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## **Balancing the Needs between Training for Future Scientists and Broader Societal Needs – SECURE Project Research on Mathematics, Science and Technology Curricula and Their Implementation**

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**ABSTRACT:** SECURE is a collaborative project under FP7 to provide research results of current mathematics, science and technology (MST) curricula across Europe. The research focuses on the MST curricula offered to 5, 8, 11 and 13 year old learners in ten European countries. The consortium invited 60 schools from each partner country to participate in the project. Altogether almost 9000 pupils, 1500 teachers and 600 schools took part in the study. The research framework is constructed upon the curriculum spider web. A mixed method approach for the analysis of the MST curricula is applied throughout three different representations of the curriculum: the *intended* (formal curriculum documents), the *implemented* (the actual process of teaching, researched on the basis of questionnaires and interviews with teachers) and the *attained curriculum* (focus on learning experiences, researched on the basis of questionnaires and interviews with learners). This contribution is a part of our broader study concerning the average European results on learners' and teachers' attitude towards MST subjects and their opinions on the role of affective domain in everyday school practice. The objective is to investigate the influence of topics, activities and teachers on liking the MST subjects by pupils and to research teachers' perception of motivation in everyday school practice. The study shows a substantial drop of the impact of all three factors on students' positive attitude towards all MST subjects, especially between ages 8 and 11. This trend is repeated by mathematics teachers in their opinions about easiness of motivating learners towards their subject, but not duplicated by the teachers of science and technology. Teachers are also divided as regarding the importance of motivating the students: only the mathematicians agree that this aspect is crucial. The study shows a significant misunderstanding between learners and teachers of science and technology in aspect of motivation towards school subjects across Europe.

**KEY WORDS:** SECURE, mathematics, science, technology, curriculum

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## INTRODUCTION

In the United States as in many nations, efforts are being made to improve science, technology, engineering and mathematics (STEM) education and make it a national priority to strengthen the nation's position in discovery and innovation globally (The White House, 2009). The skills in STEM areas that students acquire in middle school lay the foundation for a successful career in STEM (Woolley, Strutchens, Gilbert, & Martin, 2010). Most STEM occupations require competencies in science, mathematics and logical thinking to allow problem solving. Middle school is a crucial stage in student development as students prepare for a fast changing future (George, Stevenson, Thomason, & Beane, 1992). An information 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 a 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.*

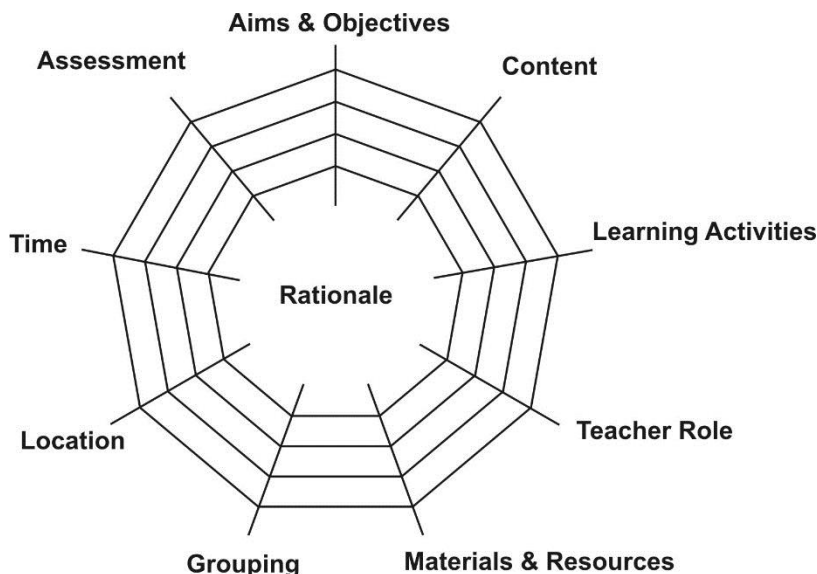
The role of affective domain in learning was recognized many years ago and for at least 40-50 years it has been studied intensively by researchers, among others in MST education (e.g. Middleton & Photini, 1999; Osborne et al., 2003; Logan and Skamp, 2008). Cognitive and affective components of learning have been recently 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.

The study took place in ten European countries (regions) of well-defined educational systems: Austria, Belgium (Flanders), Cyprus, Germany (Saxony), Italy, the Netherlands, Poland, Slovenia, Sweden and the United Kingdom (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. The overall aim of the study was to find out if the “balance between training for future scientists and broader societal needs” is secured. The role of the project was to learn what kind of needs, in addition to those expressed by policy makers, (among others in Recommendation on key competences for lifelong learning), should be addressed in future MST education in order to enhance MST literacy in the society. One of the main streams of the project is the examination of the role of an affective domain in everyday practice. In this contribution we particularly focus on one of the aspects of learners’ attitude towards MST subjects (meaning the impact of different sources on liking mathematics, science and technology) and on teachers’ opinions about importance and difficulties of motivating the learners.

### **THEORETICAL FRAMEWORK**

A curriculum can be considered as a “plan for learning” (Taba, 1962). As such it can be researched from three perspectives: as it is *intended* by the writers, *implemented* by the teachers and *perceived* by the learners (Goodlad, 1979), which is especially useful in the analysis of the effectiveness of the curricula. In 2003 van den Akker proposed a more detailed approach, in which the curriculum was represented on a spider web (Figure 1), visualizing the relationships between different curriculum components – Rationale in the centre of the picture, surrounded by nine other aspects of learning, Aims and Objectives, Content, Learning Activities, Teacher Role, Materials and Resources, Grouping, Location, Time, and Assessment. In view of the overall focus of the project, yet another aspect, “Attitude and Interest” has been added to the study. This item is indispensable for researching perceptions of teachers and learners, and can be considered as both, the result of previous learning process and a prerequisite of education in the future. As such, it lies at the heart of the research of needs in education.



**Figure 1. Curriculum spider web, based on the original work of van den Akker (2003).**

Attitude and interest in MST may consist of a large number of components (Osborne et al., 2003; Kobella 1989) and can be researched from different angles, e.g. “attitude towards MST in general” (Jones, Howe & Rua, 2000; Francis & Greer, 1999), “attitude towards school MST” etc. They may also overlap with each other or even with other constructs, such as ‘motivation’, ‘self-esteem’ and so on (Logan & Scamp, 2008). Different sub-constructs of the attitude have been incorporated in several models of attitudes towards science (Rennie, 1986; Oliver & Simpson, 1988) and researched for mutual correlations. It was also proved that the attitude can be influenced by many factors, including parents and teachers (Gunderson, Ramirez, Levine & Beilock, 2012).

For the purpose of this study ‘attitude and motivation’ is considered as ‘attitude towards and motivation for school MST subjects’ (Osborne et al., 2003). The attitude is limited only to the affective sub-construct and the study is even further narrowed to the investigation of sources of liking the MST subjects by the learners, as other aspects of affective attitude are presented elsewhere (Sokolowska et al., 2014a). Aspect of motivation is examined only from the teachers’ point of view.

In particular three research questions have been elaborated by collecting and analysing evidences in ten European countries:

1. What is the learners’ perception of the influence of topics, activities and teachers on a learner positive affective attitude (*liking*) towards

- mathematics, science subjects and technology across ages 8,11 and 13?
2. What is the teachers of MST subjects opinion about importance and difficulty of motivating their learners towards MST across ages 5, 8, 11 and 13 and all MST subjects?
  3. What conclusions can be drawn by comparing learners' and teachers' answers to RQ1 and RQ2?

## **METHODOLOGY**

### ***Sample***

A systematic collection of data has been performed in 15 classes of each researched age group (5, 8, 11 and 13) in every country. Whenever a class was selected for the research all teachers teaching MST subjects in this class also took part in the research. Thus altogether almost 600 classes, 9000 learners and 1500 teachers participated in the study.

### ***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.

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 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. All questions are based on 2, 3, 4 or 5-point Likert scale. In every questionnaire a box for remarks is included to enable expression of the opinions and thoughts not covered by the research instrument. Altogether 35 and 38 questions per each subject have been asked respectively in questionnaires for 8 and 11-13 year olds. Some questions differ a bit for 8 and 11-13 years old learners, and for the latter the questionnaire is slightly longer. However, the wording of questions elaborated in this study (and presented in sec. 4) was exactly the same for 8, 11 and 13 year olds. Regardless the age of pupils whom they teach, all teachers have been asked exactly the same questions, however slightly varying because of the subject (mathematics vs. science and technology). The questionnaire for teachers contained altogether 160 questions, from which two have been chosen for this study and presented in sec. 4.

The semi-structured interview protocols were developed in order to gather additional information and study in depth learners' and teachers'

opinions. 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.

### ***Data collection***

The drafts of instruments were piloted in DE, IT and NL and revised afterwards on the basis of the preliminary results. The main research took place during the school year 2011/2012. A class could be selected only if on the 1<sup>st</sup> of September 2011 at least 50% of its pupils was aged 5, 8, 11 or 13, respectively.

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. Questionnaire part was skipped only in case of 5 year old learners.
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. Pupils were either selected blindly by a researcher or chosen by a teacher on the basis of communication skills (mostly in case of 5 and 8 year olds).
4. Four representatives from six selected classes of each age: 8, 11 and 13 were interviewed in every country 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.

## **RESULTS**

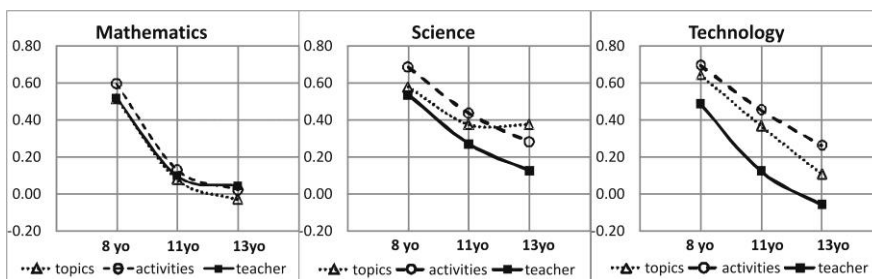
In this study selected outcomes on learners' attitude towards MST school subjects and teachers' opinions about recognition of motivation in everyday school practice, derived from learners' and teachers' questionnaires are presented. Other results of SECURE project have been included in several articles, e.g. Sokolowska, et al. (2014a), de Meyere et al. (2014).

In order to study the affective attitude towards MST subjects the following procedure was adopted. Questionnaires for 8, 11 and 13 year olds contain three sets of statements, each comprising three similar questions about sources of positive attitude towards each subject: mathematics, science and technology.

1. I like *the subject* because of the topics we study.

2. I like *the subject* because of the things we do during the lessons.
3. I like *the subject* because of my 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’ (Sokolowska et al., 2014b). It is worth to notice that whenever more than one science subject is taught at a certain age in the particular country, all the answers collected for different science subjects are summed up and rescaled to range -1...+1, accordingly. The issue of rescaling two Likert scales with differing responses is not new and was elaborated for example by Atwood et al. (1993) for the case of 2- and 4-point scales, showing correlations of not less than "r = 0.88" . The averages over the entire sample of learners, questioned in 10 European countries are presented in Figure 2.



**Figure 2.** Sources of positive affective attitude towards mathematics, science and technology school subjects derived from learners’ questionnaires.

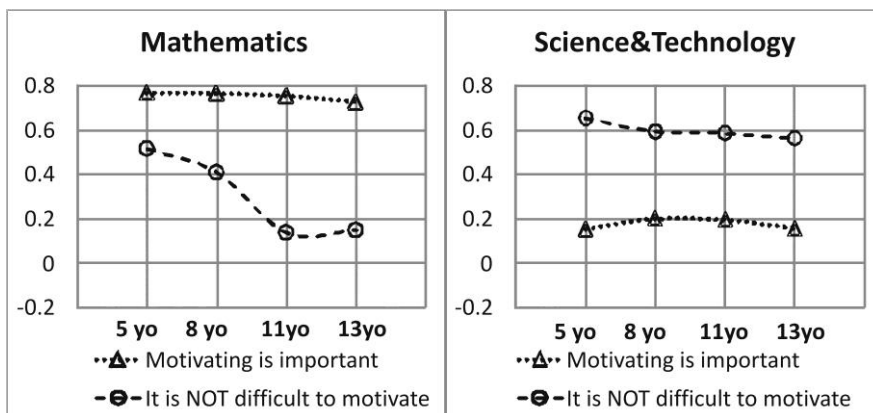
It is visible that in general the impact of all three sources on a positive attitude towards all MST subjects decreases with age, and the biggest drops take place between age 8 and 11. Nevertheless some differences between subjects can be detected. The lowest impact among sources is reported for mathematics, 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:

1. I feel one of the most important goals of *the subject* is motivating pupils for this subject area.
2. I feel it is difficult to motivate pupils in *the subject*.

A 4-point Likert scale has been attributed to each statement, similarly to questionnaire for 11 and 13yo learners. In order to enable visualization of the trends of both statements in one picture, a reverse coding has been utilized to the second statement. The average results for ten European countries available across four ages, 5, 8, 11 and 13 are presented in Figure 3.

The figure shows quite different picture comparing responses of mathematics and science & technology teachers. Mathematics teachers' feeling about motivating pupils for the subject area, being one of the most important goals of the subject, is very strong, while science and technology teachers do not share this point of view. Both groups of teachers however do not change much their opinion in that matter across ages. Science and technology teachers agree that motivating pupils for their subjects is not difficult, but, again do not share this opinion with mathematics teachers, for whom difficulty in that matter increase with learners' age.



**Figure 3.** Teachers' opinion about importance and difficulty of motivating the learners towards MST subjects (derived from learners' questionnaires).



## CONCLUSIONS

The study presented a limited selection of the data collected in SECURE project researching MST written curricula, their implementation in everyday practice and perception of 5, 8, 11 and 13yo learners and their MST teachers. We focused selectively on motivation and attitude towards MST subjects, the latter being one of the three main aspects of a wider concept of competence. The research of two other components of competence goes far beyond the scope of SECURE study, thus could not be included in this article.

The part of the research presented in this study has been further restricted by the size of the paper, so we limited ourselves to study only the sources of external motivation for a positive affective attitude towards MST subjects and teachers' opinions about motivating the learners.

The research findings show a substantial drop of the impact of all three items: topics, activities and teachers on pupils' positive affective attitude towards MST school subjects (*liking*), especially between age 8 and 11. A similar, but less pronounced decrease is observed in the opinions of mathematics teachers on easiness of motivating their pupils in the subjects, although mathematicians feel strongly that motivating learners for mathematics is one of the most important goals of their subject. On the other hand science and technology teachers do not seem to be convinced that motivating pupils for their subject areas is very much important, but at the same time they agree it is not difficult to do so in the classroom. Little concern of the teachers is reflected in learners' opinion, sustained across all three ages, that ST teachers have got the least impact on the positive attitude of pupils' towards those two subjects, much smaller than topics and activities experienced in the classroom.

The overall conclusion is that despite the favourable conditions (topics and activities appreciated by the learners more in science and technology than in mathematics), teachers of science and technology somehow lose their opportunity to enhance the learners' positive attitude towards ST subjects and that this fact is widely recognized by their learners. It is beyond the scope of this study to examine the reason of such unfavourable situation, but a possible explanation has been already offered in one of the recent papers (van Aalderen-Smeets, Walma van der Molen & Asma, 2012). It was stated that various studies had shown "a generally low level of scientific and technological literacy among (...) primary school teachers, and these teachers generally tend to have negative attitude toward science", which, among others, can lead to the situation when "they are less able to stimulate the attitudes of their students".

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