4.1. FINAL PUBLISHABLE SUMMARY REPORT

4.1. FINAL PUBLISHABLE SUMMARY REPORT

4.1.1. EXECUTIVE SUMMARY (NOT EXCEEDING 1 PAGE)

The main reason for this project was our concern raised by the Mathematics, Science and Technology (MST) benchmark for the 2010 Lisbon work plan. The figures indicated that EU member states were lagging behind their global competitors in the field of MST. Although the number of people holding higher education degrees within the EU was on the rise, this increase was not matched in the area of MST. At the same time, among those students who do graduate in MST, women are strongly underrepresented.

The overall aim of the SECURE project was to make a significant contribution to a European knowledge-based society in order to encourage and prepare children for future careers in MST from an early age, whilst at the same time, to make MST more accessible and enjoyable for all children, so that they would maintain a strong interest in math, science and technology, and understand the importance of their societal role, throughout their adult lives. Based on scientific research, the SECURE consortium provides a number of recommendations to policy makers and other stakeholders who have an impact on curriculum development as well as on teacher education. The recommendations are centered around how MST curricula and their delivery can be improved.

The specific objective of the SECURE project was to provide relevant and rigorous research data and to translate this data into recommendations that contribute to the debate among policy makers on science curricula and their objectives: balancing the needs between training future scientists and broader societal needs. This means that education in MST is on the one hand considered as highly important for the training of specialists and experts who promote scientific and technological innovation in society, and on the other hand that a basic scientific competences and a positive attitude towards the societal role of science are important for every European citizen. The progress and wellbeing of the society in general depend on both aspects.

The SECURE research scrutinized and compared existing MST curricula in the member states as they are intended by the authorities, implemented by the teachers and perceived by the learners. It focused on ages 5, 8, 11 and 13, bridging the gaps between kindergarten, primary school and middle school.

In particular, the research consists of:

- comparing MST curricula in a relevant range of 10 EU countries (Austria, Belgium, Cyprus, Germany, Italy, The Netherlands, Poland, Slovenia, Sweden, United Kingdom). The research is focused on mathematics, technology (technics), and (natural) sciences (integrated or as separate subjects: biology, chemistry and physics);
- questioning perceptions of MST teachers and learners about the curricula using questionnaires and interviews;
- analyzing, comparing and contrasting these findings.

The cornerstone of the valorization strategy of the research outcomes was the direct and active involvement of a transnational Expert Group of research and curriculum development institutions.. The constructive cooperation of the experts incited the improvement of the final outcomes of the project.

The SECURE consortium disseminated research findings and conclusions in a number of articles, presentations and meetings, both scientific and aimed at the general public. In view of promoting a vivid interest in MST, SECURE collaborated with schools to organize science events for the learners of all ages and gave them innovative learning tools and materials. Information was delivered to the policy makers and stakeholders via national and international conferences and written recommendations.

4.1.2. A SUMMARY DESCRIPTION OF PROJECT CONTEXT AND OBJECTIVES (NOT EXCEEDING 4 PAGES)

A knowledge-based society in the foreseeable future will require both specialists in narrow fields, as well as educated and informed citizens. This demand was expressed by the European Parliament, which issued in 2006 *Recommendation on key competences for lifelong learning* (European Council, 2006; Key Competences, 2007), stating:

> Key competences are those, which all individuals need for personal fulfilment and development, active citizenship, social inclusion and employment.

Among others, a mathematical competence and basic competences in science and technology were listed as those "contributing to a successful life". School subjects, such as mathematics, science and technology , become a natural platform for development of those competences, but at the same time they can substantially support progress in other key competences, such as digital competence, learning to learn, social competences and sense of initiative and entrepreneurship, giving them all a practical context.

One of the noticeable aspects in the above-mentioned documents is drawing the attention to the affective domain of learning and putting it on a par with the cognitive one:

> Competences are defined here as a combination of knowledge, skills and attitudes appropriate to the context. (...) Motivation and confidence are crucial to an individual's competence.

In its latest policy initiatives and outputs in education and training the European Union restated the importance of science literacy and numeracy as fundamental elements of key competences (European Commission 2010; European Council, 2009, 2010). It was recognized that

> …more investment should be undertaken to increase the number of graduates in science, technology, engineering and mathematics (STEM) so as to create the right conditions to deploy key enabling technologies, essential in the R&D and innovation strategies of industry and services (European Commission, 2010).

The aim of SECURE study is to examine the state-of-the-art of the mathematics, science and technology (MST) curricula intended for early stages of schooling. The focus of research is to find out whether the balance between training for future scientists and broader societal needs exists in the documents and everyday school practice. The disturbance of such a balance can prevent the increase of science literacy and numeracy among common society members as well as limit the number of budding candidates for scientists, thus leading to a slowdown in the future development of the European Union and backwardness in its competitiveness compared to other countries.

The SECURE project is an international comparative curriculum study focusing on Mathematics, Science and Technology curricula in ten European countries. Subjects within these curricula are: mathematics, biology, physics, chemistry, physical geography, and technology. A curriculum can be defined as a 'plan for learning' (Taba, 1962). It consists of the following ten components: rationale, aims & objectives, content, learning activities, teacher role, materials and resources, grouping, location, time, and assessment. A clarifying way to visualize the relationship between these components is the so-called curricular spider's web (van den Akker, 2003; Thijs & van den Akker, 2009) (see Figure 1). The core and the nine threads of the spider web refer to the ten components of a curriculum (see also Table 1).

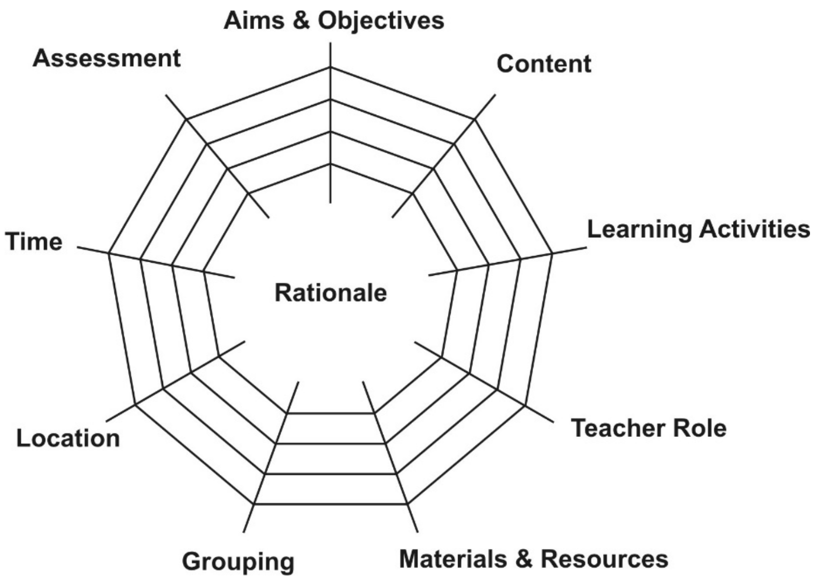

Figure 1. Curriculum spider's web (van den Akker, 2003)

Table 1. Curriculum components in question form

Component	**Core question**
Rationale	Why are they learning?
Aims and objectives	Towards which goals are they learning?
Content	What are they learning?
Learning activities	How are they learning?
Teacher role	How is the teacher facilitating their learning?
Materials and resources	With what are they learning?
Grouping	With whom are they learning?
Location	Where are they learning?
Time	When are they learning?
Assessment	How is their learning assessed?

A curriculum spider-web approach, proposed mostly for research of curricula documents, omits the affective domain of learning, so intensively promoted in the concept of Key Competences. It is noticeable that its role was recognized many years ago and for at least 40-50 years it has been studied intensively by researchers, among others in MST education (e.g. Middleton & Photini, 1999; Osborne et al., 2003; Logan and Skamp, 2008). Cognitive and affective components of learning have been recently also researched (together or separately) in a large number of studies, including world-wide studies, such as PISA, 2012 (of 15 year olds), TIMSS, 2011 (of 10 and 14 year olds) and ROSE, 2009, (Sjøberg & Schreiner, 2010 ; of 15 year olds). Nevertheless, apart from research on educational practices, the joint studies on mathematics, science and technology education barely ever come onto the stage. The SECURE project was established to fill this gap by providing research outcomes on state-of-the-art MST curricula, their implementation and their perception by teachers and learners. In order to get a complete view, the SECURE project followed the spider-web approach to research the curricula, bringing however yet another item onto stage, meaning "Attitude, Motivation and Interest".

Another starting point for this study is the typology of curriculum representations shown in Table 2. This division into six representations of a curriculum, built on the work by Goodlad (1979, see also van den Akker, 2003) is especially useful in the analysis of the processes and the outcomes of curricula. The distinction of forms emphasizes the different layers of the curriculum concept and demonstrates the often substantial discrepancies between the various forms. Although this might not always be a problem, an often-voiced desire is to reduce the gap between ideals, actions and results. The SECURE project focuses on four out of the six curriculum representations. This project will not focus on the learned curriculum, since this is the focus of other comparative studies like TIMSS and PISA. Also ideal aspect of curriculum is out of scope of the project.

Table 2. Curriculum representations. Focus of SECURE indicated by a green frame.

Intended	Ideal	Rationale (basic philosophy underlying a curriculum)
	Formal/written	Intentions as specified in curriculum documents and/or materials
Implemented	Perceived	Curriculum as interpreted by its users (especially teachers)
	Operational	Actual process of teaching and learning (also: curriculum in action)
Attained	Experiential	Learning experiences as perceived by learners
	Learned	Resulting learning outcomes of learners

Curricula can be defined on various levels (Table 3). The following division into five segments has proved to be very useful to understand the different levels (cf. van den Akker, 2003, 2006). The macro (national) level will affect the 'lower' ones, especially if they have a mandatory status that limits the room to manoeuver for large target groups.

A clear example is the influence of examination programmes and core objectives (macro) on textbooks (micro). Authors take these macro frameworks carefully into account. Teachers, in turn, place such great confidence in the textbooks that they will hardly consult the original policy documents. The relationships from macro via meso to micro become looser and looser , e.g. in the Netherlands, with its tradition of freedom of educational organization, the government tends to exercise restraint in stipulating content, and allows schools, teachers and learners a relatively large amount of curricular freedom (Thijs & van den Akker, 2009), especially in the way of teaching is being shaped. In order to get a decent overview of MST curricula in European countries the SECURE project will focus on the macro, meso as well as micro level.

Table 3. Curriculum levels and exemplary curriculum products. Focus of SECURE indicated by a green frame.

Level	**Description**	**Examples**
Supra	International	European Framework for Key Competences
Macro	System, national	Core objectives, attainment levels Examination programmes
Meso	School, institute	School programme Educational programme
Micro	Classroom, teacher	Teaching plan, instructional materials Module, course Textbooks
Nano	Pupil, individual	Personal plan for learning Individual course of learning

Based on the overview of curriculum levels and curriculum representations four research questions are formulated. A fifth research question is added to be able to give recommendations based on the outcomes of the study focusing on the first four general questions:

1. *Which MST curriculum documents are available at the national level* (macro)*, which components of the curriculum spider web are described in these documents and what is the nature of these descriptions?* (formal/written)
2. *What are perceptions and interpretations of teachers* (meso/micro) *concerning MST curricula?* (perceived)
3. *What are experiences of teachers* (micro) *with enacting the MST curricula?* (operational)
4. *What are learning experiences of learners* (micro) *concerning the MST curricula?* (experiential)
5. *Which lessons can be learned from the national curriculum documents, and the interpretations, perceptions and experiences of teachers and learners?*

4.1.3. A DESCRIPTION OF MAIN S&T RESULTS/FOREGROUNDS (NOT EXCEEDING 25 PAGES)

Target group and subjects

The SECURE study took place in ten European countries (regions) of well-defined educational systems: Austria, Belgium (limited to Flanders), Cyprus, Germany (limited to Saxony), Italy, the Netherlands, Poland, Slovenia, Sweden and the United Kingdom (limited to England). The research involved learners of ages 5, 8, 11 and 13, their MST teachers as well as the MST curricula documents relevant to those ages. Key ages of early education were chosen, complementary to the ones researched in TIMSS (2011), ROSE (Sjøberg, S. and Schreiner, 2010) and PISA (OECD, 2006, 2009).

Due to the broad variety of educational systems in research countries, the study encompassed MST subjects in all occurring forms, M - comprising mathematics, S – comprising: biology, chemistry, physics, physical geography (in some countries), science (integrated), world orientation, social and environmental studies, environmental education, and T – comprising: technology, technics and technology, technology and design, technics, technical crafts.

A systematic collection of data has been performed in every country in 15 school units, each combining altogether four classes, one per the designated age. Classes belonging to the same unit were not necessarily linked by any means. Whenever a class was selected for the research all teachers teaching MST subjects in this class also took part in the study. Thus altogether almost 600 classes, 9000 learners and 1500 teachers participated in the study.

Research Instruments

The research instruments consist of a curriculum screening instrument (CSI), and of several school data collection instruments: teacher questionnaires, learner questionnaires and interview protocols for pupils and teachers.

In table 4 the information about the relationship between the research questions and research activities is provided.

Table 4. Relationship between research questions and utilized research instrument

Research question	**Research instruments**
1. Which MST curriculum documents are available on the national level, which components of the curriculum spider web are described in these documents and what is the nature of these descriptions?	• Curriculum screening instrument
2. What are perceptions and interpretations of teachers concerning MST curricula?	• Teacher questionnaires • Teacher interviews
3. What are experiences of teachers with enacting the MST curricula?	• Teacher questionnaires • Teacher interviews
4. What are learning experiences of learners concerning the MST curricula?	• Pupil questionnaires • Pupil interviews
5. Which lessons can be learned from the national curriculum documents, and the interpretations, perceptions and experiences of teachers and learners?	• Analysis of outcomes concerning questions 1-4

The questionnaires are based on existing scientific literature on science education and science curriculum reform (e.g. Atkin & Black, 2003; Black & Atkin, 1996; van den Akker, 1998). Instruments available from previous relevant studies, such as Alting (2003), Bennett, Gräsel, Parchmann and Waddington (2005), van Driel, Bulte & Verloop (2006), van Langen, (2005) – and teacher and/or pupil questionnaires used in the Relevance Of Science Education (ROSE) study (Schreiner and Sjøberg, 2004), TIMSS (1995, 1999, 2003, 2007), and PISA (2000, 2003, 2006, 2009) have all been used as a starting point for the design. Other useful sources for instrument development are the instruments used as part of a recent comprehensive evaluation study on new context-based science curricula in Dutch Senior Secondary schools (Kuiper, Folmer, Ottevanger & Bruning, 2009, 2010).

All questions are based on 2, 3, 4 or 5-point scale (response categories). In every questionnaire a box for remarks is included to enable expression of the opinions and thoughts not covered by the research instrument. The interview protocols were developed in order to gather additional information and study in depth learners' and teachers' opinions. All interview guidelines are semi-structured meaning the guideline is flexible, allowing new questions to be brought up during the interview as a result of what respondents answer. All learners' instruments have been adjusted to the age, whilst only one type of questionnaire and one interview protocol has been designed for all the teachers.

An overview of the focus of the curriculum screening instrument, the questionnaires and the interview guidelines is given in table 5, 6 and 7. For all instruments the curriculum spider web (Figure 1), expanded by "Attitude, Motivation and Interest" item, was used as the primary framework.

Table 5. Focus of curriculum screening instrument

Curriculum screening instrument
• Rationale *(general and according MST)* • Aims and objectives *(main goals, types of goals, learning trajectories)* • Content *(learning areas, relevance, coherence)* • Learning activities and teacher role *(pedagogical principles, attractiveness)* • Materials and resources • Grouping • Location • Time • Assessment *(procedures, criteria)*

Table 6. Focus of questionnaires

<table>
<tr><th>Questionnaire</th><th>Focus</th></tr>
<tr><td>Teachers</td><td>• Teacher background
• Support
• Rationale
• Aims and objectives
• Content
• Learning activities and location
• Teacher role and grouping of learners
• Materials and resources
• Time
• Assessment and difficulty
• Aspect of motivating learners</td></tr>
<tr><td>8* year old learners</td><td rowspan="2">• Pupil background
• Attitude towards MST
• Learning activities
• Materials and resources
• Location
• Time
• Assessment
• Motivation
• Self-esteem</td></tr>
<tr><td>11* and 13 year old learners</td></tr>
</table>

*The focus of learner questionnaires for 8yo pupils is concurred with the focus of questionnaires for 11 and 13 year olds, however in the latter more questions are included.

Table 7. Focus of interview guidelines

Interview guideline	Focus
Teachers	• Rationale • Attainability and time • Learning materials and learning strategies • Relevance, attractiveness, interest and motivation of learners • Assessment • Support • General impression
5 year old learners	• Materials learners use • How learners play on the playground/schoolyard
8, 11, 13 year old learners	• Content, learning activities and learning materials • Study load, assessment, complexity • Attitude, motivation and interest

The questionnaires and the interview protocols are available in Annex 6 to this document.

Data collection

The main research took place during the school year 2011/2012. A class could be chosen only if on the 1st of September 2011at least 50% of its pupils was aged 5, 8, 11 or 13, respectively. A purposeful selection took place, meaning that 15 school units in each country should, if possible, reflect typical features of a particular country schooling system, following the characteristics: schools known as forerunners concerning MST education and schools not being the ones, city schools as well as schools in rural areas, small and large schools, public and non-public schools, schools with majority of immigrant learners as well as schools with majority of native learners.

The following procedure was implemented for school data collection in each country:

1. In classes participating in research all 8, 11 and 13 year old learners were asked to fill out a relevant questionnaire. Nevertheless there are known objective difficulties connected to question 5yo, SECURE consortium decided to make a pilot study on 5yo answering questionnaires. On the basis of the results from piloting we later decided to omit the idea for the present, but the initial steps were taken and partial interesting results from the performed pilot study may serve as a basis for a research.
2. All MST teachers of 5, 8, 11 and 13 year olds were asked to complete the questionnaire.
3. Four representatives (two girls and two boys) of each class of 5 year olds were interviewed by two researchers at the same time.
4. Four representatives from six selected classes of each age: 8, 11 and 13 were interviewed by two researchers at the same time.

5. All MST teachers teaching six selected classes of each age were interviewed by two researchers at the same time.

Response

Curriculum screening

All countries filled in the basic version of the Curriculum Screening Instrument (CSI), enabling the research of MST curricula documents, relevant to 5, 8, 11 and 13 year olds' education in each country. In the course of the data analysis, an extended list of Additional Questions to Curriculum Screening Instrument (AQ-CSI) was prepared to facilitate uniformity of the response.

A great variety of different curricula documents have been detected during the study, most of them are from 2006 or later. The researchers found out that in some countries there are only a few documents serving as a core curriculum (IT, NL, SE, UK), whilst in other countries the number of available legal documents exceeds twenty (SI). In general, the core curricula are extended and detailed, placed between two extremes: very detailed documents in case of SI and DE, and on the other hand - very general curricula in NL.

Teacher and pupil questionnaires

In table 8 an overview of a number of teachers and learners, who responded to the questionnaires, is shown across 10 countries. It should be noticed that in each of two countries, the Netherlands and Sweden, the total number of learners and teachers responding to the questionnaires is half as many as in other countries. The number of teachers researched with questionnaires in the United Kingdom (England) does not exceed one fifth of the mean value for the others, thus the group is not representative.

Table 8. Number of teachers and learners who responded to the questionnaires in each country.

	Learners				**Teachers**
Country	8yo	11yo	13yo	Total	Total
Austria	253	324	305	882	208
Belgium	298	291	272	861	136
Cyprus	255	250	264	769	144
Germany	254	277	235	766	109
Italy	321	305	343	969	201
the Netherlands	152	142	267	561	65
Poland	290	262	285	837	203
Slovenia	283	306	277	866	234

Sweden	158	176	151	485	95
United Kingdom	402	464	336	1202	30

Teacher and pupil interviews

Table 9 gives an overview of the number of interviewed teachers and learners per country. It should be noticed that teacher and learner interviews were not conducted in the United Kingdom (England).

Table 9. Number of teachers and learners interviewed in each country

	Country	Schools	Teachers	Learners
1	Austria	15 kindergartens 6 primary 6 lower secondary	5 year olds: 6 8 year olds: 10 11/13 year olds: 44	5 year olds: 60 8 year olds: 24 11 year olds: 24 13 year olds: 24
2	Belgium	15 kindergartens 7 primary 7 secondary	5 year olds: 7 8 year olds: 7 11 year olds: 8 13 year olds: 20	5 year olds: 60 8 year olds: 28 11 year olds: 28 13 year olds: 28
3	Cyprus	15 kindergartens 6 primary 6 secondary	5 year olds: 15 8 year olds: 9 11 year olds: 13 13 year olds: 21	5 year olds: 60 8 year olds: 24 11 year olds: 24 13 year olds: 24
4	Germany	12 day care centers 14 primary 6 middle schools 8 gymnasiums	5 year olds: 12 8 year olds: 12 11/13 year olds: 11	5 year olds: 46 8 year olds: 24 11 year olds: 39 13 year olds: 50
5	Italy	17 kindergartens 6 primary 6 lower secondary	5 year olds: 6 8 year olds: 6 11 year olds: 12 13 year olds: 12	5 year olds: 68 8 year olds: 24 11 year olds: 24 13 year olds: 24
6	The Netherlands	10 primary 4 secondary	5 year olds: 5 8 year olds: 6 11 year olds: 6 13 year olds: 7	5 year olds: 40 8 year olds: 24 11 year olds: 24 13 year olds: 17
7	Poland	15 kindergartens 6 primary 6 lower secondary	5 year olds: 11 8 year olds: 6 11 year olds: 17 13 year olds: 27	5 year olds: 60 8 year olds: 24 11 year olds: 20 13 year olds: 24
8	Slovenia	15 kindergartens 6 primary	5 year olds: 7 8 year olds: 6 11 year olds: 23 13 year olds: 33	5 year olds: 60 8 year olds: 24 11 year olds: 24 13 year olds: 24

9	Sweden	14 pre-schools 7 primary 6 secondary	5 year olds: 6 8 year olds: 7 11 year olds: 6 13 year olds: 6	5 year olds: 51 8 year olds: 24 11 year olds: 24 13 year olds: 24

Methods of analysis

Curriculum documents

Descriptive analysis (recursive abstraction) of curricula documents has been utilized on the basis of the two curriculum screening instruments (CSI and AQ-CSI). The available information was tabularized, compared and contrasted across spider-web items and learners' ages. The conclusions of the descriptive analysis of curricula documents in ten European countries are provided in sec. *Summary of curriculum screening* and its expanded version is available in Annex 1 *Mapping national curricula for maths, science and technology in EU countries*.

Teacher and pupil questionnaires

All questionnaires have been filled in by teachers and learners on paper and later on the answers have been transformed to a digital form. As concerning The graphs combining all answers linked to a particular spider-web item were prepared for each age and subject separately, showing results per country. Much poor statistics for teachers stimulated a production of graphs by distinguishing a few categories: (1) teachers of 5 year olds, (2) teachers of science taught as an integrated subject (including technology teachers teaching the same classes), (3) mathematics teachers teaching classes with integrated science subjects, (4) teachers of science separate subjects (including technology teachers teaching the same classes), (5) mathematics teachers teaching classes with separate science subjects. The descriptive analysis of the results shown on graphs was written down and the summaries of the cross-country analysis per each category of pupils and teachers were prepared. The conclusions of the analysis of teacher and learner questionnaires are provided in sec. *Summary of teacher and pupil questionnaires.* For the purpose of comparative analysis of selected topics the overall graphs, combining answers from all teachers teaching mathematics or science subjects or technology subjects in all ten countries were utilized to research the general trends in Europe. Those graphs, among others, were used as evidences supporting formulation of SECURE recommendations and as the basis for triangulation (see for example ANNEXES 2, 3 and 4)

Teacher and pupil interviews

In order to record the interviews, the notes were taken on paper and afterwards they were put into a digital form in national languages. As digital interview documents were not fully structuralized across countries, ages and schools, a more standardized procedure for more uniform elaboration of this part of the research was proposed. All interviews were coded, using a certain list of codes and sub-codes prepared by SECURE

Consortium. On the basis of codes the summaries of interviews with learners and teachers were elaborated and written down in English. Those country summaries, among others, were used as evidences supporting formulation of SECURE recommendations and as the basis for triangulation (see for example ANNEXES 2, 3 and 4) .

Research findings

In this sub-section the most important conclusions from the curriculum screening, the questionnaires and the interviews are summarized and presented per spider-web item. Profoundly elaborated summary of the curriculum screening can be found in ANNEX 1. A comparative analysis of the selected themes based on triangulation is provided in ANNEXES 2, 3 and 4.

Summary of curriculum screening

Rationale

Rationale of MST education, across countries, focuses on three (overlapping) areas:

- Acquisition and promotion of social skills, children's growth (identity and participation),
- Acquisition of knowledge and skills, and scientific literacy, and
- Broader societal needs: moral/ethical, socio-political, critical/creative, environmental.

Rationale of MST education includes issues such as 'stimulating curiosity about phenomena in the world around them', 'development of skills of criticism and opinion, and arguments and points of view other than their own', as well as environmental issues, and a link to the daily lives of learners.
The knowledge focus in the national curriculum documents seems to be more explicitly formulated and more dominant for the older age groups.

Aims and objectives

Aims and objectives are formulated per age group, or in a combination of age groups, e.g. combined in primary education, compulsory school, or middle school. They belong to two categories: 'goals to attain' and 'goals to strive for'. They are obligatory, but not necessarily tested.
Aims and objectives are mostly formulated in a subject-oriented manner ('knowledge *of* science'), but there are also (although to a limited extent) statements related to 'knowledge *about* science'.
A majority of countries have aims and objectives formulated for learners of 5 year old in Kindergarten or pre-primary school. Focus is hereby mostly on 'soft skills', linked to 'discovery in the familiar surroundings'.
In the national curriculum documents many references are made to the use of ICT in teaching and learning in MST.

Content

A broad similarity can be observed in the learning areas and subjects in the different countries.
The content of the learning areas is described in different ways from country to country: from broad descriptions in Sweden, The Netherlands and Belgium to very detailed descriptions in countries like Slovenia, Poland and Germany.
There is a great similarity in MST- topics that are mentioned in the curriculum documents of the partner countries, some topics in Biology and Physics are popular across all countries.
For a variety of reasons (motivation of the pupils, general principles of education, prepare pupils to live their life in the world, next educational field), connection to the daily life of pupils is an important part of MST- education. Interdisciplinary and cross-curricular goals are mentioned in curriculum documents in most partner countries. However, specific details of such linkages between disciplines and curriculum are not stated, except for a few cases, e.g. core curricula in SI and PL give explicit recommendation of topics where interdisciplinary connections can be made.
Curricula in the participating countries seem to focus primarily on the core content of MST. There is no specific focus on more modern content like computer sciences.

Learning activities

Active learning, cooperative and coherent learning, and constructivist approach are highlighted, as well as a rich learning environment, 'the importance of group work, partner work and modern learning strategies', organizing excursions, field trips and outdoor activities and to invite experts to enrich the lectures.
The use of inquiry, 'scientific approach', and research process are formulated as general principles by most countries, with the exception of some countries that have very specific guidelines for the number and nature of experiments in science.
Working in groups is recommended because of activity oriented and problem solving learning activities, as well as because of the importance for developing personal skills.

Teacher role

In the majority of countries pedagogical principles are included — one way or another - in the curriculum documents, in general terms and/or for MST education specifically, and for some or all age groups. For some countries it is stated that it is the responsibility of the school and the teacher to shape the teaching in the classroom.
In most of the national curriculum documents, the pedagogical principles seem detached from learning activities and goals. They remain formulated in general terms, leaving the implementation of these principles to the teachers, except for some explicit suggestions of learning activities

Grouping

The importance of group work and partner work is emphasized in many countries. Limited guidance on the size of the groups in the classes can be detected. In six out of ten countries the maximum number of pupils per classroom is indicated (for 5 and 8 year olds). Suggestions are concerned with smaller groups in crafts or technology lessons or experimental work, for purposes of better learning and safety.

Materials and resources

Materials and resources are described in more concrete terms for the younger, but in more implicit terms in older age groups. Only in 2 countries textbooks are prescribed, and in 4 countries experiments or activities pupils should perform are described as well, sometimes together with examples of materials and devices.
The use of ICT for MST subjects is recommended 8 countries.

Time

Only in one country learning time for 5 year olds is elaborated. In all the others schools make their own decisions concerning time allocations. Four countries indicate a timetable for MST for 8 year olds.
In one case, the timetable for MST is neither specified per learning area or subject nor per school year. In other cases, timetables for the 8 year olds are less specified (e.g. per learning area) in comparison with the 11 and 13 year olds (e.g. per subject).

Location

Some references, but not many, are included in the national curriculum documents about where learning should take place.
For science and technology subjects it is implicitly described to use other locations like a dedicated classroom or laboratory, or to do outdoor activities in the (natural) environment. Excursions and fieldtrips to subject related sites are mentioned

Assessment

The assessment procedures vary from one country to the other.
Learning achievements in MST subjects are evaluated according to national procedures and there is a tendency that assessment is performed in a formative way. Assessment activities are used to follow pupils' development. Criteria for MST assessments are described in knowledge or developmental skills, in either attainment targets or goals and except for two countries, these are valid for all ages.
In some countries the information provision to parents about the outcome of assessments is explicitly mentioned. There is a tendency that results of the exams are given in marks from 8 years and older, and that they are descriptive for younger pupils (5 or 8 year olds).
In all countries teachers play an important role in the assessment procedure.
In four countries evaluation (for the age group 5 – 13) is performed by a national or municipal examination board.

Summary of teacher and learner questionnaires and interviews

Attitude, motivation and interest

Positive attitude and motivation towards MST subjects vary with age, indicating the greatest drop between ages 8 and 11. Statistically significant gender differences can be detected in many cases (see also ANNEX 3).
Learners are motivated by practical activities and content related to their daily life. In many cases they do not know exactly what they learn for. Some of them consider undertaking MST careers. Part of them admit that MST outside the school can be much more interesting and motivating that MST school subjects.

Aims and objectives

MST goals are formulated in a broad and general way, in some countries for all age groups, in some other countries only for the lower age groups. Goals for the higher age groups are then formulated in more detail. In general teachers indicate to prefer having more concrete examples so they know which (or all) curriculum goals to include in their lessons.

Content

MST content for 5 year olds is integrated in general learning activities, together with other subjects or not specified at all.
In mathematics, geometry is a subject that almost all learners like, at all age levels. Other topics are considered difficult In science the human body and reproduction are popular, as are topics related to the universe. Most of the learners barely like botany.

Learning activities

Whole class teaching seems the norm with learners listening to the explanation of the teacher, note taking, learners being asked to explain answers and to explain what they have learnt, memorizing how to answer questions, making assignments, or working on one's own, as most common activities. The focus varies a little per age group and per subject.

Practical work is also part of the science and technology lessons, but there seems to be quite a broad range in the extent to which this happens at school. This ranges from rarely to often. In many instances learners indicate that they would like to do more practical activities. Teachers often use the issue of time as a constraint. In some countries large class sizes hinder teachers to work in smaller groups.
MST lessons include a range of practical activities including storytelling, watching movies and multimedia, games, discussions and presentations, doing experiments (in and outside school), growing plants, breeding, excursions to the park, forest, farm, visits to museums, especially for 5 year olds.
Practical activities appear to become less and less when moving up in age groups. Curriculum overload for teachers of 8, 11, and 13 year olds is a problem for all MST subjects. This has a consequence for the implementation of active learning methods.

Teacher role

Mathematics is considered difficult to teach, especially at higher grades. This is similar for physics, because of the lack of mathematical skills. Connecting mathematics activities to everyday life of learners is a challenge.
Limited language skills for some of the learners is seen as a barrier for successful MST lessons in many countries.

Grouping

In general, learners like working in smaller groups. They sometimes mention they would like to do this more often.

Materials and resources

Textbooks are the most important resource in mathematics and science for 8, 11, and 13 year olds. In general, there are no textbooks for the youngest age group. Teachers of 5 year olds use materials developed by themselves or colleagues for mathematics, and no written materials for science and technology. For technology various materials are more important than for mathematics and science.
The availability of materials and equipment varies but seems limited in many cases.
The more positive schools and teachers are about MST, the more materials they seem to use.
In general, teachers feel they need professional development to teach mathematics, science and technology in an adequate way. Majority of them did not participate in any CPD courses during the last two years prior to the SECURE study.

Time

Teachers often report the issue of time as a constraint to do more practical activities in the classroom. Curriculum overload for teachers of 8, 11, and 13 year olds is a problem for all MST subjects. This has a consequence for the implementation of active learning methods. Teachers of 5yo conclude time is not an issue. They have enough time available for mathematics, science and technology, also for practical activities and to motivate learners.
Many teachers do not have enough time for lessons preparation. The more teachers invest in active learning methods and the development of materials, the more time they need for lesson preparation.
8, 11, and 13 year old learners feel they spend a lot of time at school doing mathematics, science and technology, but do not spend a lot of time on homework.

Location

For all age groups the classroom is the most frequently used location for school activities. In general, the younger the learners, the more they go outside and
the older the learners, the more they are taught in dedicated classrooms.
The availability of dedicated classrooms is sometimes a problem. Either they are simply not there, or not available. The extent to which dedicated classrooms are equipped varies from school to school.

Assessment

In general, older learners (8/11/13 years old) are assessed differently and more often than younger learners (5 year olds). Teachers of 5 year olds assess practical skills, behavior and the application of knowledge in mathematics, and practical skills in science and technology.
In mathematics and science the most frequently used form of assessment are planned tests (8/11 year olds) and tests at the end of each chapter (13 year olds). For 8 year olds oral tests and grades for assignments are also common for mathematics and science. For technology 8 year olds are graded mostly for presentations and assignments and 11 and 13 year olds - for projects.

Comparative analysis of selected research outcomes

Analysis of MST curricula documents as well as data collected from teacher and learner questionnaires and interviews opened the opportunity for triangulation of cross-cutting issues related to searching for balancing the needs between training future scientists and broader societal needs. Elaboration of such top themes resulted in conference presentations and publications prepared by members of the SECURE consortium. In this sub-section we present the conclusions of comparative analysis on three selected topics: (1) Key competences in MST curricula and their implementation at schools, (2) Attitude towards and motivation for school MST subjects, and (3) Differentiation in MST written curricula and school practice. Each topic has been elaborated extensively in one of ANNEXES.

Key competences in MST curricula and their implementation at schools

The educational needs for development of the knowledge-based societies in the foreseeable future, have been expressed by EU *Recommendation on key competences for lifelong learning* (European Council, 2006; Key Competences, 2007):

> The key competences are all considered equally important, because each of them can contribute to a successful life in a knowledge society

Among eight key competences, "mathematical competence and basic competences in science and technology" is undoubtedly applicable for MST education. Furthermore a number of other themes that are applied throughout the entire Reference Framework, like critical thinking, creativity, initiative, problem-solving, decision-taking and attitude of collaboration as well as digital competences, can also be efficiently developed throughout the MST activities at school.

During the SECURE study it has been found out that MST curricula indirectly address the entire list of key competences, relevant to MST education, however the list itself never appears in any document. Also the emphasis put on particular statements related to this list varies a lot from country to country.

In the analysis elaborated in details in ANNEX 2, the presence of records supporting development of the European key competences and their implementation by MST teachers into everyday practice have been examined and the results shown jointly for ten European countries.

Several questions have been asked in teachers' questionnaires in order to learn how teachers implement the curricula records supporting development of EU key competences,. It seems that despite the emphasis of use of ICT tools, computers are still not frequently used to support MST teaching and learning. The answers about limitations due to ICT tools shortage are more ambivalent: either the schools are quite well equipped or most of the teachers do not see any pressing need for use of computers, or both.

Regarding organization of group work activities, the research draws a positive trend towards implementing the group work approach into everyday teaching of MST subjects across Europe, but still it seems to be only a half-way through systemic acceptance of its importance, comparably to the moderate attention paid to a group work in core curriculum documents.

It seems that time and equipment conditions for implementation of practical work in MST lessons vary a lot, most probably from country to country and between ages, but also possibly from school to school. Definitely, at least some teachers try to follow recommendations of Rocard (2007) and Osborne and Dillon (2008) at least in some of the lessons.

It seems that recommendation for promotion of the context-based learning, included in MST curricula in every researched country (see Table 1) is seriously taken by most of the teachers of all MST subjects at all ages of schooling and it is widespread across Europe.

Analytical thinking and communication skills are one of the most desired competences in a competition job market. Such skills need to be developed for a long time, preferably staring at early ages. MST lessons seem to be one of the best educational platforms for progress in that matter. Nevertheless the research shows that such an opportunity is still underestimated by MST teachers, although they make some attempts in this regard.

To conclude, teachers seem to follow the records concerning development of the key competences, however the data show that whatever is happening in the classroom never goes beyond the emphasis encountered in the legal documents. In particular more efforts are needed in implementation of group work, more practical activities and tasks enhancing the analytical thinking.

The overall trend is that MST curricula follow the European recommendations (Key Competences, 2006; Osborne and Dillon, 2008; Rocard 2007), however the relevant records seem to be not detailed or extended enough to persuade the teachers to implement them immediately and thoroughly. One of the solutions can be the creation of more favorable conditions for undertaking Continuous Professional Development (see de Meyere et al., 2013) that would put more emphasis on those features of curricula that are significant for future Europe and their translation into everyday practice.

Details of the study are presented in ANNEX 2.

Attitude towards and motivation for school MST subjects

As already indicated in sec. 4.1.2 the affective domain gains more and more attention in educational strategies across Europe, both in EU recommendations (European Council, 2006; Key Competences, 2007) and studies (ROSE, Sjøberg and Schreiner, 2010; TIMSS, 2011). As the SECURE project was established to provide research outcomes on state-of-the-art MST curricula, their implementation and their perception by teachers and learners, this domain got special attention in our studies. Detailed analysis has been shown in ANNEX 3. Below, only the main trends and conclusions derived from triangulation are presented.

Affective domain in written curricula

Study of core curricula documents reveals a great diversity of schooling systems and approaches to legal documents, which also counts for addressing the affective domain of learning. In particular when screening the curricula documents, the question has been asked, separately for each subject: '*Are there any goals belonging to affective domain (awareness, appreciation, willingness, satisfaction, attention, motivation, attitude etc.) mentioned for MST education?*'

The conclusion is that in general across MST subjects the affective domain is most frequently approached in science, a bit less in mathematics and the least – in technology education. The goals belonging to the affective domain are mentioned for older learners a bit more often in technology and a bit less frequently in science, while for mathematics the picture is more homogenous. Among eight countries, researching this aspect in their MST curricula, only AT seems to put similar emphasis on affective domain across all ages and MST subjects.

Questionnaires for teachers and learners

In learner questionnaires a set of questions related to the attitude towards MST school subjects has been proposed. For 8yo learners four items have been proposed and for 11 and 13 year olds the fifth additional item was given (Table 10).

Table 10. A sub-set of items on attitude towards school MST subjects, included in learner questionnaires.

Questionnaire for 8yo	**Questionnaire for 11 and 13yo**
1. I like the things I learn in *the subject* 2. I enjoy learning *the subject*. 3. I would like to do more *the subject.* 4*.*The subject* is boring.	1. I like the things I learn in *the subject* 2. I enjoy learning *the subject*. 3. I would like to do more *the subject.* 4*.*The subject* is boring. 5. I like *the subject* more than most other subjects.

*Reversed items

For 8yo learners only three levels of agreement has been anticipated for each statement, whilst for 11 and 13 year olds a 4-point Likert scale has been attributed to each statement. In order to facilitate a comparison between ages, each answer was scaled as follows. For 8yo 'no' has been given a value of '1' , 'a bit' – a value of '2' and 'yes' – a value of '3'. For 11 and 13yo 'I completely disagree' has been given a value of '1', 'I disagree' has been equated to '2', 'I agree' has been given a value of '3' and 'I completely agree' has been equated to '4'. Answers given by each pupil to all items in the sub-set were summed up and the sum was every time rescaled to range 0..10 (Johns, 2010), see ANNEX 3 for details.

The results reveal (Figure2) that for all three subject domains the learners' attitude decreases with age. For boys the greatest drop in positive attitude is always observed between age 8 and 11, and between 11 and 13 – the decrease is much less pronounced. For girls the trend is similar, except for technology, where decreasing trend prevails across all three ages. The boys show better positive attitude towards all subjects across primary and lower secondary schools, except for age 8, when in science and technology the girls seem to score higher in their attitude than the boys. More detailed analysis with distinction of different countries and separate science subjects is provided in ANNEX 3.

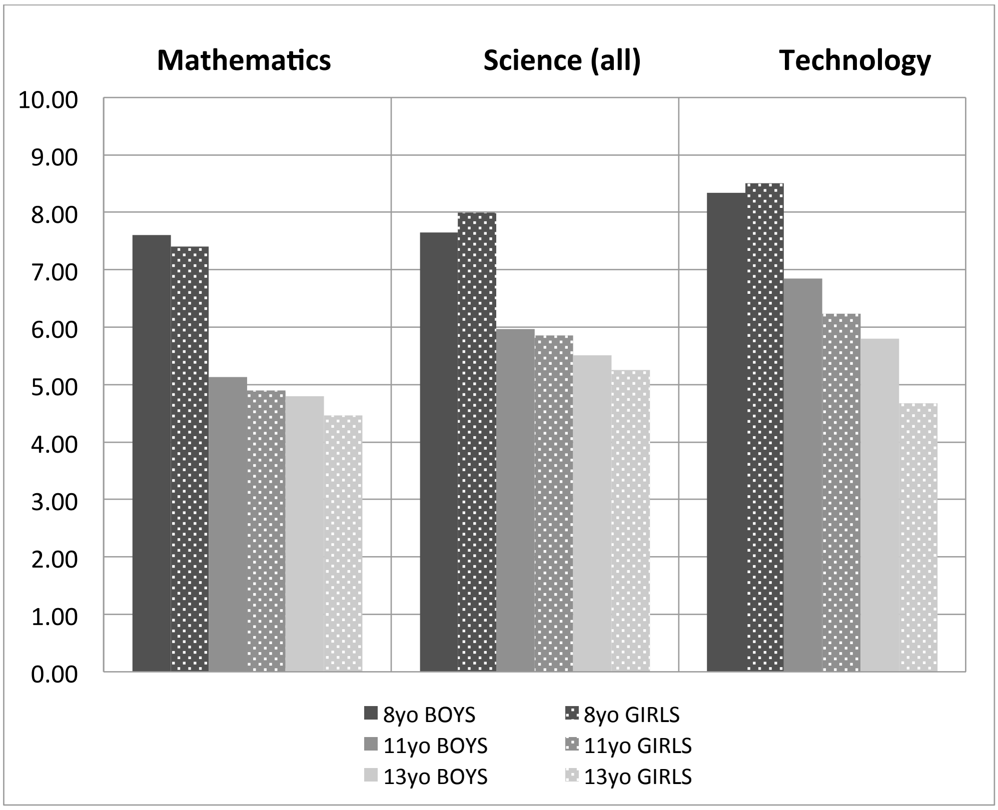

Figure 2. Attitude towards MST subjects across ages and genders in ten European countries. Results for science comprise all science subjects

A huge difference in attitude towards MST school subjects between ages 8 and 11 requires investigation of teachers attitude towards teaching. The results are shown in Figure 3.

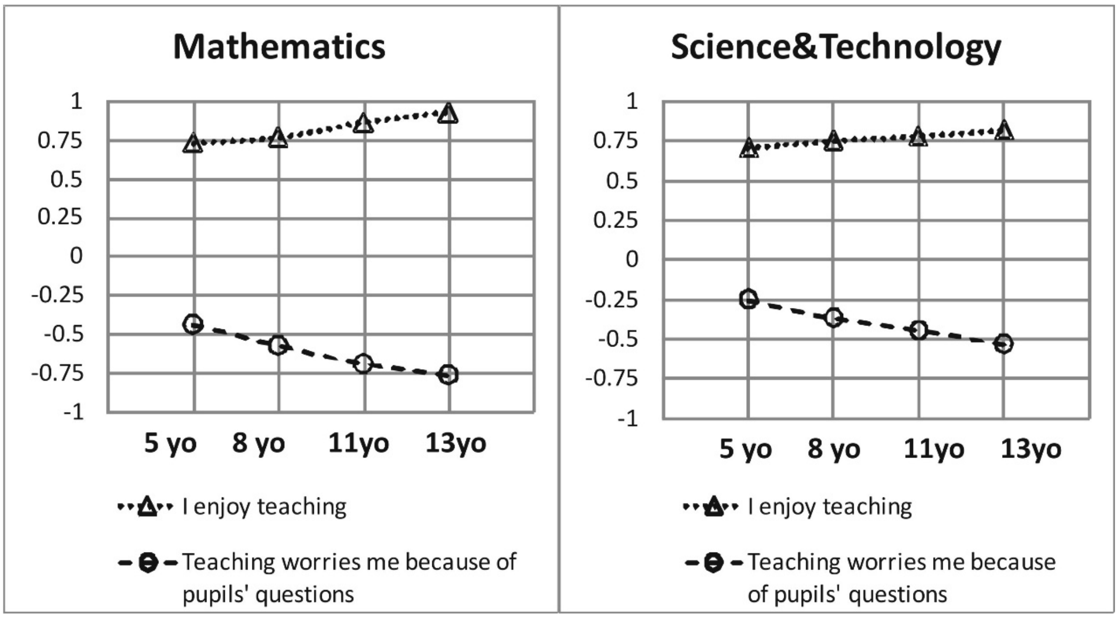

Figure 3. Attitude towards teaching MST subjects across ages in ten European countries. Results on the right comprise all science and technology subjects

Additionally, the learners have been asked three separate questions about their opinions on the impact of topics, activities and teachers on positive attitude towards MST subjects (*I like the subject because of: topics, things we do during the lessons, teacher*). For 8yo learners only two answers has been anticipated, whilst for 11 and 13 year olds a 4-point Likert scale has been attributed to each statement. In order to facilitate a comparison between ages, each answer was scaled as follows. For 8yo 'no' has been given a value of '-1' and 'yes' – a value of '+1'. For 11 and 13yo 'I completely disagree' has been given a value of '-1', 'I disagree' has been equated to '-0.5', 'I agree' has been given a value of '+0.5' and 'I completely agree' has been equated to '+1'. The overall results across ten countries are shown in Figure 4.

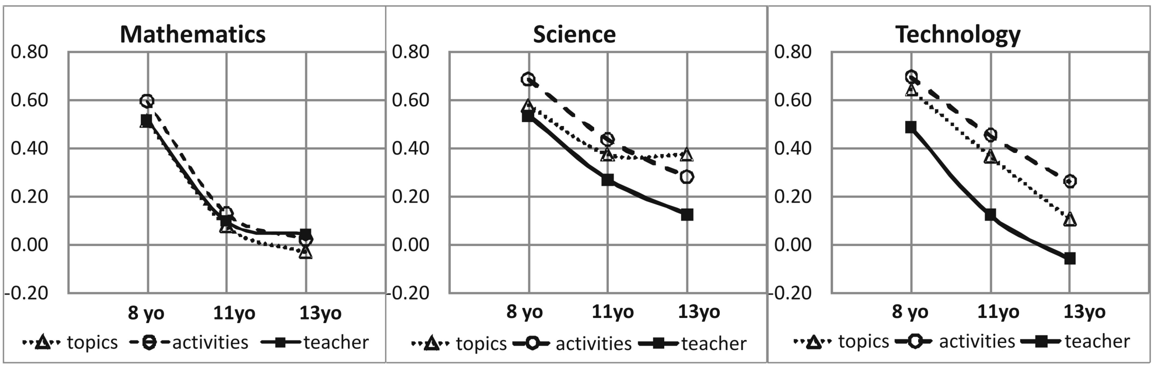

Figure 4. Sources of positive attitude towards mathematics, science and technology school subjects derived from learners' questionnaires

It is visible that in general the impact of all three sources on positive attitude towards all MST subjects decreases with age, and, similarly to the findings about the attitude, the biggest drops take place between age 8 and 11. Nevertheless some differences between subjects can be detected. The lowest impact among sources is reported for mathematics, but at the same time all three sources seem to have a very similar influence on learners' positive attitude towards this subject. On the other hand for both, science and technology the lowest impact of a teacher on liking the subject is visible across all three ages. In all three MST subjects it seems that activities across three ages have got the biggest influence on learners' positive attitude towards subject, except for science at age 13 when 'topics' are predominant.

In teachers questionnaires two statements have been included to research teachers' opinion on their learners' motivation for each MST subject. The results are presented in Figure 5.

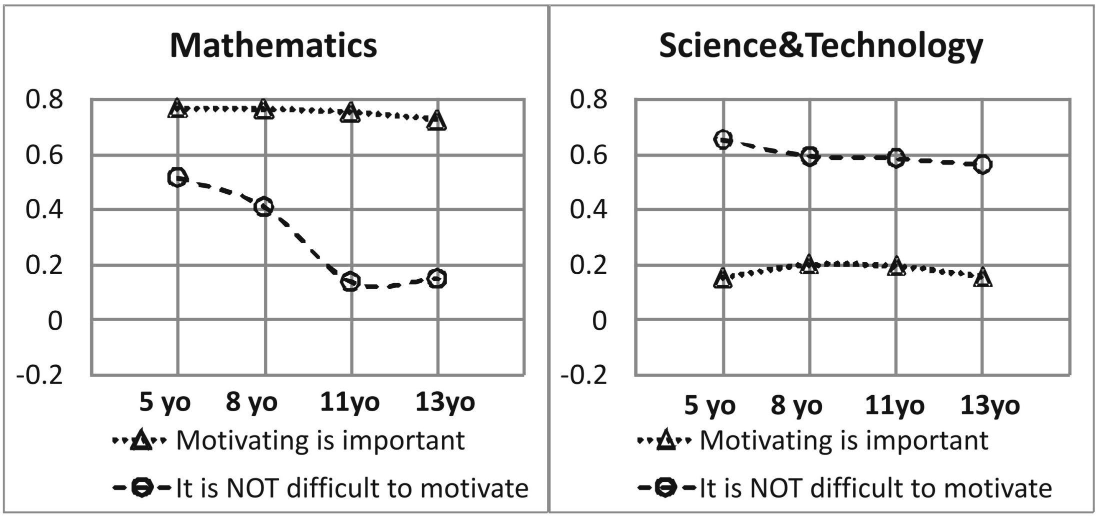

Figure 5. Teachers' opinion about importance and difficulty of motivating the learners towards MST subjects (derived from teacher questionnaires)

Conclusions from triangulation

Screening the core curricula documents revealed that the affective domain of learning, in particular goals putting emphasis on awareness, appreciation, willingness, satisfaction, attention, motivation, attitude etc. in MST education are not frequently detected in legal documents. Thus the message about their importance may encounter the problems to be transferred from research in education and general European vision (e.g. expressed in the key competences) to an everyday practice, because, as SECURE research showed elsewhere (de Meyere et al., 2013), *'whatever is happening in the classroom, rarely goes beyond the emphasis encountered in the legal documents'.*

A non-sufficient attention paid to the affective domain seems not to have consequences on very young learners, at the beginning of schooling, but may have an impact on them in the course of further education, as occurs from learners' response to the questionnaires. A substantial drop of the pupils' positive attitude towards MST school subjects has been detected between age 8 and 11 for all MST subjects across ten European countries of diverse school systems and curricula, comparably to the outcomes reported recently by Turner and Ireson (2010) on a much smaller scale. This tendency is not followed by teachers' attitude towards teaching. On the contrary, the teachers of all subjects show a very good positive attitude and self-confidence, even slightly increasing with learners' age. This contradiction is even more pronounced when the results on the impact of all three items: topics, activities and teachers on pupils' positive attitude towards MST school subjects are called. A substantial drop of the influence of all three items is visible, again, between age 8 and 11. The results show as well that despite the age, ST teachers have the least impact on pupils' positive attitude towards those two subject, much smaller than topics and activities experienced in the classroom.

Thus the joint results reveal the need for more attention to be given to the affective domain at different levels of MST curricula, by (1) inclusion in legal documents more specific goals linked to motivation, attitude and interest of pupils, (2) highlighting the importance of the affective domain in teacher pre-service education and (3) giving the teachers training supporting development of pupils' motivation for, interest in and attitude towards MST subjects.

Differentiation in MST written curricula and school practice

Five different aspects of differentiation in MST education have been directly addressed in curriculum screening instruments (CSI and AQ-CSI) as well as in questionnaires for teachers. In particular the SECURE research has addressed: (1) differentiation in general, (2) gender aspect, (3) differentiation with respect to socio-cultural background, (4) learners with special needs, and (5) learners with different cognitive abilities. A profound elaboration of the topic can be found in ANNEX 4. Below, the conclusions drawn from the triangulation across ten countries, are presented.

MST curricula

A broad variety of approaches to differentiation aspect has been detected in the curricula documents. There are countries (BE, CY, UK), where nothing has been said about differentiation at learning activities in curriculum documents, neither in general, nor about children with special needs, foreigners, pupils with different performance levels nor different interests. In two other countries, IT and PL, they have some remarks about differentiation in general and about differentiation of learning activities for children with special needs. They do not mention differentiation with respect to other differentiation issues (foreigners, different performance levels and interests). In SE there are recommendations about the need to adapt the learning activities to children with special needs and children with different performance levels. Nothing is said in the documents about differentiation in general, nor about foreigners and pupils with different interests. There are three countries (AT, DE and SI), where many references to differentiation in learning activities with respect to various aspects can be found.

In all of the countries, mentioning a differentiation issue in their documents, the need to adapt the learning activities to children with special needs is mentioned. Children with special needs receive the most of attention with respect to other differentiating criteria.

Only in AT and SI and DE children of foreigners (immigrants) and pupils with different interests receive attention within the curriculum documents and the need to adapt the learning activities to them is mentioned.

Children with different performance levels (on both ends; low-achievers and high-flyers) receive some special attention in the documents of AT, DE, SI, and additionally in SE.

Clustering of AT, DE and SI is detected with respect to differentiation in learning activities, as mentioned in curriculum documents of these countries. Clustering of some countries around some aspects, for example, for having defined some objectives for differentiation in assessment (for example, for children with special needs, AT, DE, SI, and additionally, PL and SE).

Only in AT and SI a systemic solutions written in national curriculum documents of identifying talented pupils exist. On the other hand more attention is given to low achievers and pupils with special needs in national documents of AT, IT, SE, SI and UK.

A systemic approach to the question of differentiation on the national level has been detected in Slovenia. Many specific documents exist which address various issues of differentiation (general, foreigners, special needs, low and high achievers, interests), which are also implemented into the every school practice.

Teacher questionnaires

Differentiation may take place at schools only if the appropriate conditions are secured. One of the main prerequisites supporting differentiation is the strategy of learners grouping in the classroom. Therefore the teachers have been asked several questions about the approach they implement in that matter.

For all teachers, who reported they *teach the subject as a whole-class activity* every or almost every lesson, we found that they *create various groups* slightly less frequently than those, who reported either they *teach MST subject as a whole-class activity* never, at some lessons or at about half the lessons. Creating groups of pupils working together allows for more differentiating activities than teaching the whole class together (which is contradictory to differentiation). We may conclude that more grouping and less teaching the whole class together could enable more differentiation.

The teachers have been also asked to what extend some aspects related to differentiation (like gender differences, learners' socio-economical background, pupils with special needs and different academic abilities) do limit them in teaching MST.

A teacher, being aware of gender differences in learning and also paying attention to them, may feel either limited by them in teaching a lot or not limited at all, since s/he has found a way through. On the other hand, there can be a teacher, not observing, denying, neglecting or not paying any attention to gender differences on learning on purpose, and s/he can only answer they do not at all limit her/his teaching (since they may even not exist). From answers we merely conclude there are certainly teachers, who are aware of gender differences in cumulative percent of those, who answered *a little, some,* and *a lot.* But there are possibly such teachers also among those who answered they are *not at all* limited by gender differences.

At the same time the majority of teachers do not feel limited at all or just a bit in their teaching MST due to variations in social and/or cultural background, pupils come from. The picture is not much different when age groups are distinguished. However, when one looks into countries details, the picture is not at all homogeneous and differs also in MST subjects.

When it comes to differentiation with respect to learners' special needs, on the average over the countries and over the ages both mathematics and S/T teachers feel almost the same about limits put upon their teaching; they are *not at all* limited or at most *a little* limited (more than 65% for both M and S/T). One can notice however that there are a bit more S/T teachers answering *a little* than there are those answering *not at all*. On the other hand, concerning more practical question about limitations, felt because of shortage of materials for pupils with special needs, teachers opinions differ a lot. Quite striking proportion, one third of S/T teachers are limited *a lot*, whereas only one fifth of mathematics teachers feel the same. It seems it is easier to obtain materials for pupils with special needs for mathematics than for S/T subjects. Mathematics is a major subject and a lot of time in all schools is spent for it. Materials adapted for pupils with special needs are obviously developed for mathematics and can be more easily obtained than for various small S/T subjects.

Again, when we go one step lower and see what are frequencies of responses for particular countries, homogeneity disappears and differences become visible. In particular country, teachers of all MST subjects can respond similarly; for example, both distributions of responses look very much alike in BE, CY, NL (rather small sample though). The other extreme case is AT, where distributions look complementary. There are countries, where the largest number of S/T teachers feel limited *a lot* by shortage of materials for pupils for special needs, namely AT, CY, IT, PL, SI, SE (rather small sample). However, there is one common observation: dispersion in the responses of S/T teachers in all countries except the ones with small samples (NL, SE and UK) is large; the proportions of those, who say they feel *not at all* limited, or just *a little*, or *some*, (and in few also *a lot*) are similar.

Regarding limitations in teaching, related to different academic abilities of the learners, teachers are feeling a bit more limited because of different academic abilities of their pupils at mathematics than at S/T. Noticeably a shift to more felt limitations with increasing the age of pupils can be detected. Distributions of responses in different countries vary from each other with respect to some properties, for example, are limitations felt more by mathematics or S/T teachers; or both groups feel approximately the same; or what is the average (mean) response of mathematics or S/T teachers, for some countries it is near to response *a little*, for other it is nearer to *some*.

To summarize, if we compare responses of teachers to questions about limitations put upon their teaching because of various reasons and circumstances (see Table 11), we find that in general they feel most limited because of different academic abilities of their pupils, a bit less limited because of the pupils with special needs , even less because of the socio-cultural background of pupils and the least limited because of the gender differences (answers based on scale 1[not at all] to 4 [a lot], for details, see ANNEX 4).

Table 11. Means of answers to questions about various limitations mathematics and S/T teachers feel in their teaching in relation to differentiation.

	academic abilities		socio-economic, cultural background		special needs		gender	
	M	S/T	M	S/T	M	S/T	M	S/T
Mean	**2,52**	**2,37**	**2,02**	**1,96**	**2,32**	**2,30**	**1,40**	**1,43**
N	526	886	527	881	529	881	522	873
Std. Deviation	0,985	0,972	1,138	1,082	1,217	1,175	0,987	0,983

Examples of good practices

In the course of the SECURE project a few examples of good practices, unique on the map of Europe, have been detected.

Slovenia seems to have an exceptional system of active MST learning. All classes are obliged to take part in "Nature Camp" at least twice during the primary school period of education (age 6-15). "Science weeks" are organized once a year in all primary schools. Both initiatives encourage doing research projects in the natural environment.

In Austria, Belgium and Slovenia the inclusion into regular lessons of topics based on learners' interest is explicitly indicated in curricula.

In Slovenia the system to recognize and taking care of high-flyers works efficiently on the national level.

In Poland the new curriculum requires introduction of group work and elements of IBSE (inquiry-based science education) to science education from early age. External exams start to follow the latter as well.

In Belgium regional advisory centers are established to provide continuous support to the schools on education, management and other issues, being a kind of long-life learning centers on demand, targeted to the needs of schools and particular teachers.

In Slovenia courses of MST, including lots of laboratory work, are incorporated into curriculum even for pre-service kindergarten teachers. New pedagogy (e.g. IBSE) is commonly introduced into pre-service and in-service teacher education.

Final remarks

The SECURE project has been established to make a significant contribution to European knowledge-based society by providing relevant research data that will help policy makers to improve MST curricula and their implementation throughout the EU in order to prepare children from an early age on for further careers in MST, whilst at the same time making MST more accessible and enjoyable for all children so that they will keep vivid interest in science and technology, and understand the importance of their societal role.

SECURE research focused on learners at early, key stages of schooling, meaning 5, 8, 11 and 13 years old, because the foundation of the revived interest in MST can be best laid at early age, when children are most susceptible for the wonders of the word that surrounds them.

The research instruments utilized during studies, Curriculum Screening Instruments, Questionnaires for learners and their MST teachers and interview protocols for learners and their MST teachers enabled collection of a huge amount of data. MST curricula in 10 European countries have been examined from three different perspectives: as they are intended by the writers, perceived and implemented by the teachers and finally, perceived by the learners. The wealth of data collection empowers comparative analysis of curricula and their implementation from different angles, as shown by a few examples in this chapter.

Not to our complete surprise research shows that teacher is a key player in a school system thus s/he should be supported throughout the whole period of the career. A teacher's self-confidence in the subject, engagement and good relations with pupils can motivate the whole class; visible symptoms of burnout or lack of self-confidence do not support youngsters' interest, on the contrary – it can bring fear or boredom to the classroom.

In a continuously changing world, new challenges occur in everyday life (e.g. digitalization, ICT and multimedia) as well as in the labor market (e.g. new competences are needed). The teachers who, apart from family members, are the first and most important masters of the future generations must keep up with the changes in order to move with the times.

Specific attention should be given to the curricula and methodology of pre-service teacher education, which both need improvement towards balance of practical activities and theoretical backgrounds, inclusion of teaching strategies based on the pedagogical research findings and increase of hours spent on practice at school under supervision of experienced advisers, promoting broad spectrum of teaching methods. Systemic and obligatory, long-life teacher professional development is demanded in order to keep the teachers updated with new research findings in science, technology and teaching strategies and to enable continuous revision and improvement of their school practice.

The aim of education is to prepare young generation to enter into adulthood - to become conscious citizens, to achieve an adequate level of literacy (including scientific literacy) and to develop skills needed in the future profession and everyday life. The practice shows that MST education is a key platform to promote development of key competences such as *skills for cooperation, analytical thinking, use of information and creativity.*

In order to increase mathematics and science literacy and to strengthen the encouragement to undertake careers in MST, these subjects should be introduced from early ages, i.e. already in the kindergarten.

Special attention should be put on MST education of the learners aged 8-11, as around that age learners' motivation, attitude and self- esteem in MST subjects drops suddenly across all countries and genders.

In building up MST curricula a vertical alignment must be ensured and tight correlation among MST subjects should be secured to avoid formation of learning gaps.

Education aimed on balancing the needs between training for future scientists and broader societal needs in a rapidly changing world, should put on differentiation and individualization, and promote the means leading to development of the universal competences . The school should keep up with changes in the surrounding world so as not to stay behind the overall progress in all other aspects of life.

Recognition of high-flyers and low achievers needs special attention at all school levels. Systemic differentiation in teaching should be provided, particularly in MST subjects, allowing for individual tasks and pace of learning. MST competitions for all grades, including primary schools are highly recommended. There are indications that low achievers and children with special needs are taken care off in most countries, while highly talented pupils are not given desired attention. We are losing their potential at the high end.

Education based on different resources is undoubtedly a sign of our times, and therefore educational system should put more emphasis on it and take advantage of out-of-school and informal learning, frequently recalled by learners as interesting and motivating, unlike school subjects.

Actions should be undertaken to design and promote formative and summative assessment tailored to classroom practices and active teaching and learning methods. Schools and teachers need measurement tools supporting and promoting planning and assessment of the school progress in MST subjects in order to enhance their standing. Self-assessment tools for teacher own use should be designed to measure teacher progress in making improvements in teaching MST.

The core curricula and other associated regulations are the legal documents shaping the standards of education and the school reality. They are, in many cases, the only (or most important) guidelines a teacher may refer to, thus they should be written in a clear way and should preferably contain examples of good practices of implementation. The level of detail, concerning aims and objectives, content and methodology, should be high enough to serve as guidelines for a teacher, but at the same time freedom should be given to the teacher to allow tailoring the curriculum implementation with regard to specific situation in the classroom. The research shows that in general *whatever is happening in the classroom, rarely goes beyond the emphasis encountered in the legal documents.*

SECURE Recommendations for balancing the needs between training for future scientists and broader societal needs based on research findings

Recommendation 1:

Stimulate the interest for MST-subjects more efficiently from an early age onwards, with special attention for the crucial age of 10.

Recommendation 2:

Provide more challenges and more support for both high-flyers and low-achievers based on a systematic approach and empowering curricula.

Recommendation 3:

Primarily work is needed on the promotion of interest for MST-subjects for both boys and girls at early age (including kindergarten), being aware of gender-specific differences.

Recommendation 4:

New and challenging general MST frameworks need to be established to support innovative MST education.

Recommendation 5:

Inquiry-based science education (IBSE) challenges learners, but still needs to be more structurally and consistently implemented in curricula and in practice.

Recommendation 6:

The integrated use of ICT and multimedia in teaching and learning requires special attention.

Recommendation 7:

Research based and continuously updated in- and pre-service trainings should result in more self-confident teachers, required for balancing the needs between teaching for future scientists and science for all.

Recommendation 8:

Actions should be undertaken to design and promote formative and summative assessment tailored to classroom practices and innovative learning methods.

4.1.4 THE POTENTIAL IMPACT

• The potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and exploitation of results (not exceeding 10 pages).

Impact at different levels

The outcomes of SECURE will have an impact at micro, meso, macro and supra level of our society.

On the micro level (especially teachers and learners questioned by the SECURE project) the collaboration has given a taste of research being carried out in the field of education and that collecting data and analyzing them is a way of gathering ground for future actions and policy making. By participating to a project with all together 10 countries and, very important, by giving them feedback on the results, the involvement and common feeling of these stakeholders on the classroom level within the EU, will enhance. As the recommendations that affect their work field are expressing their opinion, they will feel strengthened by realizing that in many countries the same ideas occur. Even differences will have a positive effect, as they can be looked at with a critical eye. To make this attitude even more sustainable, the SECURE project delivered quality activity kits to the classes, as to remind for many years both teachers and learners of the project and the European dimension of their collaboration.

On the meso level (schools, heads of schools, school-teams, institutions responsible for pre-service and in-service teacher training) SECURE has made clear that MST education is a key issue in all learners' learning at school. Taking the recommendations into account, SECURE can influence school policy in each of the aspects tackled by the recommendations. In particular the use of ICT, the professional development, the drop in interest before the age of 10, continuous attention for the talents of each child, especially when MST is at stake, and upgrading teaching methods are core business for each school. By explaining this to all participating schools in the first place (and whenever possible also to other schools) SECURE provides evidence based arguments for all school leaders to implement certain new strategies and insights among the school team of teachers. This might lead to planning structurally professional development trainings.

The results of the SECURE project will also influence both in-service and pre-service teacher training policy. Professional trainings based on research evidence, for example provided by SECURE, will enhance the quality of the teaching in general. However, specific research such as SECURE, provides priorities that can be taken into account in the courses. Since the data and conclusions are actual and relevant (because they are put forward by teachers and learners) it will give teacher trainers tools for better teaching in the class. For this, teacher trainers should carefully study the SECURE research and "translate" the recommendations into a better training course. The start for this process lies in the hands of the SECURE partners themselves. As many of them are in contact with teachers on a daily base, the SECURE outcomes will be used there.

The SECURE project also facilitates the development of strategies to build up a pedagogy aimed at better functioning of learners in future society. The evidence provided in this overall scientific report show certain step stones towards this global aim: gender as a factor, key competences of teachers, evidence based teaching, the purposeful use of ICT.

The third- macro- level (national, curriculum makers, educational policy contacts) is of the highest importance. This is the level that finally decides what will happen in the world of MST education (the European level is not authorized to take any decisions, but, of course, has a very important supportive role). The study of the curricula, for each country, leads to certain country specific conclusions. Whereas the European dimension serves more like a reference level, each country can draw lessons from certain parts of the research. Good and bad "positions" or "points" inevitably should lead to improvements of the curricula in the long term. It is difficult to predict the impact at the moment (no country will change a curriculum because of the results of SECURE). Many of the partners are heavily involved in (national or regional) curriculum making, which guarantees a certain effect in those countries.

On the level of politicians and policy makers, we have evidence that in some countries the results of the research has reached the highest levels of national decision makers. These are being studied to see how the recommendations can be taken into account in future actions. For example, in Belgium, two members of parliament have given a presentation during the SECURE conferences, and the minister of education has mailed that the results will be studied as soon as they are entirely available.

On the supra level (European, other countries) SECURE has established a very strong network of very diverse stakeholders. Persons responsible within the EC, others responsible for FP7 projects, MST stakeholders in the 10 SECURE countries and at least 12 non SECURE countries were intensely involved in different phases of SECURE, thus giving them all information and motivation also to use the research results. Within the "Valorization and dissemination" work package, partners attended targeted conferences to inform the local communities worldwide on SECURE and its results (IOSTE, ESERA, IASSEE, ICPE, SIF, IACPE, etc. see: deliverable SECURE_D6.6).

The list of international stakeholders - all persons that explicitly expressed the wish to remain informed - counts over 100 key persons, most of them contacted at international conferences where they either represented their country or presented their own MST research results. Deliverable SECURE_D6.7 gives an overview of this list of contacts. Out of this list about 20 experts were intensely involved in a 3 day "expert group meeting" where SECURE, its research and preliminary results were studied in detail. This engagement is translated in a group of ambassadors (" associated partners") that will take up the task of distributing the SECURE results in about 10 non SECURE countries. Deliverable SECURE_6.4 describes that in detail.

The long list of articles and presentations provided by SECURE deliverable D2.4 (available in ANNEX 7) shows another aspect of dissemination: to inform the world of science education on SECURE via professional channels of communication.

Also on the supra level SECURE established a close network with other European projects via the ProCoNet group (some 5 meetings), the Scientix meetings, the Fibonacci project (three SECURE partners were part of that project), SAILS. During the International final conference, eight big science projects were invited to present themselves, in the meantime connecting to SECURE as well. By spreading news and outcomes on these fora, SECURE results contribute to the general processes and discussions that take place there.

In Spain, during the first ICMT conference (http://jornadasicmt.com/), the workshop on SECURE provoked intense discussions on technics, science and mathematics education in the independent region of Valencia. This gave rise to further cooperation between various stakeholders (community, museum, universities). To be continued.

In Greece, the researchers from the university of Crete, will use the Greek version of the research tools to study the MST curricula and their implementation in their own country.

During the IOSTE conference in Turkey (October 29 - November 1 2013) in one of the keynote lectures the SECURE project was mentioned along with TIMMS and PISA to rely on for planning further actions on the European level.

These three examples show clearly that, in very different ways, the SECURE project offers many opportunities for further dissemination and valorization, and in this way has an added value for the debate that is going on about MST education.

As the results are spread also in non-SECURE countries, where a vivid interest was experienced, it will influence also curriculum makers there.

Impact on different topics

The massive amount of data provided by SECURE should also provoke a debate based on specific themes that pop up from the research. The topics themselves are elaborated elsewhere in this report.

According to the analysis of the gender issue it has become very clear that the difference in perceptions of boys and girls, related to MST education, should play a role in teaching, and hence in teacher trainings. Teachers should be aware of this difference and act accordingly.

SECURE discovered in its research that the motivation of learners shows a significant drop before the age of ten. SECURE advices all stakeholders to take action to further investigate this drop and meanwhile act in a way to avoid it.

SECURE also notices that ICT is not enough used as a tool to enhance the learning of students. The consequences are that teachers need appropriate training, well suited computer programmes should be developed, and teachers should get training to learn how to use them for better learning.

Other outcomes of the SECURE research are the reluctant way in which inquiry based learning is introduced via the curricula, the moderate way in which key competences as stated in the Lisbon agreements are present in the curricula, that they play little role in the way teachers are professionalizing and also that differentiation is not really a priority in teaching.

Despite the fact that there are indications that teaching methods are changing, The SECURE research found evidence that assessment is still very traditional and very much aimed at product of learning (summative) en only very little as a tool to encourage and enhance the learning process of the learners (formative).

All these themes, translated in 8 compact recommendations are, one by one, very important and vivid in view of the ongoing debates in educational environments in Europe. These findings very likely going to have an impact on these discussions.

SECURE proves the need for research on the relationship that young people have with science

It is of extreme importance to realize that SECURE is different, even complementary to other big educational research programmes such as TIMMS and PISA. While the main subject of SECURE was the study of the curricula of four age groups, and in all MST subjects, results which are very typical for the SECURE project, the study of the perceptions of the learners and the teachers on MST subjects in education is also crucial.

Whereas TIMMS and PISA aim at the results of the learning process of the students, SECURE researches the perception of the learners (including motivation, attitude, relevance of MST subjects, the role of the teachers, the didactics applied in the class room). This section of the SECURE research is in line with the aims of the ROSE project, which also provides data on the relevance of science education. ROSE focusses on the age 15, while SECURE aims at 5,8, 11 and 13 year old learners. As far as the teachers are concerned, the SECURE results can be connected to the TALIS (OECD Teaching and Learning International Survey) research. The findings are very analogous. As reference the "Responsible Research and Innovation (RRI), Science and Technology" (2013) research, carried out by the EU as well as the PIAAC survey by the OECD give information of attitude towards science and technology for adults, which is in contrast to SECURE which focuses on young learners. The conclusion is that SECURE to a high degree is complementary to other big research programmes carried out by different organizations. Although SECURE is much smaller and only can carry out the research once, the project shows clearly the gap in knowledge about the attitude towards MST of the youngest learners, the possible link with the attitudes of their parents, and, above all, also show the need for this kind of research to be continued.

Impact on management strategies

SECURE has developed specific tools for managing a project. These tools are based on the EFQM philosophy. The democratic approach, along with a very well planned and structured guidance of the (a) project, partners and participants know well in advance all tasks and duties. Structured and flexible the SECURE partnership has shown an enormous motivation to bring the project to an excellent end. A potential impact, but not measurable since the project has come to an end, is that partners are inspired by this approach and adapt the method in their working environment. As TMK, and moreover DKO vzw as a school and teacher coaching organization, develop tools for quality managing of change processes on all educational levels (groups of teachers, schools as organizations, groups of schools) the ones developed within SECURE are also usable in the future by new projects (provided the organization asks for permission by the EFQM organization).

The organization of the expert group meeting is a nice example of how these principles also were applied on a short term, very intensive meeting, with excellent results and, above all, with very positive evaluations by the expert group meeting participants. Deliverable SECURE_D6.3 provides all details.

Part of this quality approach is to develop a mission-vision- action-reflection-adaptation strategy for all organizations. This quality screening instrument, used as a self-reflection tool, shows that, at least for the SECURE participants' organizations, "there is a long way to go", as commented by one of them.

Some evidence, also in this field, was revealed by SECURE: most MST teachers do not have a documented vision on their job: it is not provided by the school either.

Impact of SECURE in the future.

The dissemination and valorization process continues, even after the official finish of the project:

- articles are written for future publications (IOSTE and ESERA)
- presentations are given to decision makers (Belgium/Flanders: to all umbrella organizations, to the ministry, to pedagogic coaches and curriculum maker; Poland: at seminars organized by the Educational Research Institute, by organizations promoting Horizon 2020 etc.)
- there are several contacts of (young) researchers that would like to use the data for further investigations (Spain, Poland)
- the tools will be used for additional research in other countries than the ones involved in SECURE (Greece)

This should be acknowledged as a result of the project.

4.1.5. PUBLIC WEBSITE ADDRESS

http://www.secure-project.eu

4.1.6. ANNEXES

An extended summary of results derived from MST curricula documents is included in ANNEX 1.
Comparative analysis has been utilized to elaborate the SECURE research findings on selected topics. They have been collected in three annexes listed below.
In ANNEX 5 the extended version of recommendations, including supporting evidence and suggestions for future improvement at different levels of the educational system is provided.
In ANNEX 6, research instruments implemented in the schools, i.e. questionnaires and interview protocols for both, learners and teachers are presented.
ANNEX 7 gives an overview of dissemination of the information of the SECURE project and its research result, conducted across Europe in many seminars and conferences, as well as publications on national and international level.
In ANNEX 8 – a complete set of references quoted in Final Report and seven other ANNEXES is provided.

ANNEX 1.
MAPPING NATIONAL CURRICULA FOR MATHS, SCIENCE AND TECHNOLOGY IN EU COUNTRIES

ANNEX 2.
KEY COMPETENCES IN MST CURRICULA AND THEIR IMPLEMENTATION AT SCHOOLS

ANNEX 3.
ATTITUDE, MOTIVATION AND SELF-ESTEEM RELATED TO MST SCHOOL SUBJECTS

ANNEX 4.
DIFFERENTIATION IN MST WRITTEN CURRICULA AND SCHOOL PRACTICE

ANNEX 5.
SECURE RECOMMENDATIONS – EXTENDED VERSION

ANNEX 6.
RESEARCH TOOLS UTILIZED AT SCHOOLS

ANNEX 7.
LIST OF ARTICLES AND PRESENTATIONS DISSEMINATING SECURE PROJECT AND ITS FINDINGS

ANNEX 8.
REFERENCES