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SCIENCE EDUCATION for Responsible Citizenship

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REPORT TO THE EUROPEAN COMMISSION
OF THE EXPERT GROUP ON SCIENCE EDUCATION

SCIENCE EDUCATION for Responsible Citizenship

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Carlos Moedas
European Commissioner
Research, Science and Innovation

Foreword

This publication on science education offers a 21st century vision for science for society within the broader European agenda. It is the culmination of many months of work by a group of experts brought together by the Commission in 2014.

As the world becomes more inter-connected and globally competitive, new economic opportunities often come hand in hand with complex societal challenges. Therefore, we must engage all of society in research and innovation processes. We must provide the space for open, inclusive and informed discussions on the research and technology decisions that will impact citizens' lives.

Experts refer to this as 'responsible research and innovation', the process of aligning research and innovation to the values, needs and expectations of society. We need science to inform policy, objectively. We need science to inform citizens and politicians in a trustworthy and accessible way. We need to make decisions together – rather than from polarised positions – and to take responsibility for those decisions, based on sound scientific evidence.

As policymakers, we need to better understand, and communicate, the transformative connection between science, innovation and society. How we will provide the workforce for future markets and innovative industries in Europe is still uncertain. For young people to aspire to such careers in science, technology, engineering and mathematics we need to bring emerging technologies and markets closer to the classroom, we need to ignite their imagination. Skills gaps do not fill themselves, people do. We need to engage young people at an early age. Responsible research and innovation should, by its very definition, get everyone involved.

This report is aimed primarily at science education policy makers. It identifies the main issues involved in helping citizens to access scientific debate; it provides guidance on how industry can contribute to science education; and it proposes a new framework for all types of science education from formal, to non-formal and informal approaches. Public engagement has already made a real difference in the governance and decision-making process of Horizon 2020: providing a space for the citizen to tell us what works and what doesn't, what's important and what's not. Now it's hard to imagine going back.

I commend the work of the experts who have compiled this report. I believe that it makes a substantive contribution to the policy debate within Europe on how best to equip citizens with the skills they need for active participation in the processes that will shape everyone's lives.

Executive Summary and Recommendations

The European Union has set ambitious goals: to promote smart, sustainable and inclusive growth, to find pathways to create new jobs and to offer a sense of direction to our societies.[1] This requires significant strengthening of our knowledge and innovation capacity and our creative capability as drivers for future growth.[2]

As the world becomes more inter-connected and competitive and as research and technological know-how expands, new opportunities along with more complex societal challenges arise. 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. It will involve input from user groups, specialists and stakeholder groups. Professionals, enterprise and industry have an important role to play. In this way, everybody learns and benefits from the involvement.[3]

At the moment, Europe faces a shortfall in science-knowledgeable people at all levels of society and the economy. Over the last decades, there has been an increase in the numbers of students leaving formal education with science qualifications. But, there has not been a parallel rise in the numbers interested in pursuing science related careers nor have we witnessed enhanced science-based innovation or any increase in entrepreneurship.[4]

Science education research, innovation and practices must become more responsive to the needs and ambitions of society and reflect its values. They should reflect the science that citizens and society need and support people of all ages and talents in developing positive attitudes to science. We must find better ways to nurture the curiosity and cognitive resources of children. We need to enhance the educational process to better equip future researchers and other actors with the necessary knowledge, motivation and sense of societal responsibility to participate actively in the innovation process.

This is a good time to expand opportunities for science learning, in formal, non-formal and informal settings. Evidence shows that European citizens, young and old, appreciate the importance of science and want to be more informed and that citizens want more science education.[5] Over 40 % believe science and technological innovation can have a positive impact on the environment, health and medical care and basic infrastructure in the future.[6]

This report identifies the main issues involved in helping all citizens acquire the necessary knowledge of and about science to participate actively and responsibly in, with and for society, successfully throughout their lives. It provides guidance concerning increasing the participation of enterprise and industry to science education policy and activities. It sets out the challenges we face and how science education can help Europe meet its goals and equip citizens, enterprise and industry in Europe with the skills and competences needed to provide sustainable and competitive solutions to these challenges. A more responsive science education *can* promote broader participation in knowledge-based innovation that meets the highest ethical standards and helps ensure sustainable societies into the future.[7]

The *Framework for Science Education for Responsible Citizenship* identifies six key objectives and associated recommendations, which in combination, can help bring about the systemic changes required to generate a sustainable effect across our societies and in our communities.

Objectives and Recommendations

1

Science education should be an essential component of a learning continuum for all, from pre-school to active engaged citizenship.

- Education policies and systems should:
  - Ensure that science is an essential component of compulsory education for all students;
  - Support schools, teachers, teacher educators and students of all ages to adopt an inquiry approach to science education as part of the core framework of science education for all;
  - Address socio-economic, gender and cultural inequalities in order to widen access and provide everyone with the opportunities to pursue excellence in learning and learning outcomes;
  - Create mechanisms to foster individual reflection and empowerment.
- Science education should balance requirements of breadth and depth of knowledge about science to ensure young people and adult learners are both motivated to learn and equipped to fully engage in scientific discussions and decisions and to facilitate further and deeper study.

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.

- Greater attention should be given to the value of all disciplines and how inter-disciplinarity (STEAM rather than STEM) can contribute to our understanding and knowledge of scientific principles and solve societal challenges.
- Educational institutions, at all levels, should boost understanding the importance of science education as a means of acquiring key competences to ease the transition from “education to employability” (E2E), by
  - Learning about science through other disciplines and learning about other disciplines through science;
  - Strengthening connections and synergies between science, creativity, entrepreneurship and innovation.
- More emphasis should be placed on ensuring all citizens are equipped with the skills and competences needed in the digitalized world starting with preschool.

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.

- Actions should be taken to continually improve teaching quality, with greater focus on teacher competences, disciplinary knowledge, avoiding gender stereotyping and on students and teachers learning together.
- Efforts should be undertaken to attract more highly qualified and motivated people to become teachers and to boost the status and prestige of the profession.
- Greater emphasis should be given to closing the research-practice gap, by embedding science education research findings into teacher preparation, curriculum development, teaching and learning and assessment for learning (AfL).
- Appropriate methodologies should be developed for teaching research ethics and raising awareness of research integrity.
- Continuous Professional Development (CPD) should become a requirement and a right for all teachers throughout their teaching career.

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.

- Encourage "open schooling" where
  - Schools, in cooperation with other stakeholders, become an agent of community well-being;
  - Families are encouraged to become real partners in school life and activities;
  - Professionals from enterprise, civil and wider society are actively involved in bringing real-life projects into the classroom.
- Promote partnerships between teachers, students, researchers, innovators, professionals in enterprise and other stakeholders in science-related fields, in order to work on real-life challenges and innovations, including associated ethical and social and economic issues.
- Develop guidelines on how to integrate responsibility and responsiveness into formal, non-formal and informal Science Education, following the principles of CSR (Corporate Social Responsibility) and RRI (Responsible Research and Innovation).
- Promote partnerships that foster networking, sharing and applying science and technology research findings amongst teachers, researchers and professionals across different enterprises (start-ups, SMEs, large corporations).

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.

- The link between scientists, researchers, science educators and the media should be strengthened to ensure more effective public communication, in a way that makes the underlying issues and consequences understandable by citizens.
- Science educators, at all levels, have a responsibility to embed social, economic and ethical principles into their teaching and learning in order to prepare students for active citizenship and employability.
- Publicly-funded science education researchers have a responsibility to openly communicate, share and disseminate research outcomes with wider society and to the international research community.
- Citizens should be actively and directly involved in science research and innovation projects.

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.

- Links between Responsible Research and Innovation strategies at local, regional and national level should be strengthened and evaluated in order to overcome regional and other disparities across Europe and to increase the innovation capabilities of enterprise, particularly SMEs.

- Collaborating and sharing knowledge of and about science and science communication, as well as identifying solutions for global societal challenges facing humankind, should be actively pursued with international partners.

- Science education should benefit from an agreed set of international guidelines, evidence-based and grounded on collaborative and inclusive deliberations.

RECOMMENDATIONS TO THE EUROPEAN COMMISSION

Given the multi-facetted nature of the objectives and recommendations, it is strongly recommended that key actors across the European Commission come together to initiate an EU-wide response, to include a participatory consultation and dialogue process on the report and the proposed actions.

A comprehensive programme of dissemination should also be developed.

1 Addressing Societal Challenges

The world around us is changing.[8] Global competition and technological developments are transforming the world economy and integrating the labour market while opening personal, professional and business opportunities for all citizens, enterprise and industry across Europe. This has encouraged new patterns of social mobility and migration, greater inter-connectivity between and within societies and cultures and boosted individual and community empowerment.

Our population is growing but it is also aging; more people are living in cities and in smaller households. Digital technologies are used intensely and extensively throughout all aspects of contemporary life. Children entering school now will live beyond the end of this century and are likely to change careers two or three times over their lifetimes.[9]

As these developments quicken pace, there is much greater appreciation of the necessity to involve the entire pool of human resources and talent. They are placing new demands on our governments, educational institutions, businesses and civil society organisations to meet the evolving needs of society and the workplace. They are also straining existing resources, including: energy, environment, food, water, housing, communication, social cohesion and culture.

To meet these scientific and technological challenges, the European Union has adopted a strategy based on three key drivers:[10]

- Smart growth (fostering knowledge, innovation, education and digital society),
- Sustainable growth (making our production more resource efficient while boosting our competitiveness) and
- Inclusive growth (raising participation in the labour market, the acquisition of skills and the fight against poverty).

Our success in meeting these objectives is linked to the ability of our societies to educate smart, creative and entrepreneurial individuals with the confidence and capability to think autonomously and critically, engage in lifelong learning (LLL), as well as the ability to generate new knowledge, social and technological innovation and utilise and adapt to technological change. This requires input from all our citizens with the competences and confidence in future possibilities as well as

the desire, engagement and capabilities for active citizenship, from an early age.[11]

Reducing poverty, widening participation and improving socio-economic and gender equality are important personal and societal goals, but they are also vital preconditions for ensuring sustainable, inclusive and responsible development and prosperity across Europe and the rest of the world.

2 Why Science Education Matters

This is a really exciting time to be involved in science. But, are we preparing all our citizens sufficiently now and for the future?

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.

Research clearly shows that educational attainment is linked to better health, personal empowerment and active engagement in public affairs and civil society, being more trusting and supportive of other people, as well as enhanced employability.[12] Society faces a range of challenges,[13] such as feeding and housing our population, healthy living, protecting our environment, generating sufficient energy, supplying enough clean water, urbanisation and global climate change. We have a much better chance of tackling these challenges if all societal actors understand the issues and their consequences and are actively involved in helping identify and monitor society's responses.

By working together in an inclusive participatory way, we can better align the goals and outcomes of science education and research with the values, needs and expectations of European society.[14] Democratic societies require an engaged and responsible citizenry contributing at all levels of society, across Europe and the world.

Science education is vital:

- To promote a culture of scientific thinking and inspire citizens to use evidence-based reasoning for decision making;
- To ensure citizens have the confidence, knowledge and skills to participate actively in an increasingly complex scientific and technological world;
- To develop the competencies for problem-solving and innovation, as well as analytical and critical thinking that are necessary to empower citizens to lead personally fulfilling, socially responsible and professionally-engaged lives;
- To inspire children and students of all ages and talents to aspire to careers in science and other occupations and professions that underpin our knowledge and innovation-intensive societies and economies, in which they can be creative and accomplished;

- To enable public, private and third-sector organisations, based in Europe, to find appropriately skilled and knowledgeable people and to promote and nurture an innovative Europe-wide environment where companies and other stakeholders from around the world want to invest, work and live;

- To empower responsible participation in public science conversations, debates and decision-making as active engagement of European citizens in the big challenges facing humanity today.

Science learning helps us to interpret and understand our world, to manage risk and put uncertainty into perspective, to guide technological development and innovation and to forecast and plan for the future. It improves job prospects, cultural awareness and our ability to act as well-informed citizens in solidarity with citizens around the world.[15]

For some people, science refers only to knowledge of physical systems, living systems, earth and space systems and technology. Sometimes it refers specifically to STEM (science, technology, engineering and mathematical) disciplines. Too often, science is seen as something separate from all other subjects or disciplines in education, disconnected from people's lives beyond school.

But, science influences all parts of our lives and our decision-making processes. Along with language and artistic literacy, knowledge of science and mathematics is the basis for personal accomplishment and responsible citizenship, social and economic development and a benchmark of innovation, entrepreneurship and competitiveness in our global world.

A more integrative and interdisciplinary approach is required.

We need to link science or STEM with all other subjects or disciplines at all levels of education. As well as a focus on learning through science, this means taking other disciplines as a starting point to introduce scientific thinking. It means incorporating the knowledge and the methods and approaches of more than one disciplinary context to enable new ways of thinking and identifying solutions to problems that fall outside the boundaries of just one discipline. This requires new ways of working and strengthening links and interaction between formal, non-formal and informal science education.

Accordingly, our focus should shift from STEM to STEAM (within which the A includes ALL other disciplines).[16]

3 Problems and Challenges in Science Education

Science education in Europe sits at an important crossroads. Despite public and policy emphasis on the importance of science and technology and substantial improvements in participation and performance, important deficits and wide differences in educational outcomes and public understanding exist across Europe, both within and across countries.

Research is telling us that our future could be undermined by:

- Unevenness in basic science literacy across Europe which is necessary to ensure a rigorous understanding and use of scientific knowledge in decision-making, particularly in domains such as health, the environment, food, energy and consumption;[17]
- Wide disparities in participation in science education, in formal, non-formal and informal settings, across regions, cultures and gender which are blocking full involvement in society of all citizens and talents;[18]
- Declining interest in science studies and related careers that are essential to meet the demand for well-prepared graduates (at all levels) and researchers, especially amongst women, necessary for our knowledge and innovation-intensive societies and economies;[19]
- Concerns about quality arising from a mismatch between demand and supply of qualified teachers and about the gap between science education research findings and what happens in the classroom;[20]
- Insufficient understanding of the breadth of competences required of teachers and teacher educators for enhancing personal and collaborative achievement, innovation and cultural and economic sustainability;[21]
- Inadequate teaching and insufficient family involvement needed to inspire children's curiosity and the need to shift the emphasis from knowing facts to doing innovative and enjoyable things with knowledge, including being creative with the application of ideas;[22]
- Short-fall in skills and competences required to identify early-stage global trends necessary to reach EU targets for smart and sustainable growth and high value-added jobs responding to the need to design science-based solutions to the global challenges;[23]
- Insufficient investments in strategic co-operation and development of ecosystems that would foster effective adoption of latest research findings and emerging technologies in industry and enterprise, particularly SMEs;[24]

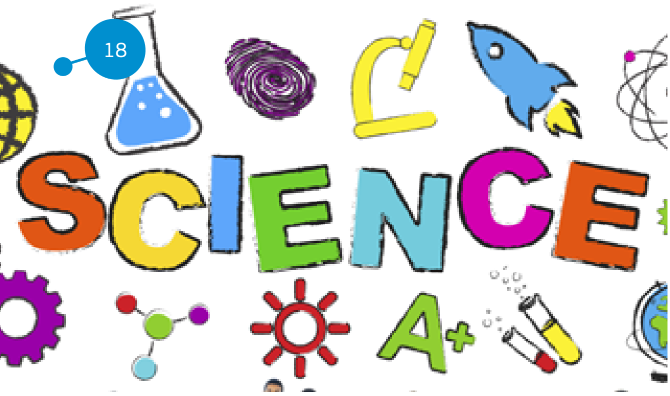
- Inadequate public knowledge about and understanding of the complexities of the scientific and social challenges facing humanity, across Europe and globally;[25]

- Little involvement of stakeholders in science education policy, research, development and innovation, particularly between students, families, teachers, employers and civil society in the formal education system.[26]

In order to meet Europe's objectives, the difficult challenge is to find ways to assess the learning outcomes of science education and the long-term impact of initiatives in different cultural contexts and to translate the results for collective impact and benefit. Continuing evaluation of outcomes should be a component of all educational initiatives. The whole process should be informed by the ways people, communities and societies learn, adapt and change their behaviour.[27]

There is an opportunity to create long-term added value through enhanced collaboration between science educators and other key actors across society at national, European and global level. We need to identify a common set of priorities to bring about systemic and sustainable reform, achievable for all.

The issues are complex and multi-factorial, but the good news is that policy decisions can and do make a difference.



4 The Way Forward

Schools are one of the most important institutions in which citizens have the opportunity to engage with structured science learning. The last 25 years has seen an expansion in the numbers of children accessing science education across Europe.[28]

But school science is just one part of the learning continuum. Underpinning personal achievement throughout one's life and meeting the needs of society and the economy into the future will require on-going life-long learning. Achieving long-term, sustainable change requires a whole-of-education and a whole-of-society approach. This involves all societal actors, building stronger links between knowledge and skills and encouraging careers in science and from science, from an early age. This includes encouraging more PhD graduates to take up positions in industry and particularly in SMEs, which are the backbone of the European economy. There is a strong need to relate science education to the innovation system.

Transforming new ideas gained from research into useful knowledge, products and services depends upon deeper and on-going connectivity between schools and non-formal and informal learning environments, families, enterprise, civil society and government.[29] At the same time, more must be done to close the gap between our highest and our lowest achievers by taking steps to reduce socio-economic, gender and regional disparities across Europe and within member states. Education systems and working life should provide inspiring challenges, learning opportunities and learning paths to help citizens reach their full potential. Ultimately, we must ensure all citizens have the same opportunities so that our societies can benefit from all talents.[30]

Our future personal and societal success is dependent upon citizens' ability to learn and acquire a "broader knowledge base, more specialised skills, advanced analytical capacities, complex communications skills" and utilise, shape and adapt technological changes.[31]

Realising these goals demands a holistic, systemic and multipronged approach described in the following chapters.

Chapter 4 – provides the evidential basis for the six high-level objectives.

Chapter 5 – presents *The Framework for Science Education for Responsible Citizenship*, which aligns each of the six high-level objectives with recommendations. Indicative actions are proposed for the EU and member states, linked to each set of recommendations.

Chapter 6 – presents *The Science Education Research Programme* which outlines research themes which can enhance our understanding of science education – what works and what we can do better.

Chapter 7 – provides *Examples of Interesting Practices* as a selection of individual projects and community and national initiatives from across

Europe and internationally, as a basis for shared learning. This section also provides a useful resource for future innovations.

4.1 Science education should be an essential component of a learning continuum for all, from pre-school to active engaged citizenship.

Research shows that learning is important for individuals of all ages. It is not a simply cognitive activity but affects who we are and how we develop.[32] Science learning contributes to personal well-being and fulfilment, promotes full economic and societal participation, supports creativity and innovation and enables people to be better informed and more autonomous and active citizens.

The concept of lifelong learning stresses that "learning throughout life is a continuum."[33] How we engage with learning, in formal, non-formal and informal settings, has an impact on our ability to take up or have access to opportunities throughout our lives. To overcome educational gaps, we should take a "whole of education" approach, embracing all levels and parts of the system in a holistic way. Because the graduate of today is the product of the entire education system, it is important to ensure complementarity and consistency in the skills and aptitudes that are nurtured and developed at all levels of education.

From an early age, children show a spectrum of capacities and propensities to observe, explore and discover the world around them. They can grasp the basics of mathematics and begin to solve challenging problems about their worlds. They often have access to the internet and digital technology through an array of devices that are wholly portable and mobile.

However, because of missed opportunities in early childhood and school education, many people do not attain "minimum levels of core skills necessary to cope with the complexities of life and work in the 21st Century"[34] As part of the shift from preparing people for lifelong employment to lifelong employability, people need to leave compulsory education with knowledge of and about science and its culture and values and with positive attitudes towards and a willingness to learn more about science.

Curiosity about the world around us, learning to act and think like a scientist and an innovator and understanding the nature of science – all provide a solid foundation for future success.[35] Quality science education builds upon these everyday experiences and settings and makes links between what is taught in the classroom and the world around us.[36] It shifts the focus away from learning discrete scientific facts to understanding how to apply science learning to new situations. It helps transform knowledge into usable forms and produce positive attitudes towards science – a vital requirement for active, responsible citizenship.[37]

Students also experience the joy and pleasure of co-creating, learning and participation.

Science education should be compulsory throughout school beginning from kindergarten.[38] It should enable and empower students, of all ages, backgrounds and talents, to be both motivated and equipped to be actively engaged in and knowledgeable about scientific matters. It should balance requirements of breadth and depth so some groups are not left behind and everybody can reach her/his full potential. Research shows success is most often due to meaningful effort rather than simply talent.[39] At the same time, we must provide a solid basis and inspiring learning experiences for those who choose to take on deeper study. Europe needs more scientists.[40]

Failure to encourage sufficient numbers of students and adults to sustain their interest in science – for example, into and through technical, vocational, professional, undergraduate and graduate/doctoral studies – could undermine the success of *Europe 2020*. Alongside demographic changes faced by many countries, this presents a serious challenge to Europe's strategy to build a competitive and sustainable knowledge-intensive society drawing more consistently on creativity, innovation and entrepreneurship.[41]

Scientifically-informed citizens can contribute to and manage change and distinguish between positive impacts and benefits and negative consequences. They are more likely to enjoy the benefits of life-long employability, societal participation and improved well-being, enabling them to lead richer, healthier and more fulfilling lives well beyond formal schooling.[42] This is especially important as more of our citizens will be living and working longer.

Embedding what we have learned from research into science education will strengthen curiosity, innovation and scientific inquiry. Systemic change is required. Our emphasis should be on educating citizens for tomorrow not simply students of today.

4.2 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.

Success in the 21st century depends upon acquiring key competences rather than simply learning facts. Being able to collaborate, listen to the ideas of others, think critically, be creative and take initiative, solve problems and assess risk and take decisions and constructively manage emotions are interdependent. They are considered essential for success in adult life and the basis for further lifelong learning.[43] They also contribute to active citizenship at local, national, European and global level.

Conventionally, science education has focused on learning in the context of science and mathematics. The OECD makes a distinction between knowledge of science and knowledge about science. Knowledge of science includes understanding fundamental scientific concepts and theories; knowledge about science includes "understanding the nature of science as a human activity and the power and limitations of scientific knowledge".[44]

Understanding science education is vital if we are to address the "grand challenges" of climate change, human health and healthy living, food and water security or sustainable cities. As the world faces these complex challenges, our ability to resolve these issues on our own or within our own field of knowledge shrinks. Due to their scale and complexity, these major social and economic problems transcend borders and disciplines and necessitate new ways of thinking and methodological and organizational frameworks.

Innovative new ideas and creative solutions often emerge at the margins of disciplines. New ways of thinking do not only come through pure, applied or commercial research or technological change but also because of changes in the way in which we do things. Social innovation takes place in daily life, in social relationships and in the home and may be focused on new services and new ways of organizing society, work and ourselves.[45]

Making connections between STEM and all other disciplines – what is often referred to as STEAM – pushes beyond the boundaries of science to embrace the creative potential of linking the arts, scientific inquiry and innovation.[46] Innovative new ideas and creative solutions often emerge at the interface between disciplines and involve different societal actors. Innovation is linked, directly or indirectly, to human experience, needs and problems. This can occur through engaging with the arts – playing or listening to music, dancing, experiencing or creating art, watching and creating video or film, or being involved in designing and making.

Linking the arts and humanities with science, technology, engineering and mathematics brings the scientist, engineer, entrepreneur, artist and designer into dialogue to offer the widest range of opportunity and academic and societal insight for experimentation and innovation.[47] Involving the social sciences helps us understand what works, what doesn't work and how to improve the quality of life for everyone.

Successful learning in the 21st century depends upon "horizontal connectedness across areas of knowledge and subjects as well as to the community and the wider world"[48]; it emphasizes the fact that knowledge and technologies do not exist in isolation.[49] "Interdisciplinary innovation is primarily about team-work, where members of the team bring different skills and perspectives" which together bring added benefit.[50]

People learn in formal, non-formal and informal spaces, at home, in the community and in activities linked to large enterprises and SMEs. These developments require people with the competences to apply learning to real-life problems and find effective solutions. People who are comfortable working collaboratively and in interdisciplinary teams which span organisations and national boundaries are more prepared for their future roles as innovators.

This has implications for the way in which students learn science and teachers teach across the educational continuum and link education to employability (E2E). Because creativity is a key competence that differentiates innovators from non-innovators, the learning environment matters. Students of all ages should be inspired to be innovative and entrepreneurial in their approach to generating ideas and applying them to solving problems and helping develop sustainable responses to society's challenges.

Conventional modes in teaching and learning contribute little to developing innovation competencies. Research shows that graduates are more likely to participate in innovation processes if their studies involve working with practical knowledge and authentic problems.[51] They develop the same attributes that employers and students identify as essential for employability into the future.[52]

Working across disciplines helps build deep and diverse relationships, which are important for work and for life. It fosters comparison, exchange and synthesis of different systems of knowledge in a way which can lead to transformational change, enabling new ways of thinking about societal challenges. By focusing on competences, connections with the world of work and society are made explicit.

4.3 The quality of teaching, teacher induction, pre-service preparation and in-service professional development should be enhanced to improve the depth and quality of learning outcomes.

Educational quality and outcomes are key factors underpinning personal accomplishment and contributing to innovation and competitiveness. The EU has pioneered the shift towards learning outcomes: what the learner knows, understands and is able to do with what they learn. Because our future depends on the quality of our education systems, society wants to know that the learning outcomes achieved by students meet society's expectations.[53]

Since quality education and learning outcomes are the bedrock of the future society, we must aim to bring about systemic changes to teacher induction and pre- and in-service professional development as well as what happens in classrooms. We need to shift the focus to how students and teachers teach and learn together. Many of these actions are within the direct control of individual teachers, course leaders and schools.[54]

The quality of an education system cannot exceed the quality of its teachers.[55] However, some "systems face teacher recruitment problems, especially in areas like mathematics, science and ICT". [56] Studies show that the highest performing systems internationally have teachers who are seen as important members of their communities and attract high-achieving and committed students into science teacher education. This helps ensure teaching is undertaken by teachers with the appropriate disciplinary, pedagogical and professional competences underpinned by suitable incentive structures and continuous professional development.

Schools and science teachers do not work in isolation. Where change is conducted with the support of others, through collaborative networks of educators, students, science education researchers and other stakeholders, it is likely to be more invigorating and successful for everyone.[57] Engaging with colleagues in professional development programmes increases interest in improving teaching.[58] More opportunities should be provided to collaborate with enterprise and civil society and bring real-life problems into science education preparation and CPD.

Research also shows innovation and job satisfaction are not mutually exclusive; teachers become more satisfied when they are directly involved.[59] By translating research outcomes into changes in classroom practice, teachers develop into more effective professionals.[60]

CPD for teachers and teacher educators should be both a requirement and a right. Evaluation should include follow-up in the classroom, ideally with the participation of the teachers and students in this process. Crucial to success is how CPD functions to create learning communities of teachers and to promote collaborative learning and teaching.

Closing the gap between what we have learned from science education research and classroom practice are vital. Inquiry-oriented science education can produce positive results, but this requires reforms in classroom practice, including a shift towards assessment for learning (AfL). Embedding the outcomes of science education research into teacher preparation, curriculum development and continuing professional development offers rich possibilities.

Science teachers and educators also have a responsibility to embed concepts of Responsible Research and Innovation (RRI) directly into their teaching. For example, no teacher sets out to show that science is only for boys and men, yet some people draw this conclusion from how they learn and the examples and pictures that are used.[61] Responsible science education encourages a view of science and scientists that is inclusive in terms of gender, social, economic and cultural diversity.

In some systems, both school and post-secondary teachers can acquire additional credit for adopting Responsible Research and Innovation and embedding it in their practice.[62] Undergraduate and post-graduate students can also practice responsible citizenship through option modules in community-based research and volunteering.[63] These opportunities should be available to all students and teachers.

Given the importance of science education to Europe's goals, there is a case to be made for adapting the lessons of the Bologna Process to establish *European Standards and Guidelines for Science Education*. These would emphasise the range of outcomes expected from science education, both science specific competences and more generic transversal competences.

4.4 Collaboration between formal, non-formal and informal educational providers, enterprise, industry 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.

Despite the depth of the recent economic crisis, the demand for skilled labour in the European knowledge-based economy of the future will outstrip supply. Future skills forecasts show that the share of people with high-level qualifications will rise to more than a third of the labour force with people with medium-level qualifications accounting for about half. Some of the greatest skill shortages are forecast to occur across STEM-related careers because too few students are choosing to study these disciplines.[64] And, unfortunately, women are also less likely to end up working in science-based occupations than men.[65]

What is to be done?

Collaboration between science educationalists, formal, non-formal and informal education providers, research centres, enterprise and industry and other professionals can play a vital role in increasing interest in science and science-careers. Recent work shows the benefits of drawing on expertise in innovation beyond school to co-create knowledge and stimulate innovation.[66] Partnerships between teachers, students and stakeholders in science-related fields can offer exciting ways to introduce real-life challenges, with their ethical and social issues, into a classroom setting while also aiding problem-solving skills.

In a global, competitive environment it has become increasingly important that professionals and enterprises have early and fluent access to the latest research findings and emerging technologies. Building and developing networks that foster sharing of knowledge, life-long learning, innovations and co-creation of better solutions should form an integral part of quality science education.

Research also shows the value of collaborating across schools, science educators, families, researchers, enterprise and industry and civil society organisations.[67] Collaboration may involve museums, science and leisure centres, zoological parks, botanic gardens, nature centres, science and technology and business parks, etc. taking an approach to science education that embeds principles of responsibility would make these voices more evident in setting the agenda for change, leading to benefits for all.

Where learning activities are carried out within partnerships, all parties benefit as appropriate to their different agendas.[68] Important results can derive from applying learning to real-world problems, focusing on the relevance and meaning of the ideas and topics discussed and improving the over-all quality of teaching and learning. Public and private sector organisations and university students can play an important role and help stimulate a desire to work in the field or even in the same organisation while gaining a deeper understanding of the challenges of school science.

Collaboration is wide-ranging and can include:

- Science ambassador and tutor schemes and volunteering in schools and communities;
- Development or co-creation of pre-service and CPD courses, modules, materials;
- Placements in external stakeholders, laboratories, companies and third sector organisations;
- Promoting STEAM entrepreneurship;
- Networks of companies supporting schools;
- Competitions, festivals, web quests;
- Cooperation with/between science museums, science centres, zoological gardens, botanical gardens, planetaria, observatories;
- Cooperation with/between NGOs, Foundations, Academies of Sciences and other community and society organisations;
- Summer or after-school science programmes, at universities and research centres, with targeted promotion for girls and marginalised groups;
- Involving students as researchers and participants in the design, development and evaluation of innovation;
- Support structures that help schools or local, regional authorities develop science education strategies;
- Mentoring by entrepreneurs, SMEs and other stakeholders.

Through mutual investigation and innovation, collaboration can produce better outcomes than working alone.[69] But, care needs to be taken to ensure these collaborations are meaningful, with clear objectives and respectful evaluation of intended and unintended outcomes, to ensure the benefit is shared.[70] There are obligations on all sides; on science education as well as on employers and civil society.[71]

Well-conceived and developed projects with partnerships between formal, non-formal and informal education can have positive effects on girls' participation in science activities. They can help broaden student's awareness of potential science-based careers, especially for students coming from socio-economically disadvantaged and other under-represented backgrounds.

Above all there is a need to involve citizens, young and old, as active agents at the heart of inquiry-oriented science learning – in identifying and framing the research problems and leading to the discovery of solutions and innovations which help situate science in every-day life. [72] In this way, we involve a richer pool of talent in framing a more responsible and ethical approach to research and innovation. Work in related fields such as health education, climate change and environmental education shows several ways to empower students and citizens to know and act in accordance with Responsible Research and Innovation.[73]

Empowerment is a powerful force in/for life-long learning and active citizenship. Accordingly, science learning becomes more relevant and connected to learners' lives and societal priorities.

Science education, in its broadest sense, has a responsibility to contribute to solving problems on its doorstep in collaboration with societal actors and to make connections to regional and global contexts. Whether living in rural areas or in large cities, young or old, all societal actors should work together to positively change their environment while providing a valuable learning experience in science and active citizenship.

Collaboration and team learning enhances key competences essential for the 21st century and highlights the benefits of portraying positi ve views of science.[74] Working collaboratively, in a spirit of co-creation, leads to benefits that are greater than the sum derived from the constituent parts.

4.5 Greater attention should be given to promoting Responsible Research and Innovation and enhancing public understanding of scientific findings and the capabilities to discuss their benefits and consequences.

Over recent decades, there has been growing acknowledgement that knowledge of science and knowledge about science are essential for an ethical, sustainable and progressive society.[75]Yet, surveys consistently show that while many Europeans are interested in science and technology they feel inadequately informed. Less than half have studied science or technology at any level and many more feel that our governments are doing too little to stimulate young people's interest in science.[76]

Quality science education involves a range of actors in different learning settings, including social, cultural and enterprise organisations. Many organisations are already involved in science-based activities without thinking of themselves as developing science understanding, including, for example: recycling initiatives, patient support groups, community, health and environmental groups, gardening clubs and children's computer coding groups.[77] A key characteristic of meaningful participation is the emphasis on self-discovery, curiosity and fun.

Quality science education is not evenly distributed across Europe.[78] Many sections of our population miss out during compulsory school and are then cut off from many of today's big decisions about the future of our society. There are also big gaps between our highest and our lowest achievers.[79]

This presents a serious challenge. Finding solutions to society's complex challenges involves a broader understanding of social and technological innovation. Valuing and evaluating the quality and outcomes of science education and science education research should take account of collaboration and stakeholder involvement, adherence to RRI values, internationalisation and societal impact and benefit[80]. This requires new ways to define and measure what counts as success in order to match the objectives of science education for active and responsible citizenship.[81]

Novel approaches that place an emphasis on learning and collective change such as those at the centre of health promotion, community arts and community and social development should be encouraged.[82] This would help bring about more inclusive forms of science education and help reduce disparities.

The intended shift to more active participation by citizens in science reflects the growing realisation that participatory approaches, which respect human rights and meet the highest ethical standards, bring tangible benefits for all.[83]

Science and society benefit when RRI principles are embedded in projects from the outset and in all spaces where people learn.[84] Promoting research integrity is an essential element; it is the basis of the trust society vests in the scientific endeavour. It is not only a way to protect and be in harmony with society but should also be seen as a prerequisite for achieving quality in research. This includes non-formal and informal learning spaces, in the identification of research questions, as well as the co-creation of approaches, resources and solutions.[85]

Sharing knowledge of and about science education for responsible citizenship with colleagues around the world should be an intrinsic part of all initiatives. This must be pursued actively with our international partners, through joint projects, enhanced mobility for science educators, researchers, students and key stakeholders. Adherence to the principles of RRI is necessary to ensuring stakeholders are involved throughout the process.

Citizen science involves people directly in research projects, for example: monitoring bird migration patterns, changes in environmental phenomena, astronomical events or identifying ways to use "urban waste as a resource".[86]Involving all citizens, from an early age and throughout the life-cycle, provides a valuable way to mainstream science education and create a more balanced science-informed society.

Open and online access to the results of publicly-funded research is another important mechanism for knowledge exchange that can facilitate new research and innovation.[87] Too often this is interpreted simplistically as publicising scientific results or holding public lectures. But genuine links between scientists, science educators and communicators involves *two-way* communication.

All these actions are vital to ensure that the value, impact and benefit of such research is fed back and actually incorporated into policy and practice for the benefit of citizens. This will help broaden societal understanding of science and technology related decisions and their consequences – desirable and undesirable.

4.6 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.

Europe's challenges of low growth, insufficient innovation and a diverse set of environmental and social threats do not stop at city or national borders. [88] Nor do the challenges of feeding our population, controlling disease, generating sufficient energy, supplying adequate water and limiting (if not reversing) the dangers of global climate change stop at the boundaries of Europe. Because science and innovation are key factors that will help Europe move towards smart, sustainable, inclusive growth, the actions we take must address these challenges by finding sustainable global solutions.

This means ensuring that what is promoted and undertaken at the European level is linked to complementary actions at the national and regional level and vice versa. At the same time, attention should be focused on establishing and strengthening international collaboration and partnerships.

Inevitably, different organisations work to their own requirements. Too often research and knowledge about interesting practices is fragmented, unknown or misunderstood. But, working to a common agenda can help bring about sustainable change if all citizens understand the issues, the rationale and consequences.[89] The cross-fertilisation of expertise and disciplines helps demonstrate the advantages of collaboration and interdisciplinarity and moving from STEM to STEAM, while also highlighting the negative impact on scientific and technological performance of disjointed public resources.

People who have experienced an inclusive and collaborative science education become enthusiastic promoters of inquiry-oriented learning[90]. They set high expectations for each other. They exude energy and enthusiasm for learning that is contagious. When this learning involves system leaders and participants, wider changes are possible. However, holistic system change has major challenges, especially of accountability, evaluation and assessment.

Science education reform has to be part of systemic efforts at different levels. It should be aligned with and contribute to strategies developed by decision-makers or governments at all levels of society. All stakeholders across the learning continuum, including schools, universities, enterprises and civil society organisations should develop strategies that link with these wider societal goals. Structures should be established to provide crucial support to develop and implement science education for responsible citizenship.

Successful reforms are not top-down quick fixes to problems, nor are they bottom-up solutions to immediate needs. They are collaborative programmes for enduring change, at local, regional, national, European and international levels.[91]

Where changes are supported at different levels, they are more likely to become part of the reality of the participants. They become self-sustaining; they act as living examples for others in similar situations. When this happens and there is good involvement of stakeholders, change becomes embedded.[92] Links between science education and innovation strategies should be strengthened in order to remove regional, gender and socio-economic disparities across Europe and the world and to make Europe an attractive hub for new investments and professionals and enterprises that want to succeed. It is this prolonged, deep change that should be the focus of science education in *Horizon 2020* and beyond.

A smart, sustainable and inclusive Europe can only exist and only makes sense when it is open to the world and collaborates and interacts dynamically with partners internationally. Because borders are porous, challenges in one part of the world can quickly become problems in another part.[93] Thus, the attributes and characteristics of global citizenship and solidarity are critical components of science education for responsible citizenship.

This also means, science education everywhere in Europe must continue to meet international benchmarks for quality and excellence and conform to best ethical practice. Our students and graduates, teachers and teacher educators and researchers and science professionals are already working in a globalised world. Research shows that students with international experience are most likely to do better in work.[94] We should expand the opportunities for collaboration.

European programmes and projects, focusing on science education, should explicitly include sharing expertise and practices with countries that cannot afford or do not have the means to develop such science strategies. Dissemination and valorisation of what is and can be achieved through science education, within *Horizon 2020*, should remain an essential component of European-funded projects. All educational actors, enterprise and industry, as well as public and civil society organisations have a role to play in disseminating "good practices" at all levels and within their "communities of practice".

European science education has much to contribute to embedding principles of smart, sustainable and inclusive growth around the world.

Pursuit of the principles of ethical, Responsible Research and Innovation are key characteristics of Europe's integrity internationally. Solidarity with other countries, especially disadvantaged countries and helping develop quality science education for responsible citizenship strategies, will be mutually beneficial for everyone.

5 The Framework for Science Education for Responsible Citizenship

The world is changing so fast that citizens need a deeper understanding of global societal challenges and their implications for themselves, their families and their communities. This requires a broader vision of an active, engaged and responsible citizenship for the 21st century.

Drawing on evidence presented in this report and published research, the *Framework for Science Education for Responsible Citizenship* provides a comprehensive set of objectives, recommendations and actions.

There are six high-level objectives, with recommendations aligned to each objective. Indicative actions are associated with each objective and recommendation. The actions are appropriately identified for implementation at either EU or member state level.

The *Framework for Science Education for Responsible Citizenship* provides a powerful tool-kit for action which can bring about systemic, synergistic and sustainable change for collective impact.

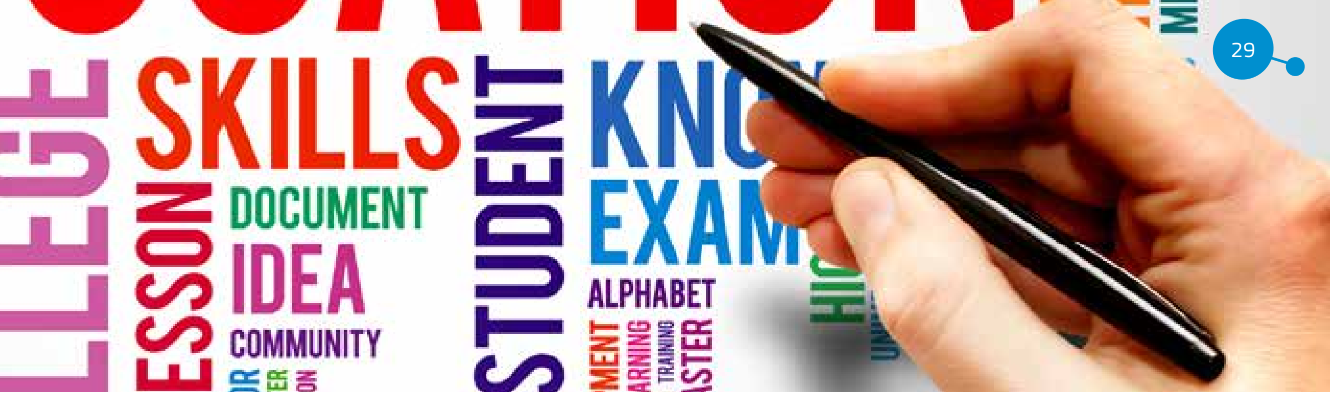
To be successful, they require a collective vision and shared sense of accountability responsibility and innovation by all society's stakeholders. This includes schools plus further and higher educational institutions, families, teachers and students, enterprise and business and public and civil society organisations. It involves all members of the European Union, at local, regional, national and EU level, acting together in a coherent and integrated way.

RECOMMENDATIONS TO THE EUROPEAN COMMISSION

Given the multi-facetted nature of the objectives and recommendations, it is strongly recommended that the European Commission brings together key actors from within the European Commission to initiate a participatory consultation and dialogue process across the EU on the report and proposed actions and how they should be implemented.

The European Commission should use the report to build synergies and co-operation across portfolios in order to lead to tangible results. Collaboration and networking between the different communities across the EU can provide important opportunities to enrich the lives of European citizens.

Finally, the European Commission should also implement a comprehensive dissemination programme. In the spirit of engaging citizens in the understanding and about science, the dissemination programme should include a combination of workshops, leaflets, comic book formats, video, film, community theatre etc. An accompanying public communications strategy should be developed in order to reinforce a consistent message.



FRAMEWORK FOR SCIENCE EDUCATION FOR RESPONSIBLE CITIZENSHIP

1

Objective

Science education should be an essential component of a **learning continuum for all**, from pre-school to active engaged citizenship.

RECOMMENDATIONS AND ACTIONS

Recommendations

- Education policies and systems should:
  - Ensure that science is an essential component of compulsory education for all students;
  - Support schools, teachers, teacher educators and students of all ages to adopt an inquiry approach to science education as part of the core framework of science education for all;
  - Address socio-economic, gender and cultural inequalities in order to widen access and provide everyone with the opportunities to pursue excellence in learning and learning outcomes;
  - Create mechanisms to foster individual reflection and empowerment.
- Science education should balance requirements of breadth and depth of knowledge about science to ensure young people and adult learners are both motivated for learning and equipped to fully engage in scientific discussions and decisions and to facilitate further and deeper study;

Indicative Actions EU Level

1. Develop *Guidelines for Systemic Change* to underpin *Science Education for Responsible Citizenship* initiatives and their evaluation
2. Initiate actions which strengthen links and cooperation between formal, non-formal and informal science education;
3. Introduce actions to promote gender sensitive practices and innovations in science learning;
4. Introduce actions to address socio-economic and cultural inequalities to ensure access to science education, with an emphasis on rural, isolated and disadvantaged communities;
5. Support the expansion of ICT to widen access and participation in science education, for all talents, in and beyond the classroom.
6. Develop educational pathways for scientific and technical employees and unemployed workers especially young people, to access scientific and technical qualifications.
7. Provide student-centred science education programmes which recognise and are sensitive to different learning methods.

Indicative Actions National Level

1. Adopt a "whole of education" policy approach to establish an Educational Forum bringing together key actors from pre-school to LLL and across formal, non-formal and informal science education;
2. Introduce initiatives to support LLL for all citizens – including those who seek to learn and/or enhance their science knowledge and understanding through scientific models, including development of accredited online courses and programmes and other innovative formats;
3. Develop benchmarking and quality certification of curricular and/or extra-curricular programmes and outreach activities to provide pathways to higher, vocational and professional science education and training;
4. Expand use of ICT to enrich science education, for all ages, in and beyond the classroom, including via accredited online courses and programmes in innovative formats, in order to support the different paces of learning and profiles of learners.

2

Objective

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.

RECOMMENDATIONS AND ACTIONS

Recommendations

- Greater attention should be given to the value of all disciplines and how inter-disciplinarity (STEAM rather than STEM) can contribute to our understanding and knowledge of scientific principles to solve societal challenges.
- Educational institutions, at all levels, should boost understanding of the importance of science education as a means of acquiring key competences to ease the transition from "education to employability" (E2E), by:
  - Learning about science through other disciplines and learning about other disciplines through science;
  - Strengthening connections and synergies between science, creativity, entrepreneurship and innovation;
- More emphasis should be placed on ensuring all citizens are equipped with the skills and competences needed in the digitalized world beginning from preschool.

Indicative Actions EU Level

1. Promote research and support actions that emphasize a balanced approach to the acquisition of scientific and generic competencies;
2. Create a *European STEAM Forum* with representatives from all stakeholder groups, with European and international representation, to ensure Europe is a leader in science and innovation education;
3. Support arts-based initiatives with a STEAM focus, e.g. film, media, visual arts, etc. to develop resources promoting science learning, positive views of science and scientific culture;
4. Develop a portal with information on "good practices" in STEAM, targeted at encouraging collaboration between enterprise and business (including SMEs), arts and design organisations and educational institutions at all levels for more contextualized contents;
5. Develop actions which extend the use of ICT to young people and adult learners to scientific and transversal competences.
6. Design project evaluation criteria that endorse and promote inter-disciplinarity, equity and active citizenship.

Indicative Actions National Level

1. Promote actions that build on curiosity and enhance the relevance of science education to learners' lives, including connections to societal challenges.
2. Specific attention should be given to projects and educational programmes that promote creativity, innovation and entrepreneurship throughout the educational life-cycle;
3. Develop innovative teaching and evaluation practices to support STEAM and inter-disciplinary learning with a focus on competences for science, innovation and education to employability (E2E);
4. Promote the establishment of incubators bringing together companies with a strong STEM focus with stakeholders in other fields especially in arts and design;
5. Support the creation of local, regional and national STEAM initiatives by companies or sectors highlighting examples of good practice.

3

Objective

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**.

RECOMMENDATIONS AND ACTIONS

Recommendations

- Actions should be taken to continually improve teaching quality, with greater focus on teacher competences, disciplinary knowledge, avoiding gender stereotyping and on students and teachers learning together;
- Efforts should be undertaken to attract more highly qualified and motivated people to become teachers and boost the status and prestige of the profession;
- Greater emphasis should be given to closing the research-practice gap, by embedding science education research findings into teacher preparation, curriculum development, teaching and learning and assessment for learning (AfL);
- Appropriate methodologies should be developed for teaching research ethics and raising awareness of research integrity;
- CPD should become a requirement and a right for all teachers throughout their teaching career.

Indicative Actions EU Level

1. Develop *European Standards and Guidelines for Science Education* to enhance quality, aid accreditation and improve comparability of teacher education programmes;
2. Establish a *European Network of Science Teacher Educators* linked with stakeholders to exchange knowledge, expertise and new approaches;
3. Encourage teaching strategies to enhance student motivation for learning and to develop students' self-regulation for science learning, including classroom-based actions;
4. Develop RRI guidelines and tools to enhance and inform teacher preparation and CPD, to communicate the respect that Research and Innovation should have for society;
5. Stimulate chambers of commerce, business and enterprise to work closely with career counselling to promote career opportunities in and from science;
6. Promote actions that support the involvement of enterprises in the design and implementation of CPD for all educational professionals, in order to make their needs more transparent and understandable.
7. Promote collaborative learning and participatory research approaches for educational professionals.

Indicative Actions National Level

1. Promote innovations of technology-enhanced teaching and learning, as well project-based learning through, e.g. field studies, laboratory work and various kinds of outdoor activities;
2. Introduce teaching self-assessment and self-regulation methods to support students, teachers and schools in their efforts to improve the development of competences for science, innovation and employability for all students;
3. Develop mechanisms to support schools and teacher teams working with reflective, evidence-based approaches to develop and share innovations in teaching, e.g. team-learning and pair/peer teaching between pre- and in-service teachers and other stakeholders, blended learning, curriculum innovation, teachers as responsible innovators and educational entrepreneurs;
4. Encourage schools and teacher teams to adopt explicit responsibility for connecting student learning to creativity, innovation, collaboration, cultural diversity and economic sustainability.

4

Objective

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 and employability and competitiveness.

RECOMMENDATIONS AND ACTIONS

Recommendations

- Encourage "open schooling" where:
  - Schools, in cooperation with other stakeholders, become agents of community well-being;
  - Families are encouraged to become real partners in school life and activities;
  - Professionals from enterprise, civil and wider society are actively involved in bringing real-life projects into the classroom;
- Promote partnerships between teachers, students, innovators, researchers and stakeholders in science-related fields, in order to work on real-life challenges and innovations, including associated ethical and social issues;
- Develop guidelines on how to integrate responsibility and responsiveness into formal, non-formal and informal Science Education, following the principles of CSR (Corporate Social Responsibility) and RRI (Responsible Research and Innovation);
- Promote partnerships that foster networking, sharing and applying science and technology research findings amongst teachers, researchers and professionals across different enterprises (start-ups, SMEs, large corporations.

Indicative Actions EU Level

1. Introduce support actions that engage learners in meaningful real-life problem-solving situations, within education, workplace and other learning environments.
2. Encourage science studies and science-based careers by supporting cross-community networks of stakeholders to directly address societal issues and challenges;
3. Introduce mobility initiatives to support placement of science teachers and science education students in enterprises or civil society organisations across Europe;
4. Support initiatives that adapt, innovate and integrate CSR (Corporate Social Responsibility) and RRI (Responsible Research and Innovation) in science education;
5. Establish structured early-stage researchers and student dialogues at the European level to address global and societal challenges.

Indicative Actions National Level

1. Promote the development of *Innovation Hubs* that link formal and informal science education with business and enterprise, SMEs and civil society organisations, at municipal and regional level, in order to:
   - Foster, share and apply science and technology research to different genres of enterprises, e.g. start-ups, SMEs, corporations;
   - Encourage mentoring across different groups in order to take full advantage of science and technology;
   - Facilitate mainstreaming of innovations from key enabling technologies (KET) and fields such as health education, climate change and environmental education;
2. Support the co-creation of innovative curricula, with defined learning outcomes involving teachers, teacher educators, researchers and representatives from enterprise and civil society;
3. Support pilot projects which help develop the capacity for greater school-family and school-enterprise synergies;
4. Encourage industry-funded innovation to become part of the LLL programmes.

5

Objective

Greater attention should be given to **promoting Responsible Research and Innovation (RRI) and enhancing public understanding of scientific findings** including the capabilities to discuss their benefits and consequences.

RECOMMENDATIONS AND ACTIONS

Recommendations

- The link between scientists, researchers, science educators and the media should be strengthened to ensure more effective public communication, in a way that makes the underlying issues and consequences understandable to citizens;
- Science educators, at all levels, have a responsibility to embed social, economic and ethical principles into their teaching and learning in order to prepare students for active citizenship
- Publicly-funded science education researchers have a responsibility to openly communicate, share and disseminate research outcomes with wider society and to the international research community;
- Citizens should be actively and directly involved in science research and innovation projects.

Indicative Actions EU Level

1. Support actions and projects which adopt the following characteristics:
   - STEM/STEAM stakeholders and other users, should be involved from the beginning, as co-producers of knowledge;
   - (Science) journalists and media practitioners should be involved so as to enhance the dissemination of relevant project results;
   - Direct work of Secondary and post-secondary science students with science researchers, science education researchers and science educators should be encouraged;
2. Initiate, support and promote RRI public interest campaigns (e.g. “Young STEAM Reporters”, “European City of Curiosity”) to encourage active engagement and scientific understanding of all citizens;
3. Establish industry-science “open days” to encourage on-going communication between science education actors about global science challenges;
4. Stimulate scholarship on ethical dimensions of science education as the basis of academic exchange;

Indicative Actions National Level

1. Enhance training of science journalism and encourage greater cooperation with journalists’ associations for better communication of science;
2. Public authorities should ensure all science educators develop a deeper awareness and responsibility for promoting RRI and of the range of outcomes expected from science education;
3. In partnership with science communicators, develop a comprehensive programme of activities to promote STEAM and RRI awareness, involving science education, business and enterprise, as well as research actors;
4. Actively involve STEAM stakeholders in policy debates to help shape strategies at national or local level;
5. Introduce training in science communication for early stage researchers in doctoral and post-doctoral programmes.

6

Objective

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.

RECOMMENDATIONS AND ACTIONS

Recommendations	**Indicative Actions** EU Level	**Indicative Actions** National Level
• Links between Responsible Research and Innovation strategies at local, regional and national level should be strengthened and evaluated in order to overcome regional and other disparities across Europe and to increase the innovation capabilities of enterprise, particularly SMEs; • Collaborating and sharing knowledge of and about science and science communication, as well as identifying solutions for global societal challenges facing humankind, should be actively pursued with international partners; • Science education should benefit from an agreed set of international guidelines, evidence-based and grounded on collaborative and inclusive deliberations.	1. Establish a single comprehensive *European Repository of/for Science Education* to bring together all EU and national funded projects plus other institutional, community and industry resources to ensure the greatest impact on education and throughout society; 2. Support special initiatives targeted to support and promote science teacher educator collaboration between Europe and the rest of the world; 3. Explore ways to translate and make RRI initiatives available in science and science education across languages and cultures, while communicating its impacts on reducing inequalities. 4. Expand initiatives that encourage science educators and students to collaborate internationally to strengthen citizen awareness and understanding of global challenges and ability to work towards solutions.	1. Introduce initiatives to support sustainable "communities of learning" (at local, regional, national and European levels), to collaborate internationally and improve practice; 2. Teacher induction and pre-service preparation should ensure science educators are aware of their responsibility for preparing learners to be responsible and innovative citizens; 3. Promote and link high-quality formal, non-formal and informal science education opportunities, such as museums, science centres, festivals and competitions, to broaden participation and understanding of citizens of all ages; 4. Expand international cooperation and development programmes with emerging and developing countries to focus specifically on the grand challenges and enhance science education opportunities for wider publics.

6 Programme for Science Education Research

Over the last 25 years, the European Union has funded a remarkable number of research projects and initiatives in the broad area of science education.[95] Research has involved a progressive move towards more active participation by citizens directly in research projects and a realisation of the benefits of participatory approaches. It has also revealed a growing understanding of the importance of science education as a lifelong process and not something that occurs only during compulsory schooling.

Key lessons from this research are:

- There are a wide range of interesting examples of innovation in science education practices, many of which have been tried out in classrooms or professional development programmes and to a lesser extent in pre-service teacher education;

- Successful developments in science education are characterised and driven by, *inter alia*: (a) collaborations between school-teachers and external agents such as higher education institutions (HEIs), academies of science, research laboratories, business and community groups, various informal science-promoting actors e.g. science museums, enterprise and civil and society organisations etc., (b) cooperation when designing teaching-learning sequences and ICT-enhanced learning environments, (c) robust teacher preparation and induction as well as long-term teacher professional development initiatives, all focused on student learning and (d) active student and family engagement;

- There is a diversity of educational system structures and priorities within and between EU member states, with different countries having different or similar strategies and outcomes.

There is the opportunity to create long-term added value through enhanced collaboration between science educators and other key actors across educational systems.

However, to ensure that the changes proposed within this report meet the objectives, there is a need for on-going and further research and evaluation. This research should ensure a sound basis for long-term decision-making.

Research projects should embody the principles of Responsible Research and Innovation; they should focus on both the intended and unintended outcomes from the changes and how these might relate to the local and wider contexts. Impacts can be long term, with seemingly minor events having important consequences for science learning and involvement.[96] Such work would include not only the science content currently assessed in programmes, such as PISA, but wider outcomes such as the effects of

participation and uptake of further science education and in science throughout society and enterprise and science-based decision-making and Responsible Research and Innovation actions.

The ***Programme for Science Education Research*** identifies broad research areas, aligned with the six high-level objectives of the *Framework for Science Education for Responsible Citizenship* and *Europe 2020* objectives for a "smart, inclusive and sustainable society".

The first heading addresses research questions that refer to "smart" science education: how to improve scientific knowledge or competence in order to promote citizenship growth. The second heading deals with "inclusive" science education: how to engage more citizens, more schools universities and civil society organisations in science education matters? The third heading deals with the "sustainable" aspects of science education: how to support science education throughout life-long learning.

To support decision-making, the research questions are presented in order of priority and potential impact and benefit is identified.

THE PROGRAMME FOR SCIENCE EDUCATION RESEARCH

1

Objective

Science education should be an essential component of a learning continuum for all, from pre-school to active engaged citizenship.

Potential impact and benefit

Improved long-term understanding of science learning, the roles of the learner, with better-informed citizens engaging with the grand challenges.

EUROPE 2020 OBJECTIVES

Smart	Inclusive	Sustainable
Students' self-regulated learning: How to develop diverse teaching approaches and methods that have the potential to support students' self-regulated learning? What is the role of a combination of investigation, direct methods and formative assessment on a range of outcomes, including motivation for learning? **Learning scientific concepts, principles or theories**: How to promote more robust understanding of the big ideas of science that are necessary for engaging in innovation and informed active citizenship? How to design research-based learning progressions for science topics in relation to RRI (such as biotechnology, alternative energy and fuels, nanotechnology, etc.)?	**Assessment for learning:** What is the influence of formative assessment on the effectiveness and responsiveness of teaching and learning as well as on the inclusiveness of learning? What are the impacts of different innovative teachers' strategies to address the diversity of students In a classroom? **Science education for all talents:** How to make better use of evidence of learning outcomes (knowledge, competences and attitudes) to attain cumulative progress on effective teaching methods? How to improve the participation and inclusion of all individuals, of all talents, in science learning in diverse contexts (addressing socio-economic and gender inequities)?	**Longitudinal studies on educational innovations**: How to assess the mid and long term impacts of teaching-learning innovations, especially with regard to the development of the scientific competences for all, throughout the lifespan from early childhood to adulthood? **From education to employability**: How to improve the transversal competences (e.g. ethical awareness and behaviour, persistence, critical thinking skills, autonomy, collaboration etc.) of science students at all levels in order to ease transition from education to employment and throughout working life?

2

Objective

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.

Potential impact and benefit

Ensured scientific and transversal competencies as well as digital literacy for all. Improved employability and informed citizenship.

EUROPE 2020 OBJECTIVES

Smart	Inclusive	Sustainable
STEAM courses: How to enhance the relevance and quality of science learning through interdisciplinary connections in science learning? **Using ICT:** How to make effective use of ICT tools in scientific experimentation, as well as modelling, understanding and analysing phenomena?	**Scientific competences:** How to develop and validate teaching and education strategies aiming to improve competences for science literacy and transversal competences through science for all people, from pre-school to further and higher education, vocational and lifelong learning in both formal and informal settings. **Inclusive Digital Literacy:** What are the rules and criteria for efficient and ethical use of ICT to support improved quality science teaching and learning for all? How can ICT be used to support RRI and the development of competences for science literacy and through science learning?	**Systemic changes:** How to implement innovative approaches systematically in the medium and long term? What factors make innovations sustainable? **School management:** What is the role of team learning by science teachers and education professionals in promoting and maintaining innovation and sustainability?

3

Objective

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.

Potential impact and benefit

Bridging gaps between science education and teacher education research, teacher preparation, teaching practices and learning.

EUROPE 2020 OBJECTIVES

Smart

Education of science teachers and education professionals: How to use evidence to simultaneously promote better understanding of scientific content and effective teaching practices? What strategies are available to make initial and continuing education of teachers and other education professionals more research based?
Pre-service science teacher education: How to improve the quality of science teacher preparation and connect it more effectively to school teaching practice?

Inclusive

Effective strategies to enhance motivation for science learning: How to support science teachers, educational professionals and learners to promote and monitor integration of effective motivation strategies for all learners in science education? How does motivation for science learning impact on perceptions of science and participation in civil society and RRI?
School and university connections: How to promote closer collaborations between educational institutions at different levels in making science more engaging and in making science careers more attractive?

Sustainable

Evaluation of science teaching and educator development programmes: What are the main quality criteria for evaluating formal and informal approaches to educator development? How to integrate quality evaluation methods into educator development, support and participant research systems?
Project and Programme evaluation: How to develop more comprehensive methods for impact assessment that emphasize quality of engagement of all learners and stakeholders in evaluation and assessment of impacts?

4

Objective

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.

Potential impact and benefit:

Better understandings of the effects of collaboration between science education providers, civil society and enterprise.

EUROPE 2020 OBJECTIVES

Smart

Teacher team learning in context: How does the context, both people and resources, enhance science teacher and educator collaborative learning and practice that lead to quality outcomes for responsible citizenship?
Pursuing excellence: How to design and evaluate collaborative settings and processes that support appreciation of all talents and concerted pursuit of excellence in both learning process and learning outcomes for all citizens?
Analysing synergies: What kinds of synergies can be created between formal, non-formal and informal science education activities, enterprise and civil society organisations? How are powerful learning practices transferred between different sectors?

Inclusive

Collaborative research: How to engage students, parents, researchers, educators and enterprise within joint research projects about learning innovations (particularly assessment and regulation of learning in science education) explicitly connected to improving learning outcomes for all? What are the challenges and appropriate conditions required to support collaboration between educational providers, enterprise and civil society?
Participatory approaches: What are the effects of participatory approaches to assessment, regulation of learning and development of indicators of educational quality?

Sustainable

Education of science teacher educators: What are the factors that contribute to the effectiveness of the education and training of teacher educators, school managers, inspectors, pedagogical advisors, career advisors and other educational personnel?
Building communities: What are the characteristic features of co-created CPD and lifelong learning programmes that effectively promote the development of communities of practice, involving a range of stakeholders, for inquiry approaches to science teaching and learning?

5

Objective

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.

Potential impact and benefit

Development of a culture of responsibility, responsiveness, innovation and broad participation in all aspects of science, science education and science communication.

EUROPE 2020 OBJECTIVES

Smart

RRI in Science Education: How to conceptualize Responsible Research and Innovation in science education in diverse contexts? How to bridge the gap between science education research results, the educational practices and the varied perceptions of parents, learners, employers and the media?
Ambassador systems: How ambassador systems implemented by different European member states support civil society bodies (industry, museums, science centres, media, artists, parental associations, teacher and head-teacher unions) to promote STEAM education, citizen engagement and employability?

Inclusive

Formal and informal learning: What are the benefits for under-represented groups of different forms of cooperation and collaboration between science educators from formal, non-formal and informal sectors, including media professionals, artists and community workers?
Innovative Science Communication: How to promote synergies between researchers, media professionals and artists in order to create new inclusive approaches and formats for communicating widely accessible scientific research outputs?

Sustainable

Learning communities: What participatory approaches to the design, implementation and dissemination of science education research programs lead to the development of sustainable lifelong learning communities? What factors sustain informal science education such as recycling groups, gardening clubs, patient support groups and workplace learning?
Responsible Science Education: What are the critical features and challenges for responsible and responsive provisions of science education and science communication?

6

Objective

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.

Potential impact and benefit

More coherent and sustainable policies and practices for connecting science education with RRI.

EUROPE 2020 OBJECTIVES

Smart

Mainstreaming successful projects: How to develop efficient, effective, relevant and sustainable strategies in mainstreaming successful science education project outcomes for responsible innovation?
Monitoring: What are meaningful indicators for monitoring the impact of science education on the innovation system? How to ensure better access and use of resources that have been developed by science education projects as well as their contribution to perceptions of RRI?

Inclusive

Longer term and longitudinal studies: How can we evaluate the effectiveness of funded initiatives and projects in order to ensure sustainability, demonstrated impact and benefit for all?
Indicators of quality: What are meaningful indicators for responsible, smart and inclusive science education?

Sustainable

Disseminating within and beyond Europe: How can science education research outcomes be made more widely available to other countries and language groups within Europe and beyond, through exchange and mutual learning activities? How can these processes support developing countries outside Europe to exchange and transfer expertise?
Mobility of educators: How to use intended and unintended outcomes of STEAM educator mobility and international collaboration for developing RRI?

7 Interesting Practices Promoting Responsible Science Education

There is a very wide range of interesting, contemporary examples of science education practices, from across Europe and around the world, which can provide ideas for new initiatives to be adopted from local to European level.

Two sets of examples have been chosen to inspire teachers and teacher educators and trainers, enterprise and industry, social organisations and policy-makers to promote responsible science education.

The first set provides examples from EU FP7 projects.

The second set includes a wide range of initiatives that have been tried out in schools, classrooms, in pre-service and professional development programmes, with enterprise, industry and municipalities and in other formal, non-formal and informal educational settings. Many of these examples have been mainstreamed; some have been formally evaluated. Some are large initiatives while others are small. All examples show, that with creativity and motivation and through collaboration, responsible science education can be enhanced to the benefit of citizens of all ages.

Each example is aligned to the six high-level objectives of the *Framework for Science Education for Responsible Citizenship*, with reference to sections 4.1-4.6 above.

Examples from some FP7 Projects

PATHWAY Germany and partners

Objective 4.1, 4.2, 4.3, 4.4

Target population	Description	What makes the practice interesting
6 – 18 years students, teachers, teacher trainers, CPD providers, Policy makers, Researchers	Various science education stakeholders aim to promote use of IBSE in primary and secondary schools by describing Best Practices in IBSE: School based IBSE , School – Science Centre/ Museum Collaboration, School – Research Centre Collaboration and Effective Pre-service Teacher education and CPD.	The description of each practice focuses on how each of those practices relates to one of ten underpinning principles of IBSE and to the 13 key competencies for science teachers.

http://www.pathway-project.eu/

SCIENTIX Belgium

Objective 4.1, 4.2, 4.3, 4.4, 4.5, 4.6

Target population	Description	What makes the practice interesting
Primary and secondary STEM teachers, educators, researchers, policy-makers, industry, CSO, other STEM professionals	It supports a Europe-wide collaboration among STEM stakeholders. An online portal was built (2009-2012), to collect and present European STEM education projects. It organised teacher workshops and two European Conferences. From 2013 – 2015 Scientix expanded to the national level, setting up NCPs (National Contact Points) and involve STEM teachers as Scientix ambassadors.	The network of the Scientix ambassadors is operational to support teachers and schools implementing STEM. The National Contact Points (NCPs), aim to reach out to national teacher communities and contribute to the development of national strategies for wider uptake of inquiry-based and other innovative approaches to science and maths education.

http://www.scientix.eu/web/guest

INGENIOUS Belgium and partners

Objective 4.1, 4.3, 4.4, 4.5

Target population	Description	What makes the practice interesting
6 – 18 years students, teachers, teacher trainers, CPD providers, Policy makers, Researchers	It focuses on school-industry cooperation to promote STEM education and careers. It aims to reinforce young Europeans' interest in science education and careers and thus address anticipated future skills gaps within the European Union. A database of interesting practices is available.	It is (i) developing an analysis of existing initiatives in school-industry cooperation in Europe; and (ii) through teachers as Ingenious Ambassadors it is testing innovative approaches to stimulate school industry cooperation. It is creating a major learning community of practitioners.

http://www.ingenious-science.eu/web/guest/about

FIBONACCI France and partners

Objective 4.1, 4.2, 4.3, 4.4, 4.5, 4.6

Target population	Description	What makes the practice interesting
Primary and secondary teachers, educators, CPD providers, other STEM stakeholders	In large scale dissemination, institutions with high expertise in IBSME worked with other institutions to develop IBSME. It developed a wealth of pedagogical materials, CPD, peer learning visits, seminars and conferences.	It produced a blueprint for a transfer methodology valid for a larger dissemination in Europe. The project lasted 38 months. 60 tertiary education institutions throughout Europe were involved, reaching some 7,000 teachers and over 300,000 students. Several countries developed IBSE CPD centres such as Italy with the SID centres etc.

http://www.fibonacci-project.eu/
Italy SID project: http://www.anisn.it/scientiam.php

SiS-CATALYST United Kingdom and partners

Objective 4.1, 4.3, 4.4, 4.5, 4.6

Target population	Description	What makes the practice interesting
Children (7-14)	The focus is on the children least likely to progress to higher education. The objectives are: to learn and share knowledge about the different models of enabling children to aspire and progress to higher education, specifically by their engagement with science and secondly, to consider how this practice can have an impact on policies at institutional, national and European levels.	The project has developed ethical guidelines, practical guides and self-evaluation tools to help institutions to assess their progress. It has set up a mentoring programme for newcomers and offered internships for students to engage in SiS activities. A website, workshops and case studies of successful interactions between children and H.E. highlight the potential of the SiS Catalyst approach.

http://www.siscatalyst.eu/

INQUIRE BOTANY United Kingdom and partners

Objective 4.1, 4.3, 4.4

Target population

Primary and secondary teachers, educators

Description

The aim is to act as catalyst, training and supporting teachers and educators to develop their proficiency in IBSE and become reflective practitioners. The partners have each developed a 60 hour IBSE teacher training course. The INQUIRE courses are inspirational and are training hundreds of teachers and educators and reach thousands of children.

What makes the practice interesting

The content of the courses focus on biodiversity loss and climate change, two major global issues of the 21st century. The INQUIRE website supports the project through disseminating information and resources and promoting dialogue between partners and teachers.

http://www.inquirebotany.org/en/about.html#sthash.XrlwhlZb.dpuf

PRIMAS Germany and partners

Objective 4.1, 4.2, 4.3

Target population

Primary and secondary teachers, educators

Description

The aim is to promote the implementation and use of IBSME. It has developed materials for the class and for CPD. It has run CPD and has supported professional networks. The ultimate objective is that many more pupils have a more positive disposition towards the further study of these subjects and the desire to be employed in related fields.

What makes the practice interesting

PRIMAS has worked with stakeholders such as policymakers, school leaders and parents to create a supportive environment for inquiry-based learning. Formative and summative evaluations were made. The MASCIL project continues working in the spirit of PRIMAS.

http://www.primas-project.eu/en/index.do

VOICES Belgium and partners

Objective 4.1, 4.4, 4.5

Target population

All stakeholders and citizens interested in research

Description

VOICES (Views, Opinions and Ideas of Citizens in Europe on Science) is a ground-breaking consultation, using the opinions of 1000 people from across 27 EU countries to shape the future of European research. According to the principles of Responsible Research and Innovation, European research must do more to adapt to the needs of citizens.

What makes the practice interesting

VOICES devised a specialised yet flexible methodology, using 100 three-hour focus groups in order to engage citizens and gather their opinions and ideas about research and innovation. The consultations were run by science centres and museums, as the natural interface between science and society.

http://www.voicesforinnovation.eu/

Interesting Practices Promoting Responsible Science Education, from across Europe and around the world

PROJECTS FOR SPECIFIC GROUPS AND LEVELS

SCIENCE IN THE KINDERGARTEN Cyprus

Objective 4.1, 4.3

Target population	Description	What makes the practice interesting
Kindergarten (3-6 years) Lower Primary School (6-8 years)	Initiative for kindergarten teachers comprising a set of curriculum materials for designing early childhood science activities and 35 lessons, CPD to support the resource packet and a website with new lessons, examples of children's work.	Focused on kindergarten and lower primary school teachers, who are trained and supervised when implementing it. Resources developed are integrated in pre-service teacher education in Cypriot and Greek universities.

http://lsg.ucy.ac.cy/other/nepiagogeio

IKAMVAYOUTH South Africa

Objective 4.1, 4.2, 4.5

Target population	Description	What makes the practice interesting
8-12 years	The challenge is to increase possibilities of employment for disadvantaged young people, giving them skills to continue their education and enter the labour market and inspire them so that on their own and with the help of others they can get out of poverty. Offers free after-school tutorial support to youngsters who attend voluntarily 3 times a week. There are no academic requirements for participation but students must attend at least 75 % of sessions to retain their place on the programme.	Volunteer tutors, 77 % of who are ex-students who are repaying the support they previously received, work with 5 youngsters. Classes in digital literacy and eLearning and workshops on career guidance, media, Image and expression and health and life skills. Students participate in activities spanning scientific experiments to photography workshops, with trips to museums or famous places.

http://ikamvanitezone.org

LUKA'S LAND OF DISCOVERY Germany

Objective 4.1, 4.4

Target population	Description	What makes the practice interesting
5-13 years	This refers to a German education initiative in the field of photonics. In the frame of this initiative a series of experiment books was published as teaching material for schools to attract children to light and light-based technologies. These experiments were presented to school classes and children at several conferences, exhibitions and in museums within the past years.	The initiative deals with experiments linking the field of photonics to the school curriculum. Many innovative technologies and applications are addressed and students experiment with them. As an outcome experiment books have been published in German.

http://www.photonik-campus.de/schulexperimente/primarstufe-sek-i-lukas-experimente/

HANDISCIENCE INS HEA Institut d'Enseignement Supérieur et de Recherche, France

Objective 4.1, 4.3, 4.5

Target population	Description	What makes the practice interesting
Primary and secondary school children with various abilities	Focuses on helping SEN (Special Education Needs) teachers working with children of various abilities to set up STEM projects. Creates a learning community by sharing expertise and stimulating joint development of new projects.	Organises different events and CPD activities to support objectives; has also developed a database of pictures and videos illustrating various pedagogical projects developed.

http://handisciences.inshea.fr

ALTERNATE EDUCATION FOR RURAL DEVELOPMENT Peru

Objective 4.1

Target population	Description	What makes the practice interesting
Secondary education	An innovative programme for young people from rural communities who usually leave secondary school early. Recognized by the Peruvian government as a successful learning model for rural areas. It aims to create permanent interaction between social and professional development and school life in which students alternate between home and school for two-week periods. It has a very strong STEM focus.	Includes: 1) adaptation of school curricula to rural environment, 2) recruitment and training of rural teachers, 3) involvement of parents in school management and teacher training and 4) accessible facilities and infrastructure. Methodology has been successfully used since 2002 and is now implemented in 40 alternate rural schools in 11 Peruvian regions. Nominated for the WISE awards.

http://www.wise-qatar.org/alternate-education-rural-development-peru-spain

SCIENCE FOR MUMS Australia National University (ANU), Australia

Objective 4.1, 4.4

Target population	Description	What makes the practice interesting
Mothers of 7-9 years	20 mothers of children learn about fundamentals in science in a fun and relaxed environment to feel confident helping their children. It is often their first exposure to formal science.	Gives mothers an active role to support the science their children (7-9 years) learn at school.

http://cpas.anu.edu.au/study/short-courses/science-communication-mums

COOPERATION SCHOOLS, (SCIENCE) MUSEUMS AND INTER-ACTIVE (SCIENCE) SCIENCE CENTRES

SCIENCE GALLERY Dublin, Ireland

Objective 4.4

Target population	Description	What makes the practice interesting
Primary, secondary, tertiary and adults	Unique interactive museum creatively exhibiting “white-hot scientific issues” at the interface between science, technology and art.	The aim is to open science to a wider public through innovative events and exhibitions. It has been an outstanding success and is now being franchised in other jurisdictions.

http://dublin.sciencegallery.com

SETAC: Science Education As a Tool for Active Citizenship Italy

Objective 4.4, 4.5

Target population	Description	What makes the practice interesting
Teachers, primary and secondary pupils, museum educators/ explainers	Science education as a tool to develop active citizens in the knowledge society. It is developed by formal and informal science education organizations working on: new pedagogy for science education, teaching resources and guidelines for quality science education.	It considers museums and science centres as key resources. It aims at developing creative content, raising awareness of the role of science in contemporary society and stimulating dialogue about science with young people.

http://www.museoscienza.org/setac

PLACES PROJECT Wide range of cities

Objective 4.1, 4.4, 4.5, 4.6

Target population	Description	What makes the practice interesting
All age groups	Creates *City Partnerships* between science communication institutions and local policy makers and aims to stimulate interaction between science, politics and citizens, through networking opportunities: workshops, annual conferences and the online PLACES OPEN platform. Aims to establish the European City of Scientific Culture.	Focuses on: environmental sustainability, ageing populations, healthcare, social security, drinking water, agriculture, biodiversity, transportation, clean energy, education policies and innovation for economic growth. Activities contribute greatly to promoting RRI.

http://www.ecsite.eu/activities_and_resources/projects/places

WISSENSCHAFT IM DIALOG Germany

Objective 4.1, 4.4, 4.5, 4.6

Target population	Description	What makes the practice interesting
Learners of all ages	Centre for science communication organises exhibitions, science fairs and symposia through which it promotes discussion and the exchange of ideas surrounding research. It encourages dialogue between those who carry out research and those who profit from its results and maintain it. It promotes RRI.	Stimulates discussions between schoolchildren, students, adults and scientist through exhibitions, film festivals, science shows or Science Nights. It encourages debate with researchers so that all learn from one another and wants to create understanding and trust, stimulate curiosity and generate a fascination for research - in children, young people and adults.

http://www.wissenschaft-im-dialog.de

SCIENCE ENTERPRISE INITIATIVE Europe

Objective 4.2

Target population	Description	What makes the practice interesting
Upper secondary school	Simulation of a small business developed by JA-YE Europe, with support of ARAMCO Cy. It aims to motivate 15-18 year-old students to consider STEM careers and develop entrepreneurship skills.	Students apply knowledge, competences and skills learned at school and develop new skills: entrepreneurship, teamwork, leadership, presenting, planning and financial control as they take responsibility for their company. A strong focus on STEM and entrepreneurship.

WONDERFUL WORLD OF WATERCRESS University of Winchester, England

Objective 4.3, 4.4

Target population	Description	What makes the practice interesting
Primary school children	Cooperation between 4th year pre-service teacher education students and SMEs, In cooperation with the Vitacress conservation Trust (a SME), a science resource booklet for primary school children has been developed based upon watercress farming and the river eco-system. Students are introduced to business, watercress farming methods and associated environmental initiatives.	Resource pack supports development of primary school children's scientific understanding based upon watercress farming and relationship to the environment in Hampshire. It is based upon clearly identified needs established through communication between SMEs and local schools.

http://www.vitacress-conservation.org/educational-resource-pack

ME & MY CITY PROJECT Finland

Objective 4.2, 4.4

Target population	Description	What makes the practice interesting
6th grade students	Module on society, working life and entrepreneurship conducted in a learning environment which hosts at least 15 companies and public services. Pupils work in a profession, earn a salary and act as consumers.	Pupils apply knowledge, competences and skills learned in classroom in a real company environment cooperating with STEM professionals. Several cities/regions have adopted the concept with local stakeholders involved.

http://yrityskyla.fi/en

QUANTUM SPIN-OFF: Connecting Schools with High-Tech Research and Entrepreneurship Belgium

Objective 4.2, 4.4, 4.5

Target population	Description	What makes the practice interesting
Upper secondary school students and their teachers	Science teachers and pupils are in contact with research and entrepreneurs in nanotechnology and quantum physics. Pupils' teams do research, make business plans and implement a scientific paper with researchers and entrepreneurs.	Direct contact with research and entrepreneurship in high-tech. Aims to educate scientifically literate European citizens and inspire young people to choose STEM careers. Shows students how innovative ideas lead to applications in real life.

http://www.quantumspinoff.eu

THIS WORKS! TECHNOLOGY COMPETITION Federation of Finnish Technology Industries (FTTI), Finland

Objective 4.2, 4.3, 4.4

Target population	Description	What makes the practice interesting
Primary and secondary school pupils (from 1st to 6th grade) and their teachers	Regional and national competition enabling teachers to promote innovation and entrepreneurial skills and attitudes as a part of the curriculum to promote STEM careers. Pupils work in teams developing a moving toy using simple materials.	Innovation and entrepreneurial skills and attitudes are promoted by suitable teaching/learning methods. Evaluation shows increased enthusiasm of pupils and teachers in STEM, innovation activities and co-operation with external partners.

http://www.tamatoimii.fi
http://www.teknologiateollisuus.fi/openet/ajankohtaista/tama-toimii--teknologiakilpailun-2014-voittajaryhmat-vilppulasta-tikkalasta-ja-espoosta

PHOTONICS EXPLORER KIT EXCITE YOUTH FOR SCIENCE, ENGINEERING AND TECHNOLOGY(EYEST) International

Objective 4.3, 4.4, 4.5

Target population	Description	What makes the practice interesting
12-18 years	An intra-curricular "educational" kit for secondary schools, developed by an international team of teachers and experts to fit into diverse educational systems and teacher cultures. It equips teachers with a set of experimental materials within a didactic framework; given to teachers free of charge but only in conjunction with teacher training courses. Available in 8 EU languages.	Kits are sponsored by industry, governmental and educational authorities or foundations. EYEST is responsible for fundraising, assembly and distribution; raises interest of youngsters for STEM by supporting teachers to convey the fascination of STEM to pupils and students to prepare the next generation of engineers and scientists.

http://www.eyest.eu/Programs/Photonics-Explorer

MERA Cyprus Pedagogical Institute, Cyprus

Objective 4.2, 4.5

Target population	Description	What makes the practice interesting
Primary School, Middle School and High School	Competition aimed at participation of pupils and teachers in research projects. They indicate their research aims, methodology etc. Selected projects receive an induction programme. They are supported by a research expert throughout the school year.	Competition encourages young people to follow research careers. It is an effort to attain early engagement with research activities as a means of gaining authentic experience and highlighting their educational value to the community.

http://ec.europa.eu/research/conferences/2005/forum2005/showcase_mera_en.htm

DEMOLA CENTRES Finland and International

Objective 4.1, 4.2, 4.4

Target population	Description	What makes the practice interesting
Post-secondary students	Offers university students an opportunity to add real-life experience in their STEM career studies. They work on projects with a multidisciplinary, international team to solve real-life cases together with companies. It is part of the degree program.	Open innovation model is designed and co-created with partners. It offers ways and practices for collaboration between students, universities and business partners. For companies or other organizations, it offers access to young talents.

www.demola.fi

THE WORLD AT YOUR FEET! Belgium

Objective 4.1, 4.5

Target population	Description	What makes the practice interesting
Upper secondary schools (16-18 years)	Enhances cross-curricular competences in the Flemish education system. It aims at stimulating students to choose STEM studies at university level, with a particular focus on encouraging girls especially to pursue careers as civil engineers.	Innovative way to make young people think about their contribution to society and the role of science, technology and business in our globalized world with a focus on ethical issues.

http://www.ingenious-science.eu/web/guest/practices/gallery?practiceId=360

GENDER ISSUES : WOMEN IN SCIENCE

ATHENA SWAN United Kingdom

Objective 4.1, 4.4

Target population	Description	What makes the practice interesting
Women careers in STEM	National scheme to promote women's careers in STEM. Universities promote the Athena SWAN Charter. There are over 90 member institutions.	Gives universities and departments the space to reflect on and celebrate, current organisational and cultural practices that promote gender equality in STEM. It offers a valuable framework for introducing cultural changes to create better working environment for both men and women.

http://www.ecu.ac.uk/equality-charter-marks/athena-swan

WOMEN IN TECH (WIT) Finland

Objective 4.1, 4.4

Target population	Description	What makes the practice interesting
Students in upper secondary and higher education – particularly girls, women and men in technology based professions	Organised by women leaders in technology companies to encourage those interested in the future of business and technology. Activities aim to discuss how women can have a larger role in creating success stories in business and technology.	Led by committed women leaders and involves variety of stakeholders from different sectors of society. Student unions organise activities and events for upper secondary schools girls together with companies.

http://www.mytech.fi/women-in-tech

RAILSGIRLS Finland

Objective 4.1, 4.2

Target population	Description	What makes the practice interesting
Girls and women, especially girls and women at university and in upper secondary education	Gives tools and creates a community for women to make technology more approachable. It is a global, non-profit volunteer community organising workshops for girls.	Workshops have demonstrated that the way learning and teaching takes place plays a major role in motivating students for STEM and in improving the learning outcomes in software programming (and STEM in general).

http://www.railsgirls.com

GIRLS WHO CODE USA

Objective 4.1, 4.4, 4.5

Target population	Description	What makes the practice interesting
Primary and secondary girls	Works to inspire, educate and equip girls with the computing skills to pursue 21st century opportunities. Objective is to reach gender parity in computing fields by ensuring economic prosperity of women, families and communities across the globe and equip female citizens with 21st century tools for innovation and social change.	Has developed a new model for computer science education, pairing intensive instruction in robotics, web design and mobile development with high-touch mentorship and exposure led by industry's top female engineers and entrepreneurs.

http://girlswhocode.com/about-us

GIRLS GO TECH BRIDGE (GGT) USA

Objective 4.1, 4.2, 4.4

Target population	Description	What makes the practice interesting
11-18 years girls	A nationwide program to spark interest in STEM with girls, offers STEM activities to Girl Scout Councils. Significant is the programs-in-a-box offering engaging hands-on projects and career exploration activities for girls. Meeting role models is part of experience.	Training/support offered to Leader Guides designed for users with little to no STEM background, training videos and take-home resources. Studies show a significant impact on girls' interest in STEM careers.

http://techbridgegirls.org/index.php?id=4

ASTEP ACCOMPAGNEMENT EN SCIENCE ET TECHNOLOGIE À L'ECOLE PRIMAIRE (Support in Science and Technology in the Primary School) France

Objective 4.2, 4.4

Target population

Primary school teachers and Higher education students

Description

Higher Education students in STEM studies assist primary school teachers in organising and implementing science lessons. They do not replace the teacher but support him/her in science and technology aspects so that the latter can grow more confident in STEM teaching. Both teachers and students are trained separately and together.

What makes the practice interesting

Teachers getting support grow more confident in science teaching. Support is beneficial to children as they get better STEM teaching and information about STEM careers and research. The HE students acquire communication skills. Example of active citizenship/societal engineering with ECTS credits.

http://www.fondation-lamap.org/sites/default/files/upload/media/minisites/astep/PDF/guide_fr.pdf

INTIZE PROJECT Chalmers and Göteborg Universities, Sweden

Objective 4.1, 4.2, 4.4

Target population

Primary and secondary students

Description

Students offer disadvantaged pupils free private tutoring in maths during secondary school. 300 pupils meet their mentors (responsible for 4 pupils each) weekly.

What makes the practice interesting

Innovative system of mentors involves university students as role models for secondary students. Integrated into higher education subject "Societal engineering" with ECTS credits.

http://www.intize.org/jobba-hos-oss

MEDICS IN THE PRIMARY SCHOOL (MIPS): A SENTINUS ACTIVITY Northern Ireland, United Kingdom

Objective 4.4, 4.6

Target population

Primary school pupils
Medical students

Description

Activity to develop communication skills. Students have a placement one afternoon a week for ten weeks delivering a short science and health education programme to students.

What makes the practice interesting

Useful materials are available: a *MIPS Teaching and Learning Guide* associated activity sheets and a lesson plan outline. Shows how schools can cooperate with hospitals to the benefit of STEM education and STEM (medical) careers. Beneficial to pupils and students.

http://www.sentinus.co.uk/product.php?id=35

MATTE CENTRUM Sweden, Denmark

Objective 4.1, 4.4

Target population

Mainly secondary school pupils, most of them socio-economically disadvantaged

Description

Monthly tutors in maths (for free) around 70,000 young people in maths in 19 cities in Sweden and Denmark using 300 voluntary workers or providing support online in Swedish and English with video lessons, forums, theory, etc.

What makes the practice interesting

Creating social change by helping those who cannot afford to buy private tutoring for maths. 35 % of young people are from immigrant backgrounds making it a very interesting integration project.

http://www.mattecentrum.se
in Swedish: http://www.matteboken.se
in English: http://www.mathplanet.com

SCIENCE CAREER LADDER New York Hall of Science (NYSCI), New York, USA

Objective 4.2, 4.4

Target population

Students from 16-22 years working with younger children

Description

High school and college students participate in mentoring, CPD and career activities. Science Career Ladder (SCL) students, called “explainers” explain exhibits, perform demonstrations, support educational workshops and act as role models.

What makes the practice interesting

Motivates the SCL students for STEM careers and enhances their acquisition of soft skills. It has an impact on the careers of the young people who benefit from the interaction and opens their horizons to new careers and professions.

http://nysci.org/projects-main/explainers-folio/

TECHNOLOGY EDUCATION AND LITERACY IN SCHOOLS (TEALS) USA

Objective 4.3, 4.4

Target population

Volunteer Teachers

Description

TEALS is a grassroots program that recruits, trains, mentors and places volunteer high tech professionals from across the country who are passionate about computer science education into high school classes. They team teach as volunteer teachers where the school district is unable to meet their students’ computer science (CS) needs on its own.

What makes the practice interesting

TEALS works with committed partner schools and classroom teachers to eventually hand over the Computer Science (CS) courses to the classroom teachers. The school will then be able to maintain and grow a sustainable CS program on their own.

http://www.tealsk12.org/

INDUSTRY INITIATIVES FOR SCIENCE AND MATH EDUCATION (IISME) San Francisco, USA

Objective 4.3, 4.4

Target population

Primary, Secondary and SCHE (community college) teachers, Students 6-20 years

Description

Consortium of companies, research labs and government providing summer fellowships for workplaces with support for the teacher. Efforts are made to promote transfer of what has been learned to the classrooms.

What makes the practice interesting

One initiative (Summer Work Experience Programmes for Teachers [SWEPTs]), places teachers into high-performance work sites for the summer. They work full-time for 8 weeks, complete a project for their hosts and are paid. Teachers spend 10 % of time transferring their experience to their students and colleagues.

http://iisme.org

ROBOTICS LEGO LEAGUE Galway Education Centre, Ireland

Objective 4.3, 4.4

Target population

Young Students

Description

Introduces students to real-world engineering challenges by building LEGO-based robots to complete tasks on a thematic playing surface.

What makes the practice interesting

Teams are guided by their imaginations and adult coaches, discover exciting career possibilities and, through the process, learn to make positive contributions to society. Industrial support is an important aspect.

http://www.roboticsireland.com/resources

TALENT FACTORY @ DESY Germany

Objective 4.1, 4.2, 4.4

Target population

14+

Description

DESY is one of the world's leading accelerator centres that has hands-on school labs "physik.begreifen" at Hamburg and Zeuthen and invites pupils to fascinating experiment days. Both centres also offer a visit programme for school classes and participate in nationwide events like "Girls' Day". Pupils with a curiosity for physics will find the opportunity to discuss a variety of topics at the Science Café DESY.

What makes the practice interesting

DESY offers school girls and boys the opportunity to carry out training courses in its technical workshops and research groups. It brings in direct contact students with researchers lab personnel and introduces them to the world of frontier science.

http://www.desy.de/information__services/education/index_eng.html

JET-NET YOUTH AND TECHNOLOGY NETWORK Netherlands

Objective 4.1, 4.4

Target population	Description	What makes the practice interesting
Upper secondary schools	Leading technology companies and secondary schools facilitate students to experience technology that is challenging, meaningful and socially relevant through an educational environment for the science curriculum. Guest lessons, workshops etc. show students how they can find varied, interesting STEM jobs.	Believes that experiencing technology is the best way to promote it. It advocates "learning by doing" because every activity contains an interactive or executive component. Girls work with female professionals for primary/secondary education.

Jet-Net: http://www.jet-net.nl/english
Girlsday: http://www.vhto.nl/projecten/girlsday/

FUTURE IN FOOD PROGRAMME Scotland, United Kingdom

Objective 4.4

Target population	Description	What makes the practice interesting
Primary lower and upper secondary school (also VET)	Scottish Food and Drink Federation helps teachers, pupils and parents understand the sector. It highlights various careers and explores routes to access them. It focuses on maths, sciences, IT, technology, home economics etc. and encourages cross curricular activities.	Creates valuable educational partnerships and collective approaches supporting national Curriculum for Excellence. Pupils gain better understanding of production and processing of food and practical skills via real life experiences and active engagement with industry.

https://www.sfdf.org.uk/sfdf/schools_programme

ENTHUSE United Kingdom

Objective 4.3, 4.4

Target population	Description	What makes the practice interesting
Primary and Secondary Schools Teachers	Partnership between Wellcome Trust and others to support inspired science teaching through CPD of teachers. ENTHUSE awards bursaries support teaching staff on CPD courses at the National Science Learning Centre (NSLC).	Awards support well-structured CPD to have long-lasting sustainable effect on teachers involved, on their colleagues and on their school. They promote development of STEM strategies and learning communities of science teachers.

https://www.sciencelearningcentres.org.uk/centres/national/awards-and-bursaries/enthuse-award

STEM AMBASSADORS SCHEME United Kingdom

Objective 4.4

Target population	Description	What makes the practice interesting
Teachers and pupils of all schools	Works with schools (minimum one event per year) on voluntary basis, providing support and acting as role models for young people. The aim is to encourage STEM subjects and help students understand opportunities STEM careers offers. See also STEMNET in general.	Scheme is widely recognised and welcomed by employers (also SMEs) and those responsible for CPD. It is part of the on-going community involvement programmes for several companies. Teachers and schools benefit from access to quality-assured STEM volunteers.

http://www.stemnet.org.uk/ambassadors
http://www.nfer.ac.uk/publications/SMES01/SMES01.pdf

PRAT DE LA RIBA Centre for Research in Science and Maths Education (CRECIM), Universitat Autònoma de Barcelona, Spain

Objective 4.2, 4.4

Target population	Description	What makes the practice interesting
Secondary school students	Organises company visits for final year secondary students focusing on STEM professions. Students receive preparatory materials. Work at school helps students to consolidate the knowledge acquired.	Instructional materials are co-created by teachers, researchers and companies. The visits are part of the subjects Technology and Science within the curriculum. Students prepare the visit thoroughly and have follow-up activities.

http://www.pratdelariba.cat

LEKTOR2 SCHEME Norway

Objective 4.2, 4.4, 4.6

Target population	Description	What makes the practice interesting
Lower and upper secondary school children	Aims to increase STEM learning, recruitment to STEM careers and improve relations between schools and companies. Professionals from industry teach 3-10 curriculum-related lessons at secondary schools and act as external experts through a formalized partnership between school and industry.	Part of the national STEM strategy, with a steering committee (representatives from ministry and industry) running the project. Regional coordinators with educational backgrounds and good knowledge of the regional labour market assist schools in contacts and cooperation with social partners.

http://www.lektor2.no

SCIENCE CPD/LEARNING CENTRES AND SUPPORT FOR TEACHERS

SCIENCE LEARNING CENTRES (NATIONAL SLC AND FIVE REGIONAL SLC) England, United Kingdom

Objective 4.3

Target population

Primary and lower secondary school teachers and technicians

Description

Offer quality science CPD to enhance professional skills. Also provides young people with exciting, intellectually stimulating and relevant science education and facilitate them gaining knowledge and understanding required as future citizens and scientists.

What makes the practice interesting

Results are evidenced in increased enjoyment of science lessons and extra-curricular activities, increased confidence and understanding in learning science, development of transferable and practical skills, increased awareness of the importance of science to society, of STEM career and studies.

https://www.sciencelearningcentres.org.uk

All research and impact reports: https://www.sciencelearningcentres.org.uk/impact-and-research

LES MAISONS POUR LA SCIENCE (MPLS) Académie des Sciences/Fondation Lamap, France

Objective 4.3

Target population

Primary and lower secondary school teachers, trainers

Description

Located in universities and cooperating with initial teacher education (ESPE), they promote STEM learning and teaching by organising CPD. Funding provided by French government, regional educational authorities, universities and companies.

What makes the practice interesting

CPD is co-created and co-delivered by teams of teacher trainers, researchers, industry people or other external stakeholders. MplS cooperate with other key agents in STEM education and thus become an innovative STEM hub in the French educational landscape.

http://www.maisons-pour-la-science.org

HONEYWELL EDUCATORS @ SPACE (HESA) USA and International

Objective 4.2, 4.4

Target population

Teachers

Description

Created in partnership with the U.S. Space & Rocket Center, this professional development program is designed to help middle school math and science teachers from around the world become more effective educators in science, technology, engineering and math. Since 2004, over 2,176 educators from 55 countries, 52 U.S. states and territories have graduated from the program.

What makes the practice interesting

HESA provides educators with the opportunity to reinvigorate their classrooms with ideas, lessons and other materials to create an unforgettable learning experience for the next generation of scientists. During this five-day program, educators participate in 45 hours of intensive classroom, laboratory and training time, focusing on space science and exploration.

https://educators.honeywell.com/

FOSTERING CURIOSITY IN EARLY YEARS SCIENCE England, United Kingdom

Objective 4.3

Target population

(Pre) primary school pupils and teachers

Description

CPD units to keep teacher's knowledge of primary and stage 3 science up to date. Each unit can be viewed on line and/or downloaded as a PPP. Explores how teachers can liberate the energy and enthusiasm of young children.

What makes the practice interesting

Developed from classroom based research, each unit provides concrete information and materials to help teachers to develop their science teaching and learning potential. Each one is accompanied by videos, useful references and publications.

http://www.pstt.org.uk/resources/continuing-professional-development/fostering-curiosity-in-early-years-science.aspx

NEW TEACHER CENTER (NTC) E-MENTORING FOR STUDENT SUCCESS EMSS California, USA

Objective 4.2, 4.3

Target population

New science and maths teachers

Description

Online mentoring programme advancing instruction by accelerating effectiveness and increasing retention of new STEM teachers. New and veteran teachers and university professors in interactive online community, exchange information, ideas and experiences and expertise within a structured programme curriculum.

What makes the practice interesting

Participants' benefits are: ability and confidence to teach subject-specific content and teach challenging courses and curricula; preparedness in basic teaching and classroom management skills; willingness to experiment; overall teacher satisfaction; encouragement to remain in the field.

http://www.newteachercenter.org/services/emss

Evaluation of the impact of eMSS: http://emssmath.nsta.org/Results/Default.aspx

NATIONAL/REGIONAL PLATFORMS OR NETWORKS

DUTCH NATIONAL PLATFORM (BÈTA TECHNIEK) Netherlands

Objective 4.1, 4.2, 4.3, 4.4, 4.5, 4.6

Target population

All levels of education from primary to higher education

Description

Platform aims to ensure sufficient availability of STEM professionals by increasing the number of STEM students, to use existing talent more effectively in businesses and research and to innovate STEM education.

What makes the practice interesting

Focuses on all levels of education. By investing in children at an early age, potential reach of future STEM talents is broadened. Programmes are implemented in collaboration with companies. They are regularly evaluated to be improved.

http://www.platformbetatechniek.nl/extra/english

PROMOTION OF STEM CAREERS (FLEMISH STEM PLATFORM) Flanders, Belgium

Objective 4.1, 4.2, 4.3, 4.4, 4.5, 4.6

Target population	Description	What makes the practice interesting
All levels of education from kindergarten to higher education	Regional joint initiative developed in 2010 to address the shortages of STEM graduates and enhance cooperation with industry. Promotes: STEM-pact and intersectoral strategies with industry, STEM academies so that parents and children know which STEM opportunities are available nearby, STEM coaches from companies and STEM guest lecturers in school etc.	Action plan refers to integrated actions starting from primary education and continuing in secondary education, adult education and higher education, to actions supporting present and future teachers, communication and awareness campaigns and actions around STEM careers.

http://www.onderwijskiezer.be/v2/extra/stem_downloads.php

LUMA CENTRE (LCF) Finland

Objective 4.1, 4.2, 4.3, 4.4, 4.5, 4.6

Target population	Description	What makes the practice interesting
Primary and secondary students, teachers	LCF is umbrella for 10 LUMA Centres in Finnish Universities providing CPD and research in STEM to strengthen and promote collaboration nationally and internationally. The aim is to motivate all young people for STEM. LCF cooperates closely with education, public authorities and business.	Ministry of Education and LCF are starting a new national development programme (2014-2019) to strengthen STEM skills in 6-16 years. It will develop novel and innovative tools and approaches to teaching practices, methods and learning environments.

http://www.luma.fi/centre

STEM ENRICHMENT AND ENHANCEMENT ACTIVITIES FOR SCHOOLS (SENTINUS) Northern Ireland, United Kingdom

Objective 4.1, 4.2, 4.3, 4.4, 4.5, 4.6

Target population	Description	What makes the practice interesting
Primary and Secondary Schools	Provides wide range of programmes supporting teaching and learning of STEM within a real world context. It provides a range of employability-skill activities for schools to support Learning for Life & Work within the Northern Ireland curriculum.	Supports delivery of curriculum and engages students in practical problem solving activities, research and development and investigative projects. They enhance employability and personal development through team working, target setting, mentoring, working with adults and independent learning.

http://www.sentinus.co.uk/index.php#

PRIMARY INDUSTRY CENTRE FOR SCIENCE EDUCATION (PICSE) Australia

Objective 4.4, 4.5, 4.6

Target population	Description	What makes the practice interesting
Upper secondary pupils	National strategy of collaboration between universities, regional communities and local primary industries to attract students into tertiary science to have more skilled professionals in agribusiness and research institutions. It is preparing the next generation of researchers and industry scientists.	Primary industries targeted are agriculture, ecology, horticulture, fisheries, water security, sustainability, climate change and the environment. Impact evaluation report indicates that activities are working very effectively.

http://www.picse.net/HUB/index.htm

SCIENCE MUNICIPALITIES (SMP) – EDUCATION FOR GROWTH Denmark

Objective 4.3, 4.4, 4.6

Target population	Description	What makes the practice interesting
Primary, lower and upper secondary students and teachers	Aimed at improving science education in municipalities, as part of national strategy for developing science education funded by the Ministry of Education. Objective is to increase pupils' interest in STEM and to inspire pupils to pursue STEM studies and careers.	Development of local science education strategy, with designated STEM coordinators, a science education board and support networks for teachers. Collaboration between various stakeholders gives an overview of resources.

http://www.ind.ku.dk/projekter/science_kommuner/Science-kommuner_-_engelsk.pdf
http://www.ind.ku.dk/english/projects/science_municipalties

SCIENCE AND TECHNOLOGY FOR ALL (NTA) Sweden

Objective 4.3, 4.4, 4.6

Target population	Description	What makes the practice interesting
Primary school teachers	Supports teachers stimulate pupils´ curiosity, interests and knowledge in STEM. It offers and develops methods as well as services (CPD) and products to improve learning and teaching in STEM, both at municipal level and at individual school and school districts' level.	Teams of teachers are trained by municipalities supporting NTA financially. Training leads to local and school STEM strategies. NTA creates long-term school development plans in which local industry, institutions and others are engaged. 110 municipalities involved 180,000 students and 8000 teachers.

http://www.ntaskolutveckling.se/In-English/

NETWORK OF “LÉA” (Lieux d’éducation Associés à L’IFÉ) Associated Educational Design-experiment Centres (AeDeC), France

Objective 4.2, 4.3, 4.4, 4.6

Target population	Description	What makes the practice interesting
Primary , lower and upper secondary and vocational schools (teachers, heads)	Developing a network of centres meeting educational challenges by focusing on questions raised by teachers and educators. Research team supports activities. All stakeholders invited to co-construct a long-term project to find answers to key educational questions.	Network includes some 30 projects by (networks of) primary schools, lower and upper secondary schools and vocational upper schools etc. HEIs and non-academic centres are integrated into the network. It focuses on investigation, mathematics teaching, digital identity and reflective thinking, serious games etc.

http://ife.ens-lyon.fr/lea

LEADERSHIP AND ASSISTANCE FOR SCIENCE EDUCATION REFORM (LASER) Washington State, USA

OBJECTIVE 4.3, 4.4, 4.5, 4.6

Target population	Description	What makes the practice interesting
School Head Teachers/ Principals	Catalyst for sustainable innovation and improvement in K-12 science education. A shared vision of effective teaching and learning, supporting public/private partnership network of individuals and organizations, delivering leadership development programs and experiences and partnering with regional support networks.	Cooperation between various stakeholders supporting STEM education. It engages educators in leadership CPD through projects such as “Teachers as Researchers”. It organises STEM leadership development for principals and administrators. It supports schools, districts and regions to develop action plans and strategies for STEM education reform.

http://www.wastatelaser.org/Professional-Learning/home

CONTESTS AND COMPETITIONS, INITIATIVES PROMOTED BY FOUNDATIONS, TRUSTS AND OTHER CIVIL SOCIETY ORGANISATIONS (CSO)

CITY OF YOUNG SCIENTISTS AND SCHOLARS PRIZE Germany

Objective 4.4, 4.5

Target population	Description	What makes the practice interesting
Upper Secondary School and University Students	Promotes interest in science and research among young people by launching a prize. It is awarded to cities and towns that are exemplary in promoting cooperation between schools and research facilities and intensify their activities in STEM.	Strengthening local networks of schools, universities and scientific institutions. The experiences of project creators from schools, college and local governments and networking teachers, researchers and experts from politics, administration and business are used to promote STEM.

http://www.stadt-der-jungen-forscher.de/content/language1/html/index.asp

SCIFEST Finland

Objective 4.4, 4.5

Target population	Description	What makes the practice interesting
Upper secondary students and teachers	A yearly international festival bringing together thousands of schoolchildren, high school students and teachers to discover new experiences and learn about science, technology and the environment. The festival is free and open to all.	Future oriented and international. Key aim is to provide innovative solutions for education and workforce challenges of the future. Themes range from space to biodiversity, chemistry and water. Over 10,000 visitors and contributors come from over 50 countries.

http://www.scifest.fi

SCIENCE FAIR Cyprus

Objective 4.4, 4.5

Target population	Description	What makes the practice interesting
Upper Primary School (10-12 years) and Lower Secondary (12-15 years)	Schools teach a unit on investigations, parents' meetings are organised, students are guided to choose investigation topics and supported designing experiments, collecting/analysing data and preparing a poster on results. Parents help build an interactive exhibit and a school event.	Curriculum is inquiry-based and relies on collaborative group work focusing on creativity and entrepreneurial skills. Research refines the curriculum materials. Parents and local community are actively involved. Activities thoroughly evaluated. Pre-service teacher education students are involved.

http://www.ucy.ac.cy/en/

THE EUROPEAN UNION CONTEST FOR YOUNG SCIENTISTS (EUCYS) European Union

Objective 4.4, 4.5

Target population	Description	What makes the practice interesting
Young scientists who have won first prize in their national science competition and who are designated by their respective national jury	An initiative of the European Commission to promote ideals of co-operation and interchange between young scientists. Contest is annual showcase of best of European student scientific achievement and as such attracts widespread media interest. Winners proceed to international competition.	Young scientists have opportunity to meet others with similar abilities and interests and be guided by some of the most prominent scientists in Europe. Seeks to strengthen the efforts made in each participating country to attract young people to careers in science and technology.

http://ec.europa.eu/research/eucys/index_en.cfm?pg=home

CHAMPIMÓVEL Portugal

Objective 4.4, 4.5

Target population	Description	What makes the practice interesting
Mainly primary school pupils	Fully interactive, 3-D, transportable experience that introduces children to most cutting-edge issues in medical science with support of Ministry of Education. It stimulates creativity and imagination, motivating youngsters to join search for scientific discoveries.	Interesting creative and interactive programme to promote STEM mainly at primary school level. Awakens curiosity in cutting-edge scientific concepts like stem cells, nanotechnology and DNA and gene therapy.

http://www.fchampalimaud.org/en/education

CSO "ACTIVI PENTRU VIITOR" ("ACTIVE FOR THE FUTURE") Romania

Objective 4.4

Target population	Description	What makes the practice interesting
Primary and secondary school children	Project address gap between school and community with purpose of enabling real world experiences, collaboration and critical thinking especially in field of STEM education.	Projects foster innovation and encourage communities to share their skills and expertise. Local stakeholders from different cities help develop practices that strengthen emergence of unified action for change.

http://www.activipentruviitor.ro

SCHOOL OF THE FUTURE Ullern High school (UHS) and Oslo Cancer Trust (OCT), Norway

Objective 4.4, 4.5

Target population	Description	What makes the practice interesting
Upper secondary pupils Teachers	Collaboration aims to educate tomorrow's researchers and entrepreneurs. It is a step towards integration of school within OCC Innovation Park.	Creation of innovative and creative schools in order to develop Norway as a "Knowledge Country" by stimulating cooperation between ministries, trade and industry, research and education. Aims to foster the next generation of entrepreneurs in biotech.

http://oslocancercluster.no/portfolio-item/talent-workforce-education/

GENAU: SCHÜLERLABORE Berlin and Brandenburg, Germany

Objective 4.2, 4.3, 4.4

Target population	Description	What makes the practice interesting
Teachers and pupils of primary, lower and upper secondary schools	Network of 16 school labs organised by research centres, universities or museums organising hands-on science lab experiments for pupils and CPD for teachers. It produces teaching and practice downloadable materials. Focus is also on QA and development of future concepts for school labs.	Strong hands-on aspects for pupils and teachers. Synergy through efficient use of resources and experiences. Strengthening political and social effectiveness of extra-curricular learning centres to have more student labs.

http://genau-bb.de/labore/die-netzwerk-mitglieder

REVIR Catalonia, Spain

Objective 4.2, 4.3, 4.4

Target population	Description	What makes the practice interesting
Secondary students Teachers	Students access computerised lab working in inquiry-based learning groups with STEM instructional material co-designed and revised by researchers and science teachers covering curricular topics: road safety, chemical equilibrium of oceans, biodiversity, greenhouse gases, etc. 8,000 students involved.	Cooperative work between students through dialogic teaching, promotion of ICT tools of a computerised lab, co-creation of curricular materials, addressing societal issues, monitoring student progress, evaluation of impact on students.

http://crecim.uab.cat/revir

FAMELAB British Council and Cheltenham Science Festival, now operating in more than 20 countries: Europe, Middle East, Asia and South Africa

Objective 4.5

Target population	Description	What makes the practice interesting
Young scientists and engineers	Exciting science communication competition designed to find the new faces of science: people who can inspire and excite public imagination with a vision of science in the 21st century. It intends to inspire and motivate young scientists and engineers to actively engage with the public and stakeholders by taking science out of the classroom, make it fun and encourage young people with a passion for science and technology to share their enthusiasm with the general public.	Contestants compete to communicate a scientific topic they're passionate about to the public. Robust training, coaching and recognition build confidence and skills allowing alumni to put into practice their skills in a wide variety of situations. It works by identifying, training and mentoring young scientists and engineers to enable them to communicate effectively in a media intensive environment in the world in which they live.

http://www.britishcouncil.it/en/programmes/education/famelab

INFORMAL SCIENCE EDUCATION

CODERDOJO World-wide

Objective 4.1, 4.4, 4.5

Target population	Description	What makes the practice interesting
7-17 years	Free, volunteer-led coding clubs for young people with focus on peer-to-peer learning, tutoring and self-driven learning with an emphasis on open-source and helping others. Aim is to show how coding can be a force to change the world. An important aspect is promoting creativity and having fun in a social setting.	Makes learning to programme and developing programs fun. A dojo is an independent programming club and created in a local community that is part of the Coderdojo network. It is organised by a master and team of mentors and volunteers. Participants develop websites, applications, programmes and games and explore technology.

https://coderdojo.com

COASTER LAB FERRARI WORLD Abu Dhabi

Objective 4.2, 4.4

Target population	Description	What makes the practice interesting
Upper secondary pupils	Unique Roller-Coaster Science Educational Program in partnership with Ministry of Education provides exciting learning in STEM education. Initiative focuses on physics of rollercoasters. It is congruent with *Abu Dhabi 2030 Strategic Vision* and efforts to spread STEM.	Coursework facilitates maximum learning outcomes by balanced theory-practical curriculum and empowers students to improve skills concerning problem solving, teamwork and communication, next to analytical and creative thinking in an environment that fosters maximum creativity and challenges the norms.

http://www.ferrariworldabudhabi.com

PATIENT AND COMMUNITY GROUPS United Kingdom

Objective 4.1, 4.4, 4.5

Target population	Description	What makes the practice interesting
Patients of all ages	Objective to stimulate genuine engagement with patient groups and other stakeholders to add value to research by providing new insights into research questions. Engagement allows discussion of potential implications with those most affected and ensures research will help reach full potential for health improvement.	Involves patients as users directly in the research from the beginning. Supports researchers looking to develop their patient and public involvement activities.

http://www.wellcome.ac.uk/Education-resources/index.htm

http://www.invo.org.uk/resource-centre/resource-for-researchers/

GALILEO-MOBILE
India, Bolivia, Chile, Peru, Brazil, Uganda

Objective 4.5, 4.6

Target population	Description	What makes the practice interesting
Young people and adults	Non-profit initiative run by astronomers, educators and science communicators. It is a traveling science education programme that brings astronomy closer to young people and adults around the world and mainly across regions that have little or no access to outreach actions. By organizing astronomy-related activities in schools and villages, it fosters desire to learn through the wonders of the universe. Educational material as well as on-going support is available so that educators can pursue astronomy activities after visits.	Teaching material is compiled in a handbook called *Cartilla de Actividades GalileoMobile*, which includes instructions for hands-on activities and explanation of physical phenomena studied, which is available for free download. Cooperates closely with “Galileo Teacher Training Programme” (GTTP) and “A touch of Universe» (ATU) project.

http://galileo-mobile.org/

INVESTIGARTE: ARTISTIC CONTEST SCIENTISTS OF TODAY AND TOMORROW! Spain

Objective 4.5

Target population	Description	What makes the practice interesting
Secondary schools students , their teachers and researchers	A science and technology competition aimed at the visual arts. It focuses on students in general and vocational secondary schools and their teachers in cooperation with researchers. Students are invited to use photography to explain to future generations and society in general, scientific and technological innovations associated with their science projects.	Main goal is to bring science and technology closer to society through contest that aims to promote artistic and creative vision of science students and teachers in secondary school and vocational training in cooperation. Focuses on MACROphotographs (photos and/or videos of objects larger than one millimetre) and on MICROphotographs (photos and/or videos of objects less than or equal to one millimetre).

http://www.investigarte.es/descripcion

HACKIDEMIA NASA Ames Research Park, USA

Objective 4.2, 4.5, 4.6

Target population	Description	What makes the practice interesting
4-18 years	Involves 80 students from 36 countries trying to solve societal challenges: poverty, access to food, clean water, health care, education etc. It is a mobile invention lab enabling future change-makers to access and create a hands-on STEAM education.	Channels communities toward creation of networked local hubs that provide access to latest technologies and tools and allow young people from early age to kick-start their project and solve local grand challenges. More than 80 workshops organised, 10,000 young people and 400 volunteers in more than 40 countries involved.

http://www.hackidemia.com

STEAM ACADEMY USA

Objective 4.2, 4.4

Target population	Description	What makes the practice interesting
6-18 years	Online-schools of creativity, ingenuity and global awareness. The curriculum integrates fine arts and technology, project-based, collaborative learning, international student collaboration and service oriented living. Educators, parents and other stakeholders foster student creativity, cultural perspective and global competence.	Focus is on instructional approaches that provide students with opportunities to learn curricular material with depth and breadth that is vital to students' ability to apply new understanding. Students have heightened engagement and motivation to learn, as evidenced by the students who have attended educational institutions that implement its approaches "through and by" the fine arts.

http://thesteamacademy.wordpress.com/transforming-reality-through-the-arts

ENISCUOLA CULTURA Italy

Objective 4.2, 4.4

Target population	Description	What makes the practice interesting
8-12 years	Promotes science and culture to schools to stimulate students' interest in art and theatre. It develops multimedia lessons on the major art exhibitions supported and stages performances on issues of science and culture.	Interesting and stimulating combination of art and science. The theatre stimulates ethical debates about sustainable development and promotes creative and scientific talents of children. Focuses on Content and Language Integrated Learning (CLIL) in STEM.

http://www.eni.com/it_IT/azienda/eni-scuola/eni-scuola.html

APPENDIX 1
Glossary and Abbreviations

Assessment for Learning (AfL)

All those activities undertaken by teachers and by their students in assessing progress and evaluating prior action, which provide information to be used for feedback in order to plan or modify future action, including the teaching and learning activities in which they are engaged, in order to give an opportunity to learn to all students.[97]

Citizen Science

Refers to citizen direct involvement in research projects, usually directed by universities and research institutions.[98]

Civil Society Organisations

The multitude of associations around which society voluntarily organises itself and which can represent a wide range of interests, from ethnicity and religion, through shared professional, developmental and leisure pursuits, to issues such as environmental protection or human rights.[99] For the purpose of this report, civil society includes all those interested in and affected by policies in science education, but also more broadly by education, research and innovation for responsible citizenship.

Competence

Proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development. In the context of the *European Qualifications Framework*, competence is described in terms of responsibility and autonomy. Examples include critical thinking, problem solving, modelling, innovation, creativity, design and investigation, collaboration and team working.[100]

Inquiry Approach

A complex process of sense-making and constructing coherent conceptual models where students formulate questions, investigate to find answers, build new understandings, meanings and knowledge, communicate their learning to others and apply their learning productively in unfamiliar situations. An inquiry approach to science education is one that engages students in: i) authentic, problem-based learning activities where there may not be one correct answer; ii) experimental procedures, experiments and "hands on" activities, including searching for information; iii) self-regulated learning sequences where student autonomy is emphasized; and iv) discursive argumentation and communication with peers ("talking science").[101]

Key Enabling Technologies (KETs)

Technologies associated with knowledge-intensive R&D, rapid innovation cycles, high capital expenditure and highly skilled employment. They enable process, goods and service innovation throughout the economy and are of systemic relevance. They are multidisciplinary, cutting across many technology areas with a trend towards convergence and integration. KETs can assist technology leaders in other fields to capitalize on their research. [102]

Learning Outcomes

Statements of what a learner knows, understands and is able to do on completion of a learning process, which are defined in terms of knowledge, skills and competences.[103]

Open Schooling

"Institutions that promote partnerships with families and the local community with a view to engaging them in the teaching and learning processes but also to promote education as part of local community development."[104]

Post-secondary/Tertiary Education

All types of education (academic, professional, technical, artistic, pedagogical, long distance learning, etc.) provided by further and higher educational institutions, technological institutes, teacher training colleges, etc., which are normally intended for students having completed a secondary education and whose educational objective is the acquisition of a title, a grade, certificate, or diploma of higher education. It comprises ISCED levels 5, 6, 7 and 8, which are labelled as short-cycle tertiary education, Bachelor or equivalent level, Masters or equivalent level and doctoral or equivalent level, respectively.[105]

Responsibility in Science Education

Ensures stakeholders are involved in all stages of scientific practice and dissemination. It is a participatory approach based on principles of integrity and ethical behaviour and practice, social solidarity and trust; it uses a wide range of measures to monitor intended and unintended consequences as a "way of recognizing that we're all in this together."[106] It assumes a multidisciplinary approach that reflects the values and needs of all stakeholders.[107]

Responsible Research and Innovation (RRI)

Societal actors work together, via inclusive participatory approaches, during the whole research and innovation process in order to better align both the process and its outcomes, with the values, needs and expectations of European society.[108] RRI in science education helps "maximise the creation of shared value."[109]

Skill

Ability to apply knowledge and use know-how to complete tasks and solve problems. In the context of the *European Qualifications Framework*, skills are described as cognitive (involving the use of logical, intuitive and creative thinking) or practical (involving manual dexterity and the use of methods, materials, tools and instruments). Competencies may incorporate a skill, but are more than the skill; they include abilities and behaviours, as well as knowledge that are fundamental to the use of a skill.[110]

Small and Medium-Sized Enterprises (SMEs)

Enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million and/or an annual balance sheet total not exceeding EUR 43 million.[111]

Stakeholders

An individual, group, organization or system that affects or can be affected by policies in the field of science education for responsible citizenship, e.g. students, schools, families, post-secondary/ lifelong learning providers, regional or national policy makers, civil society organisations, enterprise/employers, science organisations, etc.

STEAM

An educational and innovation framework bringing science, technology, engineering and mathematics together with the arts/other disciplines (STEM + Art=STEAM or S-TEAM) and types of learners with the goal of being more engaging, creative and naturally successful for all members of any educational system.[112]

STEM

Teaching and learning in the fields of science, technology, engineering and mathematics. It typically includes educational activities across all grade levels — from pre-school to post-doctorate — in both formal (e.g., classrooms) and informal (e.g., afterschool programs) settings.[113]

Types of Learning[114]

- **Formal learning** – learning that occurs in an organised and structured environment (e.g. in an education or training institution or on the job) and is explicitly designated as learning (in terms of objectives, time or resources). Formal learning is intentional from the learner's point of view. It typically leads to validation and certification.

- **Non-formal learning** – learning which is embedded in planned activities not always explicitly designated as learning (in terms of learning objectives, learning time or learning support), but which contains an important learning element. Non-formal learning is intentional from the learner's point of view. It can take place in museums, science camps/ clubs etc.

- **Informal learning** – learning resulting from daily activities related to work, family or leisure. It is not organised or structured in terms of objectives, time or learning support. Informal learning is mostly unintentional from the learner's perspective.

ABBREVIATIONS

AfL	Assessment for Learning
CPD	Continuous Professional Development
HE	Higher Education
HEI	Higher Education Institutions
E2E	Education to Employability
IBSE	Inquiry Based Science Education
IBSME	Inquiry Based Science and Mathematics Education
ICT	Information and Communications Technologies
LLL	Lifelong Learning
RRI	Responsible Research and Innovation
SWAFS	Science with and for Society

APPENDIX 2
SEEG Terms of Reference

The Science Education Expert Group (SEEG) was established in 2014 to examine existing studies and available data in the field of Science Education at a European Level in order to provide the European Commission with an extensive analysis of 1) the issues at stake; 2) the policy options and 3) their possible impacts. In particular and in the context of RRI, H2020 and the ERA, it is important to assess the progress of Science Education activities financed so far under the FP6 and the FP7, identify issues at stake, define new policy options and initiatives, current challenges and existing trends in different Member States and in the broader European area.

The mandate of the SEEG was to write a detailed report, charting the key elements of future actions to be considered and undertaken by the European Commission.

The Group was asked to:

- Review the "State of Affairs";
- Identify achievements and innovations, as well as issues at stake in order to develop new policy strategies, provide a set of policy recommendations and undertake new policy initiatives;
- Provide guidance concerning the further increase of the industry participation to Science Education policy activities;
- Assist the European Commission services to further elaborate and reflect on possible new challenges as well as formulate the premises on which the future strategy, to be undertaken in the framework of the new ''Science with and for Society (SWAFS)'' Work Programmes (2015-2017) could be shaped.

The SEEG had 10 members from 10 EU Member States. Member expertise covered the fields of: science education; science and education policy issues; technology enhanced learning – educational technology – international technology and education; investigative approaches to science education, formal and informal science education and learning, industry-university and industry-school cooperation, as well as youth communication; design, evaluation, implementation of programmes in the field of science education and beyond; classroom research and development; STEM; MST; academic-research and industrial institutions collaboration in the field of science education; teacher education and training and teachers' professional development (TPD); science education research; science education and scientific/research careers; science in research and innovation.

The SEEG held six meetings in Brussels and conducted additional working remotely.

SEEG Team Members

- Prof. dr. Ellen Hazelkorn (Ireland) Chairperson
- Dr. Charly Ryan (England) Rapporteur
- Mr. Yves Beernaert (Belgium)
- Prof. dr. Constantinos P. Constantinou (Cyprus)
- Ms. Ligia Deca (Romania)
- Prof. dr. Michel Grangeat (France).
- Ms. Mervi Karikorpi (Finland)
- Dr. Angelos Lazoudis (Greece)
- Prof. dr. Roser Pintó Casulleras (Spain)
- Prof. dr. Manuela Welzel-Breuer (Germany)

APPENDIX 3
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As the world becomes more inter-connected and competitive and as research and technological know-how expands, new opportunities along with more complex societal challenges arise. Overcoming these challenges will require all citizens having a better understanding of science and technology.

This expert report identifies the main issues involved in helping all citizens acquire the necessary knowledge about science to participate actively and responsibly in science-informed decision-making and knowledge-based innovation. It provides guidance concerning increasing the participation of enterprise and industry to science education policy and activities. It sets out the challenges we face and how science education can help Europe meet its goals and equip citizens, enterprise and industry in Europe with the skills and competences needed to provide sustainable and competitive solutions to these challenges.

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