescu
Superior Counsellor
National Assessment and Evaluation Centre

SLOVAKIA

From the Scientix National Contact Point:

Gabriela Podolanová
Administrative Coordinator
University of Žilina

Other contributors:

Clerks from various Departments
Ministry of Education, Science, Research and Sport

SLOVENIA

From the Scientix National Contact Point:

Andreja Bačnik in Jerneja Bone
Senior Consultants
National Education Institute

Other contributors:

Borut Čampelj
Secretary
Ministry of Education, Science and Sport

SPAIN

From the Scientix National Contact Point:

Cintia Refojo
Head of Scientific Careers Unit
Spanish Foundation for Science and Technology (FECYT)

Other contributors:

Mar Jiménez
Head of Training and Institutional Relations Section
National Institute of Educational Technologies and Teacher Training, Ministry of Education, Culture and Sport

SWEDEN

From the Scientix National Contact Point:

Li Ljungberg Nilsson
Project Manager Competence and Education
Teknikföretagen, Swedish Association of Engineering Industries

Other contributors:

Anna-Karin Mäntylä
Director of Education, Unit for Educational Development
Swedish National Agency for Education

Karin Bårman
Director of Education, Unit for Educational Development
Swedish National Agency for Education

SWITZERLAND

From the Scientix National Contact Point:

Julien James Auzan
Scientific Collaborator, Scientix Project Manager
Swiss Media Institute for Education and Culture (educa.ch)

Susanne Forster
Scientific Collaborator
Swiss Media Institute for Education and Culture (educa.ch)

Other contributors:

Dr. Béatrice Miller
Deputy Managing Director
Swiss Academy of Engineering Sciences (SATW)

Nicole Wettstein
Scientific Collaborator
Swiss Academy of Engineering Sciences (SATW)

TURKEY

From the Scientix National Contact Point:

Tunç Erdal Akdur
Project Coordinator
Directorate General for Innovation and Educational Technologies, Ministry of National Education

UNITED KINGDOM

From the Scientix National Contact Point:

Gill Collinson
Head of National STEM Centre
STEM Learning Ltd.

Pauline Hoyle
Associate Director
STEM Learning Ltd

Other contributors:

Stephanie Aitken
Policy Officer for Science
Department for Education

Ian Menzies
Senior Education Officer for Sciences
Education Scotland

REFERENCES

Baldursson, R. H. & Stone, M. J. (2015) Scientix 2 results: How Scientix adds value to STEM education, European Schoolnet, Brussels: http://files.eun.org/scientix/scientixworks/publications/Scientix_Results_Nov2015_Publication_ONLINE.pdf

Council of the European Union (2015) 2015 Joint Report of the Council and the Commission on the implementation of the Strategic framework for European cooperation in education and training (ET 2020). New priorities for European cooperation in education and training. Adoption (23 November 2015), Brussels: http://data.consilium.europa.eu/doc/document/ST-14440-2015-REV-1/en/pdf.

European Commission (a) (2015) Education and Training Monitor 2015. Luxembourg: Publications Office of the European Union, 2015: http://ec.europa.eu/education/library/publications/monitor15_en.pdf.

European Commission (b) (2015) Science Education for Responsible Citizenship, Directorate-General for Research and Innovation, Brussels: https://ec.europa.eu/research/swafs/pdf/pub_science_education/KI-NA-26-893-EN-N.pdf.

European Commission (c) /Joint Research Centre (2015). Teaching Practices in Primary and Secondary Schools in Europe: Insights from Large-Scale Assessments in Education. JRC Science and Policy Report. Luxembourg: Publications Office of the European Union: https://crell.jrc.ec.europa.eu/sites/ default/files/files/JRC95601.pdf

European Parliament (2015) Report on Empowering Girls through Education in the EU: Committee on Women's Rights and Gender Equality: http://www.europarl.europa.eu/committees/en/femm/reports.html

Eurydice (a) (2011) Science Education in Europe: National Policies, Practices and Research, Education, Audiovisual and Culture Executive Agency, Brussels: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/133en.pdf.

Eurydice (b) (2011) Mathematics Education in Europe: Common Challenges and National Policies, Education, Audiovisual and Culture Executive Agency, Brussels: http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/132en.pdf

Kearney, C. (2011) Efforts to Increase Students' Interest in Pursuing Science, Technology, Engineering and Mathematics Studies and Careers, European Schoolnet, Brussels: http://spice.eun.org/c/document_library/get_file?p_l_id=16292&folderId=16435&name=DLFE-9323.pdf.

KeyCoNet (a) (2014). The European Policy Network on Key Competences in School Education (KeyCoNet) - Conclusions and Recommendations for Strengthening Key Competence Development in Policy and Practice, European Schoolnet, Brussels: http://keyconet.eun.org/recommendations.

KeyCoNet (b) (2014). KeyCoNet Case Study: Ireland - Project Maths, European Schoolnet, Brussels: http://keyconet.eun.org/c/document_library/get_file?uuid=82c93772-eebc-415c-82c8-26a54caabe4b&groupId=11028.

OECD (2015), The ABC of Gender Equality in Education: Aptitude, Behaviour, Confidence, PISA, OECD Publishing: http://dx.doi.org/10.1787/9789264229945-en.

OECD (2013), PISA 2012 Results: Excellence Through Equity: Giving Every Student the Chance to Succeed (Volume II), PISA, OECD Publishing: http://dx.doi.org/10.1787/9789264201132-en.

Osborne J. and Dillon J. (2008) Science Education in Europe: Critical Reflections: http://www.nuffieldfoundation.org/sites/default/files/Sci_Ed_in_Europe_Report_Final.pdf.

Rocard et al. (2007) High Level Group on Science Education, Directorate General for Research, Science, Economy and Science, European Commission, Science Education Now: A Renewed Pedagogy for the Future of Europe: http://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf.

ENDNOTES

1 http://valtioneuvosto.fi/documents/10184/1427398/Ratkaisujen+Suomi_EN_YHDISTETTY_netti.pdf/8d2e1a66-e24a-4073-8303-ee3127fbfcac (in English)

2 https://www.regjeringen.no/no/dokumenter/tett-pa-realfag/id2435042/ (in Norwegian)

3 http://www.education.gouv.fr/cid55255/mene1105413c.html (in French)

4 http://www.sciencesalecole.org/qui-sommes-nous (in French)

5 http://eduscol.education.fr/cid87584/le-college-2016-questions-reponses.html (in French)

6 https://www.dropbox.com/s/l8n89o65jrbizwm/Sc%20Strategy_published%20version.pdf?dl=0 (in English and Maltese)

7 http://public.mzos.hr/Default.aspx (in Croatian)

8 http://www.hzz.hr/UserDocsImages/Preporuke_za_obrazovnu_upisnu_politiku_i_politiku_stipendiranja_14.pdf (in Croatian)

9 https://www.lietuva2030.lt/lt/apie-nacionalines-pazangos-programa (in Lithuanian)

10 http://www.smm.lt/web/lt/strategija (in Lithuanian)

11 http://webarchive.nationalarchives.gov.uk/+/http:/www.hm-treasury.gov.uk/d/robertsreview_introch1.pdf (in English)

12 http://news.bbc.co.uk/nol/shared/bsp/hi/pdfs/science_innovation_120704.pdf (in English)

13 http://www.skillsdevelopmentscotland.co.uk/resources/skills-investment-plans/ (in English)

14 http://www.gov.scot/resource/0038/00388616.pdf (in English)

15 http://dera.ioe.ac.uk/620/1/draft_government_stem_strategy-2.pdf (in English)

16 http://www.neaman.org.il/Neaman2011/Templates/ShowPage.asp?DBID=1&LNGID=1&TMID=581&FID=646&IID=10434 (in English)

17 http://cms.education.gov.il/EducationCMS/Units/MadaTech/HinucMadaTech/Hativot/Atuda/Atuda_MadaitTechnologit.htm (in Hebrew)

18 http://www.cbs.gov.il/www/publications/pw67.pdf (in Hebrew with English abstract)

19 http://cms.education.gov.il/EducationCMS/Units/MadaTech/HinucMadaTech/Ticonim/Project_Tov.htm (in Hebrew)

20 http://cms.education.gov.il/EducationCMS/Units/Mazkirut_Pedagogit/Matematika/ChativaElyona/kol_koree_math.htm (in Hebrew)

21 http://edudoc.ch/record/117294/files/erklaerung_18052015_d.pdf (in German)

22 At this link you can find a list of all STEM institutions supporting cantons in Switzerland: http://mint.educa.ch/de/mint-foerderung-kantone (in German, French, Italian)

23 http://www.bi.zh.ch/internet/bildungsdirektion/de/unsere_direktion/bildungsplanung/arbeitenundprojekte/natech.html (in German)

24 http://www.bi.zh.ch/content/dam/bildungsdirektion/direktion/bildungsplanung/projekte/natech/NaTech_Strategiebericht.pdf (in German)

25 http://www.sbfi.admin.ch/aktuell/medien/00483/00594/index.html?lang=de&msg-id=34877 (in German, French, Italian)

26 https://www.admin.ch/opc/de/federal-gazette/2012/3099.pdf (in German)

27 http://www.vzdelavani2020.cz/images_obsah/dokumenty/strategy_web_en.pdf (in English)

28 www.vzdelavani2020.cz/images_obsah/dokumenty/strategie/dz-rgs-2015-2020.pdf (in Czech)

29 www.rokprumyslu.eu/ (in Czech)

30 https://www.hm.ee/sites/default/files/estonian_lifelong_strategy.pdf (in English)

31 Full report: https://ec.europa.eu/digital-agenda/sites/digital-agenda/files/KK-31-13-401-EN-N.pdf (in English) Executive summary: http://www.eun.org/c/document_library/get_file?uuid=9be81a75-c868-4558-a777-862ecc8162a4&groupId=43887 (in English)

32 http://www.minedu.fi/export/sites/default/OPM/Julkaisut/2012/liitteet/okm03.pdf (in English)

33 https://tiedekasvatus.wordpress.com/brief-in-english/ (in English)

34 http://luma.fi/files/luma-strategy-2014-2025.pdf (in English)

35 http://www.tubitak.gov.tr/tubitak_content_files/BTYPD/strateji_belgeleri/UBTYS_2011-2016.pdf (in Turkish)

36 http://www.pkc.gov.lv/images/NAP2020%20dokumenti/NDP2020_English_Final__.pdf (in English)

37 http://www.cbi.org.uk/media/2612000/engineering_our_future.pdf (in English)

38 http://www.secondocircolodiquarto.it/Sito%202%20CDQ/_DOCUMENTI/NORMATIVA/Linee%20Guida%20Governo%20-%20La%20Buona%20Scuola.pdf (in Italian)

39 http://www.strategy.bg/StrategicDocuments/View.aspx?lang=bg-BG&Id=904 (in Bulgarian)

40 http://dschool.edu.gr (in Greek)

41 http://photodentro.edu.gr/lor (in Greek)

42 http://photodentro.edu.gr (in Greek)

43 http://techniekpact.nl/nationaal-techniekpact-2020 (in Dutch, summary in English)

44 https://www.poraad.nl/files/kernadvies_verkenningscommissie_wetenschap_en_technologie_po.pdf (in Dutch)

45 http://techniekpact.nl/nationaal-techniekpact-2020 (in Dutch)

46 http://www.hea.ie/sites/default/files/action_plan_ict_2014_4final_spr.pdf (in English)

47 http://imst.uni-klu.ac.at/ (in German, including a short project description in English)

48 https://www.sparklingscience.at/en (in English)

49 http://cms.education.gov.il/EducationCMS/Units/HachsharatOvdeyHoraa/MoadeyHeiter/MehandesimLeHoraa.htm (in Israeli)

50 http://www.onderwijstraineeship.nl/ (in Dutch)

51 http://www.eerstdeklas.nl/ (in Dutch)

52 http://www.teachtech.nl/home.html (in Dutch)

53 http://hybridedocent.nl/ (in Dutch)

54 http://www.mon.bg/?go=page&pageId=74&subpageId=143 (in Bulgarian)

55 https://uni-plovdiv.bg/pages/index/40/ (in Bulgarian)

56 https://www.ucsyd.dk/uddannelser/laerer/om-uddannelsen/den-naturvidenskabelige-laereruddannelse/ (in Danish)

57 http://www.via.dk/uddannelser/paedagogik-og-laering/laerer/noerre-nissum/outdoor (in Swedish)

58 http://www.kormany.hu/en/ministry-of-human-resources/news/one-week-left-to-apply-for-klebelsberg-scholarships (in English)

59 http://www.edk.ch/dyn/27569.php (in German, French, Italian)

60 http://www.education.gouv.fr/cid91773/le-ministere-recrute-inscrivez-vous-aux-concours-de-recrutement-d-enseignants-de-personnels-d-education-et-d-orientation.html (in French)

61 http://www.iespejamamisija.lv/lv (in Latvian)

62 http://teachforall.org/en (in English)

63 http://oph.fi/julkaisut/2014/opettajat_suomessa_2013 (in Finnish, abstract in English)

64 http://goo.gl/PKvqwd (in Swedish)

65 http://www.teachforsweden.se/ (in Swedish)

66 http://leu.lt/lt/stojantiesiems/stoj_bakalauro_studijos/stoj_bak_studiju_programos/programs/100303.html (in Lithuanian)

67 http://stwww.weizmann.ac.il/weizmann/foto-in/File/hachshara.pdf (in Hebrew)

68 http://www.arteveldehogeschool.be/STEM-voor-de-basis (in Dutch)

69 https://set.kuleuven.be/English/news/2014/stem-school (in English)

70 http://www.pedagogicum.ut.ee/et/haridusteaduse-opetajakoolituse-edendamise-programm-eduko (in Estonian and English)

71 http://www.prisci.net (in English)

72 http://www.espe.education.fr (in French)

73 http://www.education.gouv.fr/cid87352/de-nouvelles-modalites-d-evaluation-et-de-titularisation-des-enseignants-stagiaires-de-l-enseignement-public.html (in French)

74 http://academia-kita.macam.ac.il/ (in Hebrew)

75 http://goo.gl/Nr2y7B (in Hebrew)

76 http://www.delerarenagenda.nl/de-lerarenagenda/betere-studenten-aan-lerarenopleidingen (in Dutch)

77 http://www.delerarenagenda.nl/de-lerarenagenda/betere-lerarenopleidingen (in Dutch)

78 http://www.delerarenagenda.nl/de-lerarenagenda/aantrekkelijke-en-flexibele-leerroutes (in Dutch)

79 https://www.regjeringen.no/en/topics/education/innsikt/larerloftet/id2008159/ (in English)

80 http://www.swissuniversities.ch/de/hochschulraum/studieren/studieren-in-der-schweiz/ (in German, French, Italian, English)

81 http://www.edk.ch/dyn/11670.php (in German, French, and Italian)

82 http://www.h-mat.cz/en (in English)

83 https://journals.muni.cz/pedor/article/view/2437/2004 (in Czech)

84 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/399957/Carter_Review.pdf (in English)

85 http://luma.fi/3236 (in Finnish)

86 http://www.dge.mec.pt/formacao-0 (in Portuguese)

87 http://www.ise.ro/ghid-pentru-aplicarea-programelor-de-invatamant-primar (in Romanian)

88 http://www.ore.edu.pl (in Polish)

89 http://www.kopernik.org.pl/projekty-specjalne/projekty-europejskie/projekt-przewrot-kopernikanski/ (in polish)

90 http://hedb.meb.gov.tr/net/_standart_program/ (in Turkish)

91 http://www.primas-project.eu/ (in English)

92 http://ettaedu.azoo.hr/ (in Croatian)

93 http://nastavna-sekcija.hfd.hr/pilot-projekt-croatian-teachers-programme-cern/ (in Croatian)

94 http://letssharescience.weebly.com/ | http://virtualnaucionica.weebly.com/ (in Croatian)

95 https://www.skolskiportal.hr/clanak/1774-365-pokusa-kroz-365-dana/ (in Croatian)

96 http://www.zrss.si/nama2012/ (in Slovenian)

97 http://www.zrss.si/naravoslovje2011/ (in Slovenian)

98 http://www.zrss.si/naravoslovje2013/ (in Slovenian)

99 http://www.zrss.si/naravoslovje2015/ (in Slovenian)

100 http://www.zrss.si/kupm2012/ (in Slovenian)

101 http://www.zrss.si/kupm2014/ (in Slovenian)

102 http://www.educationscotland.gov.uk/learningteachingandassessment/assessment/ssln/resources/numeracyprofessionallearningresource/index.asp (in English)

103 http://www.g-o.be; http://www.katholiekonderwijs.vlaanderen/; http://www.ovsg.be/; http://www.oko.be/ (in Dutch)

104 https://www.sciencelearningcentres.org.uk (in English)

105 https://www.sciencelearningcentres.org.uk/impact-and-research/research/research-reports/ (in English)

106 http://www.computingatschool.org.uk/ (in English)
107 http://www.mon.bg/?go=page&pageId=13&subpageId=943 (in Bulgarian)
108 http://educalab.es/intef/formacion/formacion-presencial/congresos-y-jornadas (in Spanish)
109 http://www.upc.smm.lt/veikla/about.php (in English)
110 http://www.upc.smm.lt/projektai/sklaida/naujienos/classmate.php (in Lithuanian)
111 http://mokytojotv.blogspot.com/ (in Lithuanian)
112 http://www.fhnw.ch/ph/iwb/kader/cas-naturtechnik (in German)
113 https://www.phzh.ch/de/Forschung/Forschungsgruppen-zentren/Zentrum-fur-Didaktik-der-Naturwissenschaften-ZDN/ (in German)
114 http://edudoc.ch/record/25685/files/Empf_WBLehrp_d.pdf (in German)
115 http://matematica.isjiasi.ro/ (in Romanian)
116 http://www.scientix-israel.net/files/oz/mathematics (in Israeli)
117 http://www.scientix-israel.net/files/oz/biology (in Israeli)
118 http://www.scientix-israel.net/files/oz/chemistry (in Israeli)
119 http://www.scientix-israel.net/files/oz/physics (in Israeli)
120 http://www.scientix-israel.net/files/oz/sciencetechsociety (in Israeli)
121 http://www.scientix-israel.net/files/oz/technologydisciplines (in Israeli)
122 http://www.scientix-israel.net/files/ofek/mathematics (in Israeli)
123 http://www.scientix-israel.net/files/ofek/scienceandtechnology (in Israeli)
124 http://www.scientix-israel.net/files/ofek/887.pdf (in Israeli)
125 http://www.scientix-israel.net/files/ofek/21stC_competencies (in Israeli)
126 http://www.scientix-israel.net/files/ofek/environment (in Israeli)
127 http://www.nidv.cz/cs/projekty/projekty-esf/karierni-system/vystupy.ep/ (in Czech)
128 http://okm.fi/OPM/Julkaisut/2015/osaamisen_kehittaminen.html?lang=en (in English)
129 http://www.delerarenagenda.nl/de-lerarenagenda/een-goed-begin-voor-startende-leraren (in Dutch)
130 https://www.registerleraar.nl/ (in Dutch)
131 http://www.jet-net.nl/stem-teacher-academy.html (in Dutch)
132 http://www.fondation-lamap.org/en/page/27939/houses-for-science (in English)
133 http://www.anru.fr/index.php/fre/Actualites/Evenements/Laureat-de-l-appel-permanent-a-projets-CSTI-Programme-d-Investissements-d-Avenir6 (in French)
134 http://luma.fi/suomi/ (in Finnish)
135 https://www.regjeringen.no/en/topics/education/innsikt/larerloftet/id2008159/ (in Norwegian)
136 http://www.profiles.lu.lv/fileadmin/user_upload/lu_portal/projekti/profiles/2013/PROFILES_Newsletter_4.pdf (In English)
137 http://photodentro.edu.gr (in Greek)
138 http://ebooks.edu.gr (in Greek)
139 http://ifigeneia.cti.gr/ (in Greek)
140 http://sto.carnet.hr/ (in Croatian)
141 https://www.stem.org.uk/sites/default/files/pages/downloads/isos%20report.pdf (in English)
142 http://formazionedocentipon.indire.it/wp-content/uploads/2014/12/R2_7_Executive-Summary_impaginato.pdf (in Italian)
143 http://formazionedocentipon.indire.it/wp-content/uploads/2014/12/GDA_R1-Report-INDIRE-rev.-10.07.2014_Im_def.pdf (in Italian)
144 http://www.dge.mec.pt/sites/default/files/Basico/Documentos/relatorio_final.pdf (in Portuguese)
145 http://www.agence-nationale-recherche.fr/?Projet=ANR-13-APPR-0004 (in French)
146 http://karvi.fi/en/ (In English)

147 http://player.companywebcast.com/jet_net/20150625_1/nl/Player (in Dutch)
148 http://www.fondation-lamap.org/fr/page/33194/le-2-decembre-participez-au-webinar-locean-et-le-climat (in French)
149 http://hitsa.ee/en (in English)
150 https://www.youtube.com/playlist?list=PLZ_uMqYCd3Q3gLGo-E8KW-nFQzuOpej0x (in Estonian)
151 https://www.youtube.com/playlist?list=PLZ_uMqYCd3Q0U1SiowF2ad9nWXQDbd3i2 (in Estonian)
152 http://www.zrss.si/en/ (in English)
153 https://skupnost.sio.si/ (in Slovenian)
154 www.t4.ie (in English)
155 http://kursy.epodreczniki.pl/course/index.php (in polish)
156 http://creative.dge.mec.pt/ (in English)
157 http://lsl.dge.mec.pt/ (in English)
158 http://itec.dge.mec.pt/ (in English)
159 http://online.lms.education.gov.il/course/category.php?id=7 (in Irsraeli)
160 http://teachers.vcampus.cet.ac.il/ (in Israeli)
161 http://vcampus.teachers2015.cet.ac.il/ (in Israeli)
162 http://educalab.es/intef/formacion/formacion-en-red/cursos (in Spanish)
163 http://cedec.educalab.es/ (in Spainsh)
164 https://www.youtube.com/watch?v=5TnJJnEjgOo&list=UUlumKvuZOFPuPVRLxkbtsZw (in Lithuanian)
165 http://mokomes5-8.ugdome.lt/index.php/dalijames-patirtimi (in Lithuanian)
166 http://www.mastnet.ro/ (in Romanian);
associated e-learning platform: http://elearning.mastnet.ro:8180/ael/login.jspx (in Romanian)
167 http://matematica.isjiasi.ro/(in Romanian);
associated e-learning platform: http://matematica.isjiasi.ro:8180/ael (in Romanian)
168 http://www.arnes.si/storitve/varnost/mooc-v.html (in English)
169 http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=6359 (in English)
170 http://tel.ioe.ac.uk/wp-content/uploads/2012/06/TELreport.pdf | http://www.ucisa.ac.uk/~/media/groups/dsdg/TEL%20Survey%202014_29Sep2014.ashx (in English)
171 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/315591/DfE_RR355_-_Opportunities_for_MOOCs_in_schools_FINAL.pdf (in English)
172 https://www.canvas.net/courses/managing-behaviour-for-learning (in English)
173 https://www.futurelearn.com/courses/assessment-for-learning (in English)
174 https://www.stem.org.uk/online-cpd (in English)
175 http://www.educationscotland.gov.uk/highersciences/physics/guide/professionallearningvideos.asp (in English)
176 http://moocz.dk/course/index.php?categoryid=34 (in Danish)
177 https://e2.moch.dk/klogpaanaturfag/ (in Danish)
178 http://online.lms.education.gov.il/course/category.php?id=67 (in Irsraeli)
179 http://matematikkmooc.no (in Norwegian)
180 http://mooc.educalab.es/ (in Spanish)
181 http://www.carnet.hr/eu_projects/e-schools (in English)
182 http://www.education.gouv.fr/cid72318/m@gistere-accompagner-la-formation-continue-des-enseignants.html (in French)
183 http://www.indire.it/ (in Italian)
184 https://www.ph-online.ac.at (in German)
185 http://goo.gl/4NvGMX (in English)
186 http://eprints.nottingham.ac.uk/3603/1/PearceHartleyTaylorRRI.pdf (in English)

187 https://www.epsrc.ac.uk/research/framework/ (in English)
188 https://www.gov.uk/government/groups/horizon-scanning-programme-team (in English)
189 https://www.sparklingscience.at/en (in English)
190 http://www.arkofinquiry.eu (in English)
191 http://www.rri-tools.eu/ (in English)
192 http://www.xplorehealth.eu/ (in English)
193 http://www.socientize.eu/ (in English)
194 http://www.ibercivis.es/ibercivis-y-bifi-acompanan-a-la-consejera-de-eduacion-aragon-al-acto-de-entrega-diplomas/ (in Spanish)
195 http://ojoinvasoras.info/ (in Spanish)
196 http://www.engagingscience.eu (in English)
197 http://goo.gl/I3lS9m (in English)
198 http://cms.education.gov.il/NR/rdonlyres/0C2B288B-A43C-40CD-916D-712217330E59/143181/resource.docx (in Hebrew)
199 http://www.hamaarag.org.il/en (in English)
200 http://www.asset-scienceinsociety.eu/ (in English)
201 http://www.scientix.eu/web/guest/observatory/comparative-analysis-2015 (in English)
202 http://ec.europa.eu/research/youngscientists/index_en.cfm (in English)

COUNTRY CODES

AT	Austria	**EL**	Greece	**IT**	Italy	**RO**	Romania
BE	Belgium	**ES**	Spain	**LT**	Lithuania	**SE**	Sweden
BG	Bulgaria	**FI**	Finland	**LV**	Latvia	**SI**	Slovenia
CH	Switzerland	**FR**	France	**MT**	Malta	**SK**	Slovakia
CY	Cyprus	**HR**	Croatia	**NL**	Netherlands	**TK**	Turkey
CZ	Czech Republic	**HU**	Hungary	**NO**	Norway	**UK**	United Kingdom
DK	Denmark	**IE**	Ireland	**PL**	Poland		
EE	Estonia	**IL**	Israel	**PT**	Portugal		

IN THE LONG HISTORY OF HUMANKIND (AND ANIMAL KIND TOO) THOSE WHO LEARNED TO COLLABORATE AND IMPROVISE MOST EFFECTIVELY HAVE PREVAILED.

(Charles Darwin)

www.scientix.eu

www.scientix.eu/web/guest/newsletter

@scientix_eu

groups/ScienceTeachersEurope

Scientix (2012-2015) is supported by the European Union's Framework Programme for Research and Development (FP7) and coordinated by European Schoolnet. This publication reflects the views only of the author and it does not represent the opinion of the European Commission, and the European Commission is not responsible or liable for any use that may be made of the information contained therein.