EURYDICE

Science Education in Europe:

National Policies, Practices and Research

European Commission

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FOREWORD

A basic understanding of science is considered a necessary skill for every European citizen. Concerns about low student performance in basic skills, as revealed by international surveys, led to the adoption

in 2009 of an EU-wide benchmark which states that *'by 2020 the share of 15-year-olds with insufficient abilities in reading, mathematics and science should be less than 15 %'* ([1]). In order to achieve the benchmark target by 2020, we must jointly identify obstacles and problem areas on the one hand and effective approaches on the other. This report, which is a comparative analysis of approaches to science teaching in Europe, aims to contribute to a better understanding of these factors.

Many international reports identify the potential shortage of human resources in key scientific professions and call for modernising science teaching in school. How is it possible to raise the motivation of pupils, to increase their interest in science, and at the same time, to increase attainment levels? Can school science be successful in reaching all pupils as well as educating future scientists? Approximately 60 % of higher education graduates in the fields of science, mathematics and computing are men. How can this gender imbalance be improved? These are some of the issues addressed in this study.

It follows on from the 2006 'Science Teaching in Schools in Europe' publication, which gathered systematic information on regulations and official recommendations on the subject of science teaching. This new Eurydice study provides a mapping of the organisation of science teaching in schools in Europe today and points out successful policies and strategies in place across Europe to modernise science teaching and learning. It highlights interesting measures such as school partnerships, career guidance initiatives and professional development opportunities for teachers, and reviews relevant research in these areas.

This publication provides valuable and comparable European-level data, which I am convinced will be of great help to those responsible at national level for improving science education and raising interest and motivation levels in this crucial area.

Androulla Vassiliou
Commissioner responsible for
Education, Culture, Multilingualism and Youth

([1]) Strategic Framework for European Cooperation in Education and Training ('ET 2020'), Council Conclusions May 2008, OJL 119, 28.5.2009.

CONTENTS

INTRODUCTION

This study deals with one of the priority areas of the 'Education and Training 2020' process and is linked to the 2020 benchmark on basic skills which also includes skills in science.

The study attempts to provide a mapping of the policies and strategies in place across Europe to improve and foster science teaching and learning in education systems today. It examines structural contexts and national educational policies regarding the teaching and learning of science, as well as evidence from international surveys and academic research.

Scope

The comparative overview of policies and measures in place in European countries with respect to science education forms the main part of the report. The study presents strategies in place to raise interest in science subjects, to improve motivation and raise attainment levels. It analyses organisational features of science teaching in Europe and what kind of support is available to teachers and schools for raising students' attitudes and interest with respect to science. The study also contains reviews of the research literature on science education and main findings from international performance surveys on science education.

The present study takes the **reference year 2010/11** and covers all Eurydice Network countries. All changes and reforms planned for the coming years have also been taken into account where relevant.

ISCED levels 1, 2 and 3 are covered, but the great majority of the report is devoted to compulsory rather than upper secondary education.

With respect to sources, official documents from central education authorities are the initial sources used. These also include strategy and programme papers. However, in countries where such official documents do not exist, agreements, including those which are private but recognized and accepted by public education authorities, have been used. The study also contains information on smaller-scale projects if they have been considered relevant for the purpose of this study. Apart from official sources, the results of national evaluations have equally been used where available.

The study also includes an analysis of the results of a pilot field survey conducted by EACEA/ Eurydice, which has been sent to 2500 initial teacher education programmes in order to collect information on existing practices in the initial education of science and mathematics teachers across Europe.

Only **public-sector** schools are considered, except in the case of Belgium, Ireland and the Netherlands, where the grant-aided private school sector is also considered, as it accounts for the majority of school enrolments (in the Netherlands, the Constitution provides for equivalent treatment and financing of the two sectors).

The study covers the subjects of physics, biology and chemistry in cases where no integrated approach is practised within the curriculum. According to available information (gathered in the framework of the preparation of the first Eurydice study on science education), these seem to be the most often taught science subjects in European countries.

Structure

Chapter 1 explores the patterns in achievement in science subjects referring to relevant international surveys, such as the 'Programme for International Student Assessment' (PISA) and 'Trends in International Mathematics and Science Study' (TIMSS). It looks at different factors which have a potential impact on performance patterns (home background, student characteristics, attitudes, structure of the education system, etc.)

Chapter 2 gives an overview of current approaches to and measures in place for raising interest in and motivation for science. It presents national strategies in place in European countries for the promoting science education and deepens the topics of school partnerships, science centres and guidance measures. It analyses the organisation of these various initiatives, the bodies involved and the target groups considered, looking in particular if there are specific measures in place to raise the girls' interests for science. Existing support measures for talented pupils are also presented.

Chapter 3 discusses how science teaching is organised in schools in Europe. It presents the main research arguments on: the organisation of science teaching in separated subject areas or as one integrated programme; teaching science in a context; science learning theories and teaching approaches. The organisation of science teaching in European countries is presented in terms of how many school years science is taught as one general subject and in which subjects science teaching is split afterwards. It further looks if contextual issues and specific science learning activities are recommended in steering documents of European school systems. It presents the various measures in place for support provided to low achievers as well as information on textbooks and specific teaching material for science and the organisation of extracurricular activities. The chapter also gives an overview on the provision of science teaching at upper secondary education level. Recent, on-going or planned science curricular reforms in European countries are also briefly discussed.

Chapter 4 describes the main features of science assessment in place in different countries. It presents a brief overview on research issues concerning the problem of assessment and in particular assessment in science. It further contains a comparative analysis of assessment features in science school education in European countries. It presents an overview of guidelines on assessment in the context of science teaching at primary and lower secondary education. A section describes issues related to standardised testing in science, such as the organisation of standardised tests, their main aims as well as their scope and content. The overview is complemented by data from TIMSS international survey regarding assessment practices for science.

Chapter 5 gives an overview on recent research on skills and competences for science teachers and how they may be integrated in professional development activities. It further presents some programmes and initiatives at national level on how to improve science teachers' skills. The chapter also includes the results of the pilot field survey conducted by EACEA/Eurydice, sent to 2500 initial teacher education programmes in order to collect information on existing practices in the initial education of science and mathematics teachers across Europe.

Methodology

The comparative analysis is based on responses to a questionnaire developed by the Eurydice Unit within the Education, Audiovisual and Culture Executive Agency. The report has been checked by all Eurydice National Units participating in the study. The methodology of the pilot survey is presented in detail in Chapter 5. All contributors are acknowledged at the end of the document.

Specific examples of national information are presented in an altered text style in order to set them apart from the main text. These cases provide concrete examples of general statements made in the comparative study. They may also illustrate exceptions to what is seen as a general trend in a number of countries, or provide specific details supplementing a common development.

EXECUTIVE SUMMARY

Countries support many individual programmes, but overall strategies are rare

Few European countries have developed a broad strategic framework to raise the profile of science in education and wider society. However, a wide range of initiatives have been implemented in many countries. The impact of these various activities is nevertheless difficult to measure.

School partnerships with science-related organisations are common across Europe but are very diverse with respect to the areas they cover, how they are organised and the partners involved. However, all partnerships share one or more of the following aims: to promote scientific culture, knowledge and research among students; to improve students' understanding of what science is used for; to strengthen the teaching of science at school and, to increase recruitment to MST (mathematics, science and technology) fields.

Science centres also share one or more of the aims mentioned above and contribute to improving science education by providing students with activities that go beyond what schools typically offer. Two-thirds of the countries examined report that they have science centres at national level.

Where broad strategies for the promotion of science do exist, science–oriented guidance for students is usually an integral component. However, not many other countries have implemented specific guidance measures for science and very few countries have initiatives which focus on encouraging girls to choose science careers.

Similarly, few countries have implemented specific programmes and projects to further develop gifted and talented pupils and students in the field of science.

Integrated science teaching occurs mostly at lower levels of education

In all European countries, science education begins as one general integrated subject and is taught in this way almost everywhere throughout the entire period of primary education. In many countries the same approach is continued for one or two years into lower secondary education.

By the end of lower secondary education, however, science teaching is usually split into the separate subjects of biology, chemistry and physics.

At general upper secondary level (ISCED 3), the vast majority of European countries adopt a separate subject approach, and science often forms one of the specialist branches or streams open to students at this level. As a consequence of this increased amount of choice, not all students are taught science at the same level of difficulty and/or study science subjects throughout all grades at ISCED 3.

Most European countries recommend that science should be taught in context. Usually this involves teaching science in relation to contemporary societal issues. Environmental concerns and the application of scientific achievements to daily life are recommended for inclusion in science lessons in almost all European countries. The more abstract issues relating to scientific method, the 'nature of science' or the production of scientific knowledge are more often linked to the curricula for separate science subjects which are usually taught in the later school years in most European countries.

In general, steering documents in European countries mention various forms of active, participatory and inquiry approaches to science education from primary level onwards.

In the last six years, there have been general curriculum reforms at different levels of education in more than half of the European countries examined. Naturally, these reforms have also affected science curricula. The main motivation for these reforms was the desire to adopt the European key competences approach.

No specific support measures for low achievers in science

There is no specific support policy for low achievers in science subjects. Help for low achievers is usually provided as part of the general framework of support for students with difficulties in any subject. Few countries have launched nation-wide programmes for tackling low achievement at school. In most countries, support measures are decided at school level.

Traditional assessment methods still prevail

Guidelines on student assessment generally include recommendations on techniques to be used by teachers. Traditional written/oral examinations, assessment of students’ performance in class as well as assessment of their project-based work are the techniques most commonly recommended. It is also interesting to note that no clear distinction can be made between the specific guidelines for science assessment and the general guidelines that apply to all curriculum subjects; the techniques recommended are similar in both.

In half of the European countries and/or regions examined, pupils' and students' knowledge and skills in science are assessed through standardised procedures at least once during their compulsory education (ISCED 1 and 2) and/or upper secondary education (ISCED 3). However, science clearly does not have the same prominent status as mathematics and mother tongue, although it does seem that it is becoming part of national testing procedures in an increasing number of countries.

Many national initiatives to help improve teachers’ skills

As past evaluations of science promotion strategies have shown, strengthening teacher competences is a particularly important concern.

Countries which have a strategic framework for the promotion of science education normally include the improvement of science teacher education as one of their objectives. School partnerships, science centres and similar institutions all contribute to teachers' informal learning and may provide valuable advice. Science centres in several countries also deliver formal CPD activities for teachers.

Almost all countries report that their educational authorities include specific CPD activities in their official training programmes for in-service science teachers. Less common, however, are national initiatives focusing on the initial education of science teachers.

A pilot field survey conducted with initial teacher education programmes found that the most important competence addressed in teacher education is the knowledge and ability to teach the official mathematics/science curriculum. ‘Creating a rich spectrum of teaching situations’ and applying a variety of teaching techniques, are usually mentioned as ‘part of a specific course’ in teacher education programmes; collaborative or project-based learning and inquiry- or problem-based learning are also frequently addressed.

However, dealing with diversity, i.e. teaching a diverse range of students, taking into account the different interests of boys and girls, and avoiding gender stereotypes when interacting with students, is addressed less often in teacher education programmes. Obviously, the survey results only provide indications about teachers' preparedness to teach, as their actual knowledge and ability to teach cannot be directly inferred from the content of teacher education programmes. However, the results of this survey attempt to give some indication of how future teachers are trained today in a number of European countries.

CHAPTER 1: STUDENT ACHIEVEMENT IN SCIENCE: EVIDENCE FROM INTERNATIONAL SURVEYS

Introduction

International student assessment surveys are carried out under agreed conceptual and methodological frameworks with a view to providing policy-oriented indicators. The relative standing of countries' average test scores is the indicator that attracts the most public attention. Since the 1960s, a country's relative score has become an important influence on national education policies, generating pressure to borrow educational practices from top-performing countries (Steiner-Khamsi, 2003; Takayama, 2008). This section presents the average test scores and standard deviations in science achievement for European countries as reported by major international surveys. The proportion of pupils lacking basic skills in science is also reported for each European country since European Union member states have a political commitment to reduce the proportion of low achievers. Basic information on the methodology of international surveys on science achievement is also provided.

Cross-national research may help to explain the evident differences between and within countries as well as identify any specific problems present in education systems. However, the indicators from international surveys should be used cautiously as there are many important factors outside the realm of education policy which influence educational achievement and these often differ between countries. The country level indicators have been criticised as presenting simplified indicators of the performance of an entire school system (Baker and LeTendre, 2005). When interpreting the results, it is also important to keep in mind that large-scale comparative studies face several methodological challenges: translations may generate different meanings; perceptions of some questions might be influenced by cultural bias; social desirability and pupil motivation may vary in different cultural contexts; even the political agenda of the organisations that conduct international assessments may influence the assessment content (Hopmann, Brinek and Retzl, 2007; Goldstein, 2008). However, a number of quality control procedures are implemented to minimize the impact of these methodological problems on the comparability of results.

1.1. Major surveys on student achievement in science

Currently, student achievement in science is assessed by two large scale international surveys, namely TIMSS and PISA. TIMSS (Trends in International Mathematics and Science Study) measures the mathematics and science performance of fourth grade and eighth grade students ([2]). PISA (Programme for International Student Assessment) measures the knowledge and skills of 15-year-old students in reading, mathematics and science.

These two surveys focus on different features of student learning. In general terms, TIMSS aims to assess '*what students know*', while PISA seeks to find '*what students can do with their knowledge*'. TIMSS uses the curriculum as the major organizing concept. The data collected has three aspects: the *intended curriculum* as defined by countries or education systems, the *implemented curriculum* actually taught by teachers, and the *achieved curriculum* or what students have learned (Martin, Mullis and Foy 2008, p. 25). PISA is not directly focused on any particular aspect of the curriculum, rather it aims to assess how well 15 year-old students can make use of scientific knowledge in everyday life situations involving science and technology. It focuses on scientific literacy, which is defined as:

([2]) A few countries also conduct the so-called TIMSS 'advanced', which tests student skills in the final year of secondary school.

> The capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity (OECD 2003, p. 133).

By focusing on literacy, PISA draws not only from school curricula but also from learning that may occur outside of school.

TIMSS is conducted every four years and the last round, which was conducted in 2007, is the fourth cycle of international mathematics and science assessments ([3]). Since fourth grade students subsequently become eighth grade students in the next cycle of TIMSS, those countries that participate in consecutive cycles of TIMSS also acquire information about relative progress across grades ([4]). However, only a few European countries have participated in all TIMSS surveys (namely Italy, Hungary, Slovenia and the United Kingdom (England)). Generally, less than half of the EU-27 countries participate in TIMSS. In the last round of the survey, 15 Eurydice network education systems measured mathematics and science achievement at the fourth grade and 14 measured achievement at the eighth grade.

PISA, on the other hand, covers almost all European education systems. It has been conducted every three years since 2000 and all Eurydice network education systems, except Cyprus and Malta, participated in the two latest rounds (2006 and 2009). Every PISA assessment cycle monitors student performance in the three main subject areas of reading, mathematics and science, but each has a particular focus on one subject area. Science was the main focus in 2006, mathematics in 2003 and reading in 2000 and 2009 ([5]). When the survey focused on science, it devoted more than half (54 %) of the assessment time to science (OECD 2007a, p. 22) ([6]). It included questions relating to students' attitudes to science and their awareness of the career opportunities that are available to those competent in science. Trends in science achievement can only be calculated from 2006 (when science was the major domain) to 2009 (the most recent results).

TIMSS uses a grade-based sample and PISA uses an age-based sample. The differences in assessed student population yield certain consequences. In TIMSS, all students have received a similar amount of schooling, e.g. they are in the fourth or eighth school year ([7]), but their ages differ across participating countries depending on school starting ages and grade retention practices (see more in EACEA/Eurydice (2011)). For example, in TIMSS 2007, the average age of fourth graders in European countries at the time of testing varied from 9.8 to 11.0 (Martin, Mullis and Foy 2008, p. 34), and the age of eighth graders from 13.8 to 15.0 (Ibid., p. 35). In PISA, all respondents are 15 years old, but the number of completed school years differs, especially in those countries where grade retention is practiced. The expected average grade of the 15-year-olds tested in 2009 in all European

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([3]) For a description of the instrument development, data-collection procedures and analytic methods used in TIMSS 2007, see Olson, Martin and Mullis (2008).

([4]) Due to the sampling methods used, the populations are not entirely the same, but are designed to be nationally representative.

([5]) For information on the test and sample design, methodologies used to analyse the data, technical features of the project and quality control mechanisms of PISA 2000, see Adams and Wu (2000). For PISA 2003, see OECD (2005); for PISA 2006, see OECD (2009a); and for PISA 2009, see OECD (2009b).

([6]) For comparison, in the latest round of PISA, which focused on reading, the total time devoted to the assessment of science was 23 % (OECD 2010a, p. 24).

([7]) The United Kingdom (England and Scotland) tested students in their fifth and ninth year of schooling, because their students start school at a very early age and otherwise would have been very young. Slovenia has been undergoing structural reforms requiring students to start school at a younger age so that students at the fourth and eighth grades would be the same age as students previously were in the third and seventh grades, but having had an additional year of schooling. To monitor this change, Slovenia assessed students in the third and seventh years of schooling in previous assessments. The transition has been completed at the fourth grade, but not at the eighth grade where some of the students assessed were in the seventh year of schooling (Martin, Mullis and Foy, 2008).

countries varied from grade 9 to 11, but in some countries students who completed the test were from six different grades (from 7th to 12th).

As TIMSS is focused on the curriculum, it gathers a broader array of background information relating to student learning environments than PISA. Sampling entire classes within schools allows information to be gathered from the teachers teaching science topics to those classes. Teachers complete questionnaires about the teaching methods used to implement the curriculum, their initial teacher education and their continuing professional development. In addition, the school heads of the students assessed provided information about school resources and the school climate for learning. Students were also asked about their attitudes towards science, school, interests and computer use.

With respect to the learning context, PISA 2006 asked school heads to provide data on school characteristics and the organisation of science teaching in school. In addition to background questions and attitudes towards science, students in 21 European countries completed an optional PISA questionnaire providing information about access to computers, how often they used them and for what purposes. Nine European countries also collected information about parents' investment in their children's education and their views on science-related issues and careers.

The TIMSS 2007 science assessment framework was based on two dimensions: the content dimension and the cognitive dimension. At the fourth grade, the three areas of content were life sciences, physical sciences, and earth science. At the eighth grade, there were four areas of content: biology, chemistry, physics, and earth science. The same cognitive dimensions – knowing, applying, and reasoning – were assessed in both grades (Mullis et al., 2005).

Since 2006, PISA has made the distinction between *knowledge of science* and *knowledge about science*. Knowledge *of* science includes understanding fundamental scientific concepts and theories; knowledge *about* science includes 'understanding the nature of science as a human activity and the power and limitations of scientific knowledge' (OECD 2009b, p. 128). The *knowledge of science* domain includes physical systems, living systems, earth and space systems and technology.

In conclusion, TIMSS and PISA assessments were designed to serve a different purpose and are based on a separate and unique framework and set of questions. Thus differences between the studies in the results for a given year or trend estimates should be expected.

1.2. Student achievement in science according to PISA findings

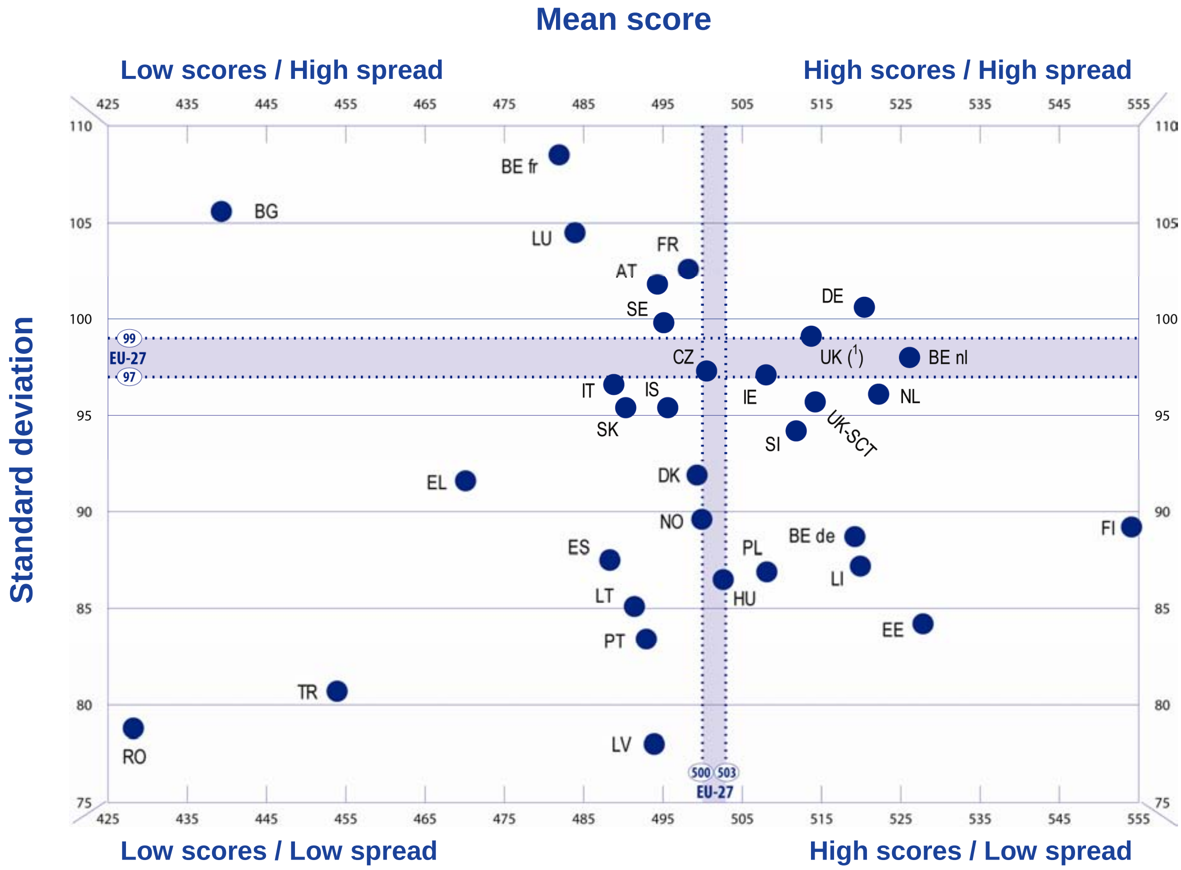
Results from PISA are reported using scales with an average score of 500 and a standard deviation of 100 set for students from all OECD participating countries. In 2006, when the standards for science achievement were set, it could be inferred that approximately two-thirds of students across OECD countries scored between 400 and 600 points. The PISA science scale is also divided into proficiency levels, which differentiate and describe what a student can typically be expected to achieve by associating the tasks with levels of difficulty. Six proficiency levels were defined on the science scale in 2006 and were used in the reporting of science results for PISA 2009 (OECD, 2009b).

Average achievement is the most common indicator when comparing the performance of education systems in international student assessment surveys. In the EU-27 in 2009, the average science performance was 501.3 ([8]) (see Figure 1.1). As in the previous round of assessment (2006), Finland

([8]) This is an average estimate taking into account the absolute size of the sampled population of 15-year-olds in each EU-27 country participating in PISA 2009. The EU-27 average score was constructed in the same way as the OECD total (i.e., the average across OECD countries, taking absolute sample size into account). The OECD total in 2009 was 496.

outperformed all other EU-27 countries ([9]). The mean score in Finland (554) was about 50 points higher than the EU-27 average, or about half of the international standard deviation. However, Finnish students did less well than students in the top performing country/region Shanghai-China (575), and performed at about the same level as students in Hong Kong-China (549).

◆◆◆ **Figure 1.1: Mean score and standard deviation in science for 15 year-old students, 2009**



	EU-27	BE fr	BE de	BE nl	BG	CZ	DK	DE	EE	IE	EL	ES	FR	IT	CY	LV	LT	LU
Mean score 2009	501	**482**	**519**	**526**	**439**	501	499	**520**	**528**	**508**	**470**	**488**	498	**489**	**x**	**494**	**491**	**484**
Difference from 2006	3.6	-3.7	3.0	-3.1	5.2	**-12.4**	3.4	4.8	-3.6	-0.3	-3.3	-0.1	3.0	**13.4**	**x**	4.4	3.4	-2.4
Standard deviation 2009	98	**109**	**89**	98	**106**	97	**92**	101	**84**	97	**92**	**88**	103	97	x	**78**	**85**	**105**
Difference from 2006	**-2.0**	5.4	**-8.6**	5.3	-1.1	-1.1	-1.2	0.6	0.6	2.7	-0.6	**-3.0**	1.0	1.1	x	**-6.3**	-4.9	**7.7**

	HU	MT	NL	AT	PL	PT	RO	SI	SK	FI	SE	UK (¹)	UK-SCT		IS	LI	NO	TR
Mean score 2009	503	**x**	**522**	**494**	**508**	**493**	**428**	**512**	**490**	**554**	**495**	**514**	**514**		**496**	**520**	500	**454**
Difference from 2006	-1.3	x	-2.7	**-16.5**	**10.3**	**18.6**	9.8	**-7.0**	1.9	**-9.2**	-8.2	-1.1	-0.5		4.8	-2.3	**13.4**	**30.1**
Standard deviation 2009	**87**	x	96	102	**87**	**83**	**79**	**94**	95	**89**	100	99	96		95	**87**	**90**	81
Difference from 2006	-1.7	x	0.5	m	-3.0	**-5.2**	-2.3	**-4.0**	2.3	**3.6**	**5.6**	**-8.3**	-4.2		-1.5	**-9.5**	**-6.5**	-2.5

m not comparable x Countries not participating in the study

Source: OECD, PISA 2009 and 2006 databases.

UK (1): UK-ENG/WLS/NIR

([9]) This and further comparisons are based on statistical significance testing on p<.05 level. This means that the statistical probability of making a false statement is set at less than 5 %.

Explanatory note

Two shadowed areas mark the EU-27 averages. These are interval indicators that take into account the standard errors. For readability, country averages are shown as dots but it is important to keep in mind that they are also interval indicators. The dots that approach the EU average area may not differ significantly from the EU mean. Values that are statistically significantly (p<.05) different from the EU-27 mean (or from zero when considering differences) are indicated in bold in the table.

Country specific note

Austria: The trends are not strictly comparable as some Austrian schools have boycotted PISA 2009 (see OECD 2010c). However, Austrian results are included in the EU-27 average.

At the other end of the scale, students in Bulgaria, Romania and Turkey had considerably lower average achievement than their counterparts in all other participating Eurydice countries. The mean scores in these countries were about 50-70 points lower than the EU-27 average. These countries also had the lowest results in 2006. However, Turkey increased its average score considerably (30 points).

Only 11 % of the variation in student performance lies between countries ([10]). The remaining variation lies within countries, i.e. between education programmes, between schools, and between students within schools. The relative distribution of the scores within a country, or the gap between the highest and the lowest achieving students, serves as an indicator of equity in educational outcomes. In the EU-27 in 2009, the standard deviation in science achievement was 98.0 (see Figure 1.1), which means that approximately two-thirds of students in the EU-27 scored between 403 and 599 points.

Countries with a similar level of average performance can have different ranges of student scores. Therefore, when making comparisons between countries, it is important to consider not only a country's average student score but also its range of scores. Figure 1.1 unites those two indicators showing on x axis the countries' average results (proxy for efficiency of education systems) and on y axis the standard deviation (proxy for equity of education systems). Countries that have significantly higher average results and significantly lower standard deviations than the EU-27 average can be considered both efficient and equitable in educational outcomes (see Figure 1.1, low right quarter). Regarding science achievement, Belgium (German-speaking Community), Estonia, Poland, Slovenia, Finland and Liechtenstein can be considered as efficient and equitable education systems.

The other side of Figure 1.1 (top left corner) indicates countries with high standard deviations and low average scores. In Belgium (French Community), Bulgaria and Luxembourg, the gap between high and low achieving students is higher than the EU average and the scores are below the EU average. Schools and teachers in these countries need to cope with a wide range of student skills. Therefore, one way to increase the overall performance might be to concentrate on supporting low achievers.

Lastly, there are several European countries where the average performance in science is lower than the EU average, although the spread of student achievement is not high. Greece, Spain, Latvia, Lithuania, Portugal, Romania and Turkey, thus, need to address science performance across a range of proficiency levels in order to increase their average performance.

The proportion of students who do not have basic skills in science is another important indicator of education quality and equity. The EU member states have set a benchmark to reduce the proportion of 15-year-olds with low achievement in science to less than 15 % by 2020 ([11]). Students not reaching Level 2 in PISA are considered low achievers by the European Council. According to the OECD (2007a, p. 43), students attaining Level 1 have such limited scientific knowledge that they can only

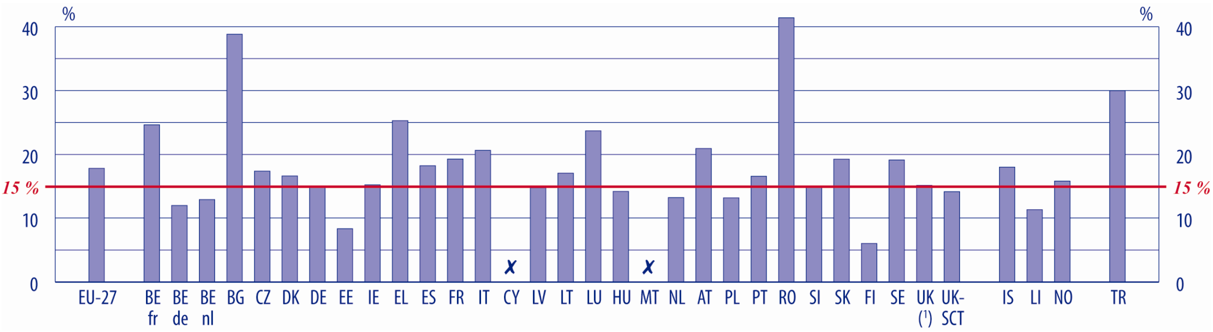
([10]) As computed by a 3-level (country, school and student) multilevel model for participating EU-27 countries.

([11]) Council conclusions of 12 May 2009 on a strategic framework for European cooperation in education and training ('ET 2020'). OJ C 119, 28.5.2009.

apply it to a few, familiar situations; they are also only able to provide scientific explanations that are obvious and follow explicitly from given evidence. Students performing below Level 1 are unable to demonstrate basic scientific competences in situations as required by the easiest PISA tasks; the lack of such skills may hinder their full participation in society and the economy.

As Figure 1.2 shows, in the EU-27 in 2009, an average 17.7 % of students were low achievers in science. Only Belgium (Flemish and German-speaking communities), Estonia, Poland and Finland had already achieved the European benchmark figure (i.e. the number of low achievers in science to be significantly lower than 15 %). The rate of low achievers was approximately 15 % in a number of European countries including Germany, Ireland, Latvia, Hungary, the Netherlands, Slovenia, the United Kingdom and Liechtenstein. At the other end of the scale, the proportion of students lacking basic skills in science was especially high in Bulgaria and Romania – about 40 % of students in those countries did not reach the proficiency Level 2. Turkey had a similarly high proportion of low achievers in science in 2006, but in 2009 this figure dropped to 30 %.

Figure 1.2: Percentage of low-achieving 15 year-old students in science, 2009



	EU-27	**BE fr**	**BE de**	**BE nl**	**BG**	**CZ**	**DK**	**DE**	**EE**	**IE**	**EL**	**ES**	**FR**	**IT**	**LV**	**LT**	**LU**
2009	17.7	24.6	12.0	12.9	38.8	17.3	16.6	14.8	8.3	15.2	25.3	18.2	19.3	20.6	14.7	17.0	23.7
Δ	**-2.0**	0.4	**-3.5**	1.3	-3.8	1.8	-1.9	-0.6	0.7	-0.3	1.2	-1.4	-1.9	**-4.6**	-2.7	**-3.3**	1.6
	HU	**NL**	**AT**	**PL**	**PT**	**RO**	**SI**	**SK**	**FI**	**SE**	**UK** (1)	**UK-SCT**		**IS**	**LI**	**NO**	**TR**
2009	14.1	13.2	20.9	13.1	16.5	41.4	14.8	19.3	6.0	19.1	15.1	14.1		17.9	11.3	15.8	30.0
Δ	-0.9	0.2	m	**-3.8**	**-8.0**	-5.5	0.9	-0.9	**1.9**	**2.8**	-1.8	-0.5		**-2.6**	-1.6	**-5.3**	**-16.6**

Δ – difference from 2006   m – not comparable   x – countries that did not participate in the study

Source: OECD, PISA 2006 and 2009 databases.   UK (1): UK-ENG/WLS/NIR

Explanatory note

Low achievers – defined as students who attain below Level 2 (<409.5).

When considering differences, values that are statistically significantly (p<.05) different from zero are indicated in bold.

Country specific note

Austria: The trends are not strictly comparable as some Austrian schools boycotted PISA 2009 (see OECD 2010c). However, Austrian results are included in the EU-27 average.

When considering the average trends in science achievement for the EU-27, there was some improvement on the PISA 2006 results. Although the increase in the EU-27 average score in science achievement was not statistically significant, the proportion of students lacking basic skills in science decreased statistically significantly compared with 2006 (by 2 %, standard error 0.51). In addition, the spread of student results in the EU-27 seems to be improving as the standard deviation in science achievement decreased from 100 in 2006 to 98 in 2009 (the difference -2.0 with a standard error 0.88 is statistically significant). Although these improvements are not extensive, it is important to take into account that they took place over a period of only three years.

Several countries experienced considerable changes in their performance in science. Italy, Poland, Portugal, Norway and Turkey had significant positive changes in average score and decreases in the proportion of low achievers compared with 2006. Turkey improved its performance by 30 score points, which is equivalent to nearly half a proficiency level. Portugal also had a considerable increase of 19 score points. In both these countries the proportion of low achievers also decreased significantly; in Turkey by 17 %, while in Portugal by 8 %. Conversely, the decrease in the average science score was significant in the Czech Republic (-12 points), Slovenia (-7 points) and Finland (-9 points). Despite these changes, all these countries remain average, or above average, performers at European level, with Finland still ranked second in the world on the PISA science assessment scale. The percentage of low achievers increased in Sweden from 16 % to 19 %. In Finland, the proportion of students performing below level 2 increased from 4 % to 6 %, yet this remains the lowest figure among all countries taking part in PISA 2009, as was the case in 2006.

The PISA 2006 assessment differentiated *knowledge of science* (knowledge of the different scientific disciplines and the natural world) and *knowledge about science* as a form of human enquiry. The former includes an understanding of fundamental scientific concepts and theories; the latter includes an understanding of how scientists obtain evidence and use data. The PISA 2006 results showed that *knowledge of science* was stronger in more European countries than *knowledge about science*. This was particularly marked in east European countries, whose students tend to do less well in questions relating to the understanding of the nature of scientific work and scientific thinking. In questions requiring *knowledge of science* students scored over 20 points higher in the Czech Republic, Hungary and Slovakia; and over 10 points higher in Bulgaria, Estonia, Lithuania, Austria, Poland, Slovenia, Sweden and Norway. In contrast, France was the only European country where students on average scored over 20 points higher in questions requiring *knowledge about science* than *knowledge of science*. Students also scored 10 points higher on such questions in Belgium and the Netherlands (OECD, 2007a, 2007b).

1.3. Science achievement according to TIMSS findings

The TIMSS scales were established using a similar methodology to PISA. The TIMSS science scales for the fourth and eighth grades are based on the 1995 assessments, setting the average of the mean scores of the countries that participated in TIMSS 1995 to 500 and the standard deviation to 100 (Martin, Mullis and Foy, 2008).

Due to the fact that relatively few European countries participate in TIMSS and not always the same countries test students in fourth and eighth grades, this section will not draw heavily on comparisons with the EU average. Instead, the discussion will focus on differences between countries. The EU average ([12]) is provided in Figure 1.3 as an indication.

At the fourth grade, Latvia (only students taught in Latvian) and the United Kingdom (England) had the highest average student achievement in science (542 points) and were the only two educational systems with higher than the EU average results. The results were nevertheless significantly lower than the worldwide top performers Singapore (587 points), Chinese Taipei (557 points) and Hong Kong SAR (554 points). The Asian countries were already the top performers in science achievement in earlier TIMSS assessments in both assessed grades. At the eighth grade, the highest average results were also achieved by students in Singapore (567 points), followed by Chinese Taipei (561 points), Japan (554 points) and Republic of Korea (553 points). After these Asian countries came the

([12]) This is an average estimate taking into account the absolute size of the population in each EU-27 country that participated in TIMSS 2007.

top performing European education systems, namely the United Kingdom (England) with 542 points, Hungary and the Czech Republic with 539 points and Slovenia with 538 points.

At the other end of the scale, at the fourth grade, Norway with 477 points, and the United Kingdom (Scotland) with 500 points, had significantly lower average results than all other participating European countries. At the eighth grade, there was a larger group of countries with poor results, namely Cyprus (452 points), Turkey (454 points), Malta (457 points), Romania (462 points) and Bulgaria (470 points).

Figure 1.3: Mean scores and standard deviations in science achievement, students at fourth and eighth grades, 2007

Grade 4			Grade 8	
Mean score	Standard deviation		Mean score	Standard deviation
530.6	78.9	**EU-27**	512	86.8
x	x	**BG**	**470.3**	102.6
515.1	75.6	**CZ**	**538.9**	71.4
516.9	76.9	**DK**	x	x
527.6	79.1	**DE**	x	x
535.2	81.4	**IT**	**495.1**	77.5
x	x	**CY**	**451.6**	85.3
541.9	66.9	**LV**	x	x
514.2	65.2	**LT**	**518.6**	78.2
536.2	84.8	**HU**	**539**	76.6
x	x	**MT**	**457.2**	113.9
523.2	59.9	**NL**	x	x
525.6	77.4	**AT**	x	x
x	x	**RO**	**461.9**	87.9
518.4	76.2	**SI**	**537.5**	72.0
525.7	87.3	**SK**	x	x
524.8	73.6	**SE**	510.7	78.0
541.5	80.2	**UK-ENG**	**541.5**	85.4
500.4	76.2	**UK-SCT**	**495.7**	81.1
476.6	76.7	**NO**	**486.8**	73.3
x	x	**TR**	**454.2**	91.9

Country specific notes

Denmark and **United Kingdom (SCT)**: Met guidelines for sample participation rates only after replacement schools were included.

Latvia and **Lithuania**: National target population does not include all of the International Target Population as defined by TIMSS. Latvia included only students taught in Latvian, Lithuania only students taught in Lithuanian.

Netherlands: Nearly satisfied guidelines for sample participation rates after replacement schools were included.

United Kingdom (ENG): At the eighth grade, met guidelines for sample participation rates only after replacement schools were included

Values that are statistically significantly (p<.05) different from EU-27 mean are indicated in bold in the table.

Source: IEA, TIMSS 2007 database.

It is important to take into account that the results for the fourth and eighth grades are not directly comparable. Even though 'the scales for the two grades are expressed as the same numerical units, they are not directly comparable in terms of being able to say how much achievement or learning at one grade equals how much achievement or learning at the other grade' (Martin, Mullis and Foy 2008, p. 32). Still, comparisons can be made in terms of relative performance (higher or lower). Therefore, for those countries that tested both grades, it can be concluded that the United Kingdom (England) and Hungary maintained a high performance in science at both fourth and eighth grades.

As discussed previously, it is important to consider not only the average results, but also their spread, or the difference between low and high achieving students. At the fourth grade, there was no European country with a significantly higher standard deviation than other participating education systems. In general, the spread of student results was fairly low in all European countries, when compared with the international standard deviation (set at 100). The standard deviation in the Netherlands (60) was much lower than in all other European countries. Latvia and Lithuania also had a very low spread of student results (standard deviations were 65-67). However, Latvia included only students taught in Latvian, Lithuania only students taught in Lithuanian. At the eighth grade, conversely, there were two countries (Bulgaria and Malta) with a much higher range of results (between high- and low-achieving students) than in other European countries.

From the first TIMSS assessment in 1995, there were many considerable changes in average scores. In Italy, Latvia, Hungary, Slovenia and the United Kingdom (England), the scores of students at the fourth grade significantly improved over time ([13]). The Czech Republic, Austria, the United Kingdom (Scotland) and Norway had significant decreases in scores. Norway had significant decreases in scores from 1995-2003, but then improved significantly from 2003-2007. In 2007, Norway's scores were almost the same as in 1995.

At the eighth grade, these education systems (except Austria, which did not assess students at the eighth grade) also had significant decreases over time. In addition, at the eighth grade, the results of Swedish students deteriorated. On the other hand, Lithuania and Slovenia had significant improvements in the average scores of students at the eighth grade.

1.4. Main factors associated with science performance

International student achievement surveys explore factors associated with science performance on several levels: characteristics of individual students and their families, teachers and schools, and education systems.

Impact of home environment and individual student characteristics

Research has clearly established that **home background** is very important for school achievement (Breen & Jonsson, 2005). TIMSS reports a strong relationship between pupils' science achievement and student background, measured by the amount of books at home or speaking the language of the test at home (Martin, Mullis and Foy, 2008). An analysis of PISA 2006 results showed that home background, measured on an index summarising each student's economic, social and cultural status, remains one of the most powerful factors influencing performance. On average in the EU countries, it explained 16 % of the student performance variation in science (EACEA/Eurydice, 2010) ([14]). However, poor performance in school does not automatically follow from a disadvantaged home background. According to PISA 2006 results, many disadvantaged students spent less time studying science in school than their more advantaged peers. They often ended up in tracks, streams or schools where there is very little choice and no opportunity to take science courses. Therefore, learning time at school should be considered when designing policies to improve performance among disadvantaged students (OECD, 2011).

PISA 2006 results showed that interest in science appears to be influenced by student background. Students with a more advantaged socio-economic background or those who had a parent in a science-related career were more likely to show a general interest in science and to identify how science may be useful to them in the future (OECD, 2007a).

Gender differences in average science performance are rather small compared with other basic skills assessed by international surveys (i.e. reading and mathematics) (EACEA/Eurydice, 2010). Yet, it is important to take into account that overall gender averages are influenced by male and female student distribution across different streams or tracks (school programmes). In most countries, more females

([13]) The rate of change within and between countries over the specified time period may differ; refer to the international reports for more information.

([14]) When compared with 0 % by gender and 1 % by immigrant status, simple linear regression predicting science achievement by these three variables.

attend higher performing, academically-oriented tracks and schools than do males. As a result, in many countries, gender differences in science were substantial within schools or programmes, even if they appeared small overall (OECD, 2007a; EACEA/Eurydice, 2010). In addition, there were gender differences regarding scientific competences and certain attitudes. On average females were stronger in *identifying scientific issues*, while males were stronger at *explaining phenomena scientifically.* Males also performed substantially better than females when answering physics questions (OECD, 2007a). Of the attitudes measured in PISA, the largest gender difference was observed in students' self-concept in science. On average, girls had lower levels of belief in their scientific abilities than boys in all European countries. Boys also had higher level of confidence in tackling specific scientific tasks. In most other aspects of self-reported attitudes towards science there were no consistent gender differences. Both boys and girls had similar levels of interest in science and there was no overall difference in boys' and girls' inclination to use science in future studies or jobs (EACEA/Eurydice, 2010; OECD, 2007b).

International student achievement studies demonstrate a clear link between **enjoyment of learning science** and science achievement. PISA 2006 showed that students' belief in whether they could handle tasks effectively and overcome difficulties (self-efficacy in science) was particularly closely related to performance. While this does not indicate a causal link, the results suggest that students with greater interest in science are more willing to invest the effort needed to do well (OECD, 2007a). TIMSS also reports a link between the level of self-confidence in learning science and achievement in the subject (Martin, Mullis and Foy, 2008).

TIMSS results seem to suggest that **attitudes towards science** differ between grades and different science subjects. According to the Index of Students' Positive Attitudes towards Science, fourth grade students generally had positive attitudes ([15]). At the eighth grade, a general index of attitudes was constructed only for countries teaching science as a single, integrated subject. In three out of four European countries where the comparison of attitudes was possible, eighth grade students had considerably worse attitudes towards science than fourth grade students. This was especially pronounced in Italy, where 78 % of fourth grade students and only 47 % of eighth grade students had positive attitudes towards science (Martin, Mullis and Foy, 2008). In countries teaching science as separate subjects, eighth grade students' attitudes to biology were the most positive, but slightly less positive to earth science and, in particular, to chemistry and physics ([16]).

There is a separate international survey ROSE – the Relevance of Science Education (2003-2005) – which analyses the views and attitudes to science of pupils towards the end of secondary school (age 15). This survey views positive attitudes towards science and technology as important learning goals in themselves (Sjøberg and Schreiner, 2010). Interests influence future career choices; moreover, attitudes to science acquired in school might determine a person's relationship to science and technology in adult life. Unfortunately, the results of the survey have to be interpreted with caution as not all participating countries managed to achieve representative samples ([17]).

The ROSE results show that attitudes to science and technology among young people were mainly positive, but students were more sceptical towards school science. The results showed some variation across countries. Students in northern European countries seemed to show less interest in science

([15]) On average in participating EU countries, 72 % of students reached a high level on the index (Eurydice calculations).

([16]) On average in participating EU countries, at the eighth grade, 57 % of students had a very positive attitude to biology, 55 % to earth science, 42 % to chemistry and 38 % to physics (Eurydice calculations).

([17]) The details on how the survey was organised in each country can be found at the project website http://roseproject.no./. The problem with the data lies in treating the school-based sample as representative for the entire student population without applying appropriate weighting techniques.

and science careers than students in southern European countries. The least interesting topics for 15 year-olds were plants (flora), chemicals and basic physics topics (such as atoms and waves). Interestingly, contextual topics were also among the least interesting, for example 'famous scientists and their lives'. ROSE results seem to indicate several differences between the attitudes of boys and girls. Boys tended to be interested in the technical, mechanical, electrical, spectacular, violent or explosive aspects of science. Conversely, girls tended to show more interest in health and medicine, the human body, ethics, aesthetics, and paranormal issues. Environmental issues were important for all, but girls were more inclined to agree that each individual can make a difference. Based on these findings, the ROSE research team suggests that the gender differences in interests and motivation should be taken into account when teaching science in schools (Sjøberg and Schreiner, 2010).

Impact of schools and education systems

International student achievement surveys are often used for country comparison. Yet, according to PISA 2009, differences between European countries explain only 10.6 % of the total variance in science performance, while between-schools differences represent approximately 36.6 %, and within-school differences approximately 52.8 % of total variance ([18]). The degree to which students' educational chances are affected by the country in which they live therefore should not be exaggerated. Yet, it is possible to distinguish certain features of education systems that can be associated with general student achievement levels and/or proportions of low achievers.

For example, PISA found that in countries where more students repeat grades, overall results tend to be worse. Furthermore, in most countries and schools where students are assigned to different tracks or streams based on their abilities, overall performance is not improved, but socio-economic differences are enhanced. The earlier the students are stratified into separate institutions or programmes, the stronger the impact the school’s average socio-economic background had on performance. Across countries, having a larger number of schools that compete for students is associated with better results (OECD, 2007a, 2010b).

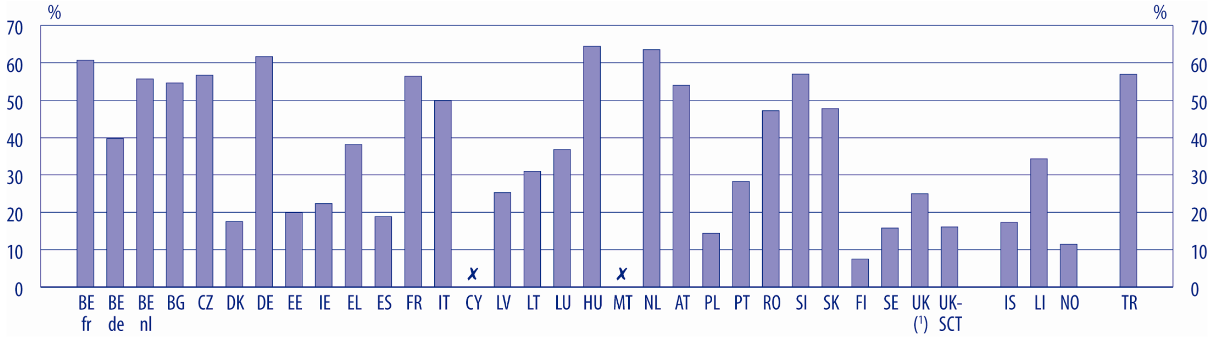
School features contributing to higher student achievement vary from country to country to a great degree and their effects need to be interpreted by taking national cultures and education systems into account. The variation in student achievement observed within schools or between schools differs greatly across countries. Figure 1.4 shows a breakdown of variance in student science performance in 2009. The length of the bars represents the percentage of the total differences in science achievement that derives from school characteristics. In 11 education systems most of the variation in student achievement was due to differences between schools. In these countries, schools, to a great extent, determined the learning outcomes of the student. In most of these countries, the streaming or tracking of students seems to have affected this result (OECD, 2007a). Other possible causes might be: differences in the socio-economic and cultural background of students entering the school; geographical disparities (such as those between regions, provinces or states in federal systems, or between rural and urban areas); and differences in the quality or effectiveness of science instruction in different schools. Between-school variation explained more than 60 % of student achievement in Belgium (French Community), Germany, Hungary and the Netherlands. In contrast, in Denmark, Estonia, Spain, Poland, Finland, Sweden, the United Kingdom (Scotland), Iceland and Norway less than one fifth of the variation lay between schools. In these educational systems, schools were rather similar.

Both TIMSS and PISA conclude that in most countries the social background of a school (measured as the proportion of socially disadvantaged students or the average socio-economic status) is strongly

([18]) The numbers are computed by a 3-level (country, school and student) multilevel model for participating EU-27 countries.

associated with science performance. The advantage resulting from attendance of a school where many students have favourable home backgrounds relates to a variety of factors, including peer-group influences, a positive climate for learning, teacher expectations, and differences in the resources or quality of schools. TIMSS results show that at both grades, on average, there was a positive association between attending schools with fewer students from economically disadvantaged homes and science achievement. Also, achievement was highest among students attending schools with more than 90 percent of students having the language of the test as their native language (Martin, Mullis and Foy, 2008). Similarly, PISA 2006 showed that students' socio-economic differences accounted for a significant part of between-school differences in some countries. This factor contributed most to between-school performance variation in Belgium, Bulgaria, the Czech Republic, Germany, Greece, Luxembourg and Slovakia. Socio-economic segregation by school might be harming equity and/or overall performance in these countries (OECD, 2007a).

Figure 1.4: Percentage of total variance explained by between-school variance on the science scale for 15 year-old students, 2009



✗ Countries not participating in the study

BE fr	BE de	BE nl	BG	CZ	DK	DE	EE	IE	EL	ES	FR	IT	LV	LT	LU
60.7	39.8	55.7	54.6	56.7	17.5	61.7	19.8	22.3	38.2	18.8	56.4	50.0	25.2	30.9	36.9
HU	**NL**	**AT**	**PL**	**PT**	**RO**	**SI**	**SK**	**FI**	**SE**	**UK (1)**	**UK-SCT**	**IS**	**LI**	**NO**	**TR**
64.4	63.5	54.0	14.4	28.2	47.2	57.0	47.8	7.5	15.8	24.9	16.1	17.3	34.4	11.5	56.9

Source: OECD, PISA 2009 database.

UK (1): UK-ENG/WLS/NIR

Summary

The international student achievement surveys provide a wealth of information on science achievement but they largely focus on individual and school factors; they do not systematically gather data on education systems (PISA) or analyse such data (TIMSS) with a view to assessing its impact on student science achievement. This study examines the qualitative data on various aspects of European education systems with a view to identifying the main factors affecting science performance and highlights good practices in the teaching of science.

CHAPTER 2: PROMOTING SCIENCE EDUCATION: STRATEGIES AND POLICIES

Introduction

Improving science education has been high on the political agenda of many European countries since the end of the 1990s. Over the last ten years, in particular, a great number of programmes and projects have been set up to address this issue.

One of the key objectives has been to encourage more students to study science. To this end, a wide range of measures, starting in the earliest school years has been introduced to try to improve pupil and student interest in science. According to the European Commission (2007), 'science teaching at primary school has a strong long-term impact' which 'corresponds to the time of construction of intrinsic motivation, associated with long-lasting effects. It is the time when children have a strong sense of natural curiosity...'. Maintaining high levels of interest is, however, still important later on at secondary level when the likelihood that students will become disengaged with science increases (Osborne and Dillon, 2008).

The aim of this chapter is to give an overview of the different national approaches to raising interest in science and motivating students to learn science. This chapter cannot however provide an exhaustive review of all projects nor analyse in detail the vast array of initiatives, programmes and projects found in European countries.

This chapter is divided into five sections: section 2.1 starts with current national strategies for the promotion of science and science education. Section 2.2 continues with programmes, projects and initiatives to foster school partnerships with stakeholders in the science field. It also explains the role of science centres and similar organisations, and outlines other activities to promote science. Section 2.3 concentrates on the specific guidance provided to young people to encourage them to consider scientific careers. Finally, section 2.4 looks at actions developed for supporting gifted and talented pupils in the field of science. Reference is made at the beginning of sections 2.2 and 2.3 respectively to key research papers and reports.

2.1. National strategies

A strategy in this context is considered to be a plan or method of approach usually developed by national or regional governments in an effort to successfully achieve an overall goal. A strategy does not necessarily specify concrete actions but normally consists of a number of objectives identifying areas for improvement together with a timeframe for completion. Usually, the overall aims of such a strategy are provided in written form and readily accessible via official websites. Few countries have such a strategy specifically devoted to the improvement of science education.

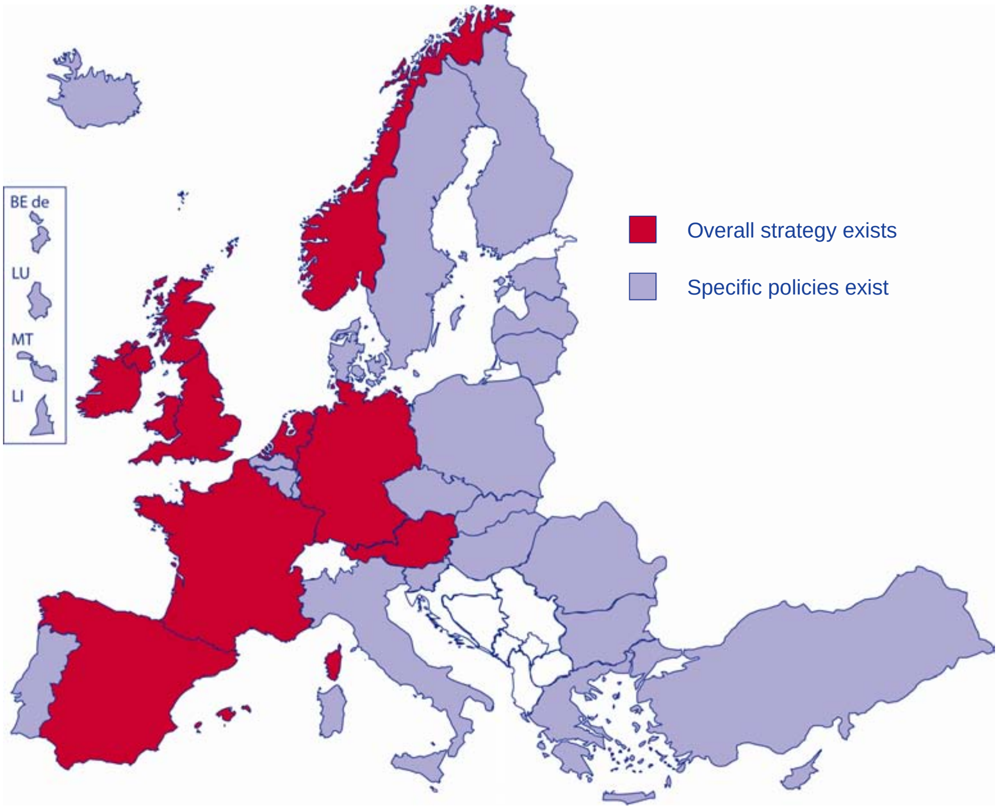
However, strategies for improving aspects of education may be broader or narrower. They may be general strategic programmes encompassing all stages of education and training (from early childhood to adult education) to programmes focusing on a particular stage of education and/or on very specific areas of learning.

Countries which have a general, overall strategy are Germany, Spain, France, Ireland, the Netherlands, Austria, the United Kingdom and Norway. Finland had a national strategy which ended in 2002. France is the country which has most recently put a strategy in place (2011).

In Malta, a strategy for mathematics, science and technology is currently developed.

In the absence of more holistic strategies, virtually all countries have developed specific policies and projects which vary in size and numbers of students/teachers involved. Many of these initiatives relate to school partnerships, the establishment of science centres and guidance measures. These specific projects are frequently joint-efforts, put in place by government institutions together with partners from higher education or from outside the education sector (see the following sections). Another important area on which many countries focus their efforts is the continuing professional development (CPD) of science teachers – these will be discussed in more detail in Chapter 5 on science teachers.

Figure 2.1: Existence of an overall national strategy for science education, 2010/11



Source: Eurydice.

Country specific note

France: The strategy was formalised in March 2011.

2.1.1. Strategic aims and actions

The reasons commonly expressed as the driving force for developing strategies to improve science education are, in most cases, a:

- declining interest in science studies and related professions;
- rising demand for qualified researchers and technicians;
- concern that there may be a decline in innovation and, consequently, economic competitiveness.

Unsatisfactory results in international performance surveys (PISA, TIMSS) (see Chapter 1) are also frequently a motor for new initiatives.

The aims expressed in these strategies are, in many cases, linked to broader educational goals for society as a whole. The most common aims are to:

- promote a positive image of science;
- improve public knowledge of science;
- improve school-based science teaching and learning;
- raise pupils' interest in science subjects and consequently increase uptake of science studies at upper secondary and tertiary education levels;
- strive for a better gender balance in MST studies and professions;
- provide employers with the skills they need and so help to maintain competitiveness.

Areas usually considered important and in need of improvement at the level of school education are curricula, teacher education (both initial and continuing) and teaching methods.

Governments are trying to achieve these aims through measures, such as:

- implementing curriculum reforms;
- creating partnerships between schools and companies, scientists and research centres;
- setting up science centres and other organisations;
- providing particular guidance measures to encourage more young people, particularly girls, to choose scientific careers;
- cooperating with universities to improve initial teacher education;
- initialising projects focusing on continuing professional development.

Not all countries' strategies include all these aims nor apply all the measures mentioned above; countries often focus their strategies on particular aspects.

A very large spectrum of concerns for science and science education unite the strategies of Germany, Spain, Ireland, the Netherlands, the United Kingdom and Norway. However, the strategies of Germany, the Netherlands and Norway share a particular focus on raising the interest level of girls/women in science. In the Netherlands, particular attention is also paid to young people from migrant backgrounds.

In **Germany**, the Federal Ministry of Education and Research launched the High-Tech Strategy ([19]) in August 2006 to encourage the development of new products and innovative services. In 2010, the strategy was reconfirmed and extended to 2020. The aim of the Federal Government is to meet the requirement for skilled staff primarily through training and continuing efforts in education. To keep up with the international competition for qualified specialist staff, conditions for staff from outside the country must also be made more attractive.

The aim is therefore to attract more young people to courses in the so-called MINT subjects (mathematics, information technology, natural sciences and technology). In this context, the National Pact for Women in MINT Professions will better utilise the potential of women to meet the need for skilled labour. Additionally, the *Kultusministerkonferenz*, issued a list of recommendations in 2009 for reinforcing MST education, including improving the image of science in society, supporting the science education already taking place in early childhood education, changing curricula and

([19]) See: http://www.hightech-strategie.de/de/883.php teaching approaches at primary and secondary levels, and creating opportunities for continuing professional development for science teachers.

In **Spain**, promoting science is a national priority, as evidenced by the creation of a separate Ministry of Science and Innovation in 2009 (previously a part of the Ministry of Education and Science). The national strategy ([20]) is formulated in a fairly broad way, not focusing only on school education. The strategy is taken forward by the *Fundación Española para la Ciencia y la Tecnología* (FECYT – Spanish Foundation for Science and Technology) which is a public foundation of the Ministry of Science and Innovation. Its general goals are: promoting the social integration of scientific and technological knowledge; involving Spanish society in science, technology and innovation; and encouraging researchers to regularly communicate their work to the general public. The Foundation's Scientific Culture and Innovation Program included three main elements in 2010.

1. The promotion of scientific culture and innovation. This element includes projects for the dissemination and communication of general scientific topics as well as projects to promote scientific vocations to young people. The FEYT offers grants to promote science and innovation in Spanish society in general. However, some of its actions are directly related to school education, teachers and non-university students.
2. Promoting network operations including projects for the dissemination of science and innovation coordinated by specific Communication and Innovation Units of the Autonomous Communities.
3. The launch of new networks including projects aimed at promoting good practice in companies or other organisations which have successfully incorporated new innovations and an entrepreneurial culture.

The time frame of the last call is 2010-2011. The Ministry of Science and Innovation funds the strategy through FECYT, with a total budget of EUR 4 million for all action lines.

Arising from the recommendations of the Task Force on the Physical Sciences report, published in 2003, the **Irish** Government set up the Discover Science and Engineering (DSE) programme. The aim of this is 'to increase interest in science, technology, engineering and mathematics (STEM) among students, teachers and members of the public'. The programme is managed by *Forfás*, Ireland's policy advisory board for enterprise, trade, science, technology and innovation, on behalf of the Office of Science,Technology and Innovation at the Department of Jobs, Enterprise and Innovation. It is headed by a high level steering group that includes representatives of the Department of Education and Skills and various industries and educational institutions. The programme was set up in 2003 and is ongoing. It addresses ISCED levels 1, 2 and 3, as well as the general public. Funding comes from the Department of Enterprise, Trade and Innovation.

In the **Netherlands**, the *Platform Bèta Techniek* ([21]) has been commissioned by the government, education and business sectors to ensure sufficient availability of people who have a background in scientific or technical education. This approach has been formulated in the *Deltaplan Bèta Techniek*, a memorandum on preventing workforce shortages. The initial aim was to achieve a structural increase of 15 per cent more pupils and students in scientific and technical education. This target has been reached. The intention is not just to make careers in science more appealing, but also to introduce educational innovations that inspire and challenge young people. The plan, therefore, targets schools, universities, businesses, ministries, municipalities, regions and economic sectors, while the objective is to ensure that the future supply of knowledge workers will meet future demand, and that talented professionals already in the job market are more effectively deployed. Particular attention is paid to girls/women and ethnic minorities. The strategy, started in 2004, was evaluated in 2010 and has a new timeframe lasting until 2016. The approach is divided into programme lines for primary and secondary education, vocational and higher education.

(20) See: http://www.micinn.es/portal/site/MICINN/menuitem.abd9b51cad64425c8674c210a14041a0/?vgnextoid=d9581f4368aef110VgnVCM1000001034e20aRCRD

(21) See: http://www.platformbetatechniek.nl/?pid=3&page=Home

In the **United Kingdom**, the Science, Technology, Engineering and Mathematics (STEM) programme [22] – which began in 2004 and was scheduled to run for 10 years – was implemented to increase students' STEM skills in order to: provide employers with the skills they need in their workforce; help to maintain the UK's global competitiveness; and make the UK a world-leader in science-based research and development.

The STEM Programme has eleven areas of work (known as action programmes) focusing on teacher recruitment, continuing professional development, enhancement and enrichment activity, curriculum development, and infrastructure. Each area of work is driven forward by a specialist lead organisation, working collaboratively with the National STEM Centre. This centre was opened in 2009. Its key objectives are to house the UK's largest collection of STEM teaching and learning resources, which will provide teachers of STEM subjects with access to a wide range of support materials; and to bring together STEM partners with a shared mission to support STEM education, thus supporting the STEM Programme.

The main goals for **Norway**'s strategy for Strengthening Mathematics, Science and Technology (MST) 2010-2014 [23] are: to increase interest in MST and strengthen recruitment at all levels, in particular of girls; and strengthen Norwegian pupils' skills in science subjects. The strategy has been developed by the Ministry of Education and research and is implemented by the National Forum for MST, an advisory body consisting of education authorities, local and regional authorities, the Research Council, the higher education sector, organisations of employers and trade unions. For primary and secondary education, the following targets have been set: Norwegian pupils should perform at least as well as the international average in international studies in science subjects; the proportion of students who choose and complete a specialisation in mathematics, physics and chemistry in upper secondary education and training, should increase by at least five percentage points by 2014; the strategy should focus on curricular reform, the provision of teaching material, guidance, the work of science centres, and teacher recruitment.

Improving teaching and learning is the focus of the French, Austrian and Scottish strategies. Particular attention is paid to gender in the French and Austrian strategies.

The **French** Ministry of Education formalised, at the beginning of 2011, the elements of a science and technology education promotion strategy with the main aims of improving students' interest in science and technology at ISCED 2, mainly by teaching science as an integrated subject; promoting scientific studies and careers at ISCED level 3, notably for female students, and using the impetus of current projects such as scientific competitions and Olympiads. This national strategy does not introduce any new reforms or initiatives; it is intended to build on current programmes, projects and structures, creating synergy between them.

In **Austria**, the national programme IMST (formerly: Innovations in Mathematics, Science and Technology Teaching, now called Innovations Bring Schools to the Top) aims at specifically improving instruction in mathematics, science and information technology. It started in 1998 and is now in its fourth phase, which will last until 2012 (mother tongue instruction was added in 2004). The programme focuses on students' and teachers' learning and involves teachers putting innovative instructional projects into practice and getting support in terms of content, organisation and finance. The project involves about 5 000 teachers across Austria who participate in projects, attend conferences or cooperate in regional and thematic networks. In the programme Examination Culture, teachers reflect on their use of different forms of assessment in various seminars. In order to investigate the impact of IMST, evaluation and research is integrated at all levels. The programme is conducted by the Institute of Instructional and School Development (IUS) of the Klagenfurt University with support from the Austrian Educational Competence Centres (AECC). Gender sensitivity and gender mainstreaming are important principles of the programme, and their implementation is supported by the Gender Network. The project is funded by the Austrian School Education and Development Fund. The innovative ideas are

(22) See: http://www.stemdirectories.org.uk/about_us/the_national_stem_programme.cfm and http://www.stemnet.org.uk
(23) See: http://www.regjeringen.no/upload/KD/Vedlegg/UH/Rapporter_og_planer/Science_for_the_future.pdf

reflected in action research by teachers and results are evaluated by researchers ([24]). The education levels covered are ISCED 1, 2 and 3. Funding is also provided by the Ministry for Education, Arts and Culture.

Similarly, in the **United Kingdom** (**Scotland**), the action plan 'Science and Engineering 21' ([25]) focuses on building the capacity and expertise of teachers; providing practical support for teachers and learners, particularly in the area of the curriculum, qualifications, assessment and careers advice; and increasing children and young people's engagement with, and understanding of real life science, engineering and technology. As well as introducing new areas the plan brings together the many models of good practice already happening in schools and seeks to make more effective use of existing resources, expertise and experience in the wider science and engineering arena.

An Advisory Group chaired by the Chief Scientific Adviser for Scotland and including representatives from the Scottish Government Learning Directorate, higher education, local authorities, the Association for Science Education and the Scottish Council for Development and Industry is responsible for delivering the action plan. The time frame is from April 2010 to March 2012 and the education levels covered are ISCED 1 and 2. The funding sources are the Scottish Government and a wide range of partners in science education. The plan will be monitored using a broad project management approach.

2.1.2. Evaluation of past strategies and current monitoring

The Netherlands, Finland, the United Kingdom and Norway have monitored the results and published evaluation reports on past or current national strategies.

Overall, although evaluation reports consider all strategies as fairly, or even very successful, they also showed that streamlining individual initiatives and making them more consistent was of great importance. A more coordinated approach was considered important at national, regional and local level (as, for example, mentioned in the evaluation report of UK-STEM ([26])). With this in mind, in order to encourage the effective evaluation of individual initiatives, the National STEM Centre in the United Kingdom has developed guidance for organisations undertaking evaluations in the STEM field ([27]).The Finnish report also stated that the role of municipalities and coordinators/multipliers at local level was very important as was the involvement of the media for promotion purposes. Using a similar approach as in the Netherlands, the Finns applied a bottom-up approach which turned out to be very successful for schools and teachers ([28]).

The evaluation of the Dutch strategy also showed that the creation of performance agreements with participating institutions was an important issue. The Netherlands chose the platform approach for carrying out its strategy with a certain level of independence from the ministry and a variety of stakeholders. This turned out to be particularly fruitful. EU-President Barroso and the European Parliament actually referred to the Dutch approach as 'good practice' ([29]).

The Norwegian evaluation of the strategy for 2002-2007 pointed out that it would be important in future work to ensure that the strategy was embedded locally, had measurable objectives, and effective reporting of results to ensure that the responsibilities of those involved were clear with respect to implementation, follow-up and dissemination of good practice. The new strategy now clearly describes the roles of the various players involved ([30]).

([24]) See: https://www.imst.ac.at/
([25]) See: http://www.scotland.gov.uk/Topics/Education/Schools/curriculum/ACE/Science/Plan
([26]) DfES: The Science, Technology, Engineering and Mathematics (STEM) programme Report, 2006
([27]) See: http://www.nationalstemcentre.org.uk/res/documents/page/STEM_Does_it_work_revised_Oct_09.pdf
([28]) See: http://www.oph.fi/english/sources_of_information/projects/luma
([29]) See: http://www.platformbetatechniek.nl/?pid=36&page=Betatechniek%20Agenda%202011-2016
([30]) See: http://www.regjeringen.no/upload/KD/Vedlegg/UH/Rapporter_og_planer/Science_for_the_future.pdf

As far as the areas for improvement are concerned, strengthening the skills of teachers in primary and lower secondary schools through initial teacher education and CPD has been considered as particularly important in all evaluations. As pointed out in the Finnish report, additional research in this area would be very useful. In addition, efforts to adapt teaching methods and cooperate with society at large in order to raise students' interest and motivation are also points considered important in all recommendations for future strategies.

2.1.3. Strategies currently being developed

Some countries are currently working on the development of science promotion strategies or smaller-scale promotion activities. Estonia is currently developing an action plan while Italy and Sweden have set up working groups for the promotion of science education.

The main goals of the action plan which is currently being developed in **Estonia** are to encourage capacity-building in the mathematics, science and technology community; increase the numbers of students and workers in the MST-area; and to ensure the sustainability of MST education.

The **Malta** Science Education Strategy consultative document published in May 2011 was formulated by a number of stakeholders including the University of Malta, the Education Directorate, state and non-state science teachers, and representatives of the Science Teachers' Association. The document provides a number of recommendations intended to explore new paths in the teaching and learning processes. It provides an audit of the state of science education and explores various programme options and resources in order to identify the predominant approaches for teaching and learning science. It predicts logistical and training needs, resources, and time frames for the implementation of the strategy.

In **Italy**, in 2007, a ministerial working group on the development of science and technology was established, now reconstituted under the name of Committee for the Development of Scientific and Technological Culture; it undertakes the following tasks:

- defines actions and structures for the dissemination of scientific and technological culture in the country;
- suggests the lines of a development policy that defines the tasks of public and private bodies;
- proposes and defines projects and system actions aimed at schools, adult citizens and society as a whole;
- proposes, in particular, actions and services for teacher training and support;
- makes suggestions for curriculum improvement.

To date, it has studied methods and strategies to improve the process of science teaching and learning and make it more effective.

In **Sweden**, the 'Technology Delegation' was established in 2008 and delivered its final report in 2010. The aim of the delegation was to find ways to counteract a predicted lack of engineers (due to large numbers of retirements). The task of the delegation was to look for ways to increase the interest of young people in MST subjects and to propose ways to increase cooperation between the various organisations in the field. The Delegation's proposals have been put forward to the government.

2.2. Raising motivation in science learning: school partnerships, science education centres, and other promotion activities

School partnerships in science education imply collaborative activities or projects set up between teachers and students on the one hand and stakeholders outside the school in the field of science on the other. The main potential partners of schools are private companies and higher education institutions. Other organisations which promote interest in science such as museums or science centres, also often work jointly with schools (Ibarra, 1997; Paris, Yambor and Packard, 1998).

Being a partner in learning activities in a school offers mutual benefits to companies and students. Whilst working with companies, students have access to role models and to career information which might stimulate a desire to work in the field or even in the same company with which the school has the partnership. Companies obtain a deeper understanding of the challenges of school science education faced in educating scientists and employees may benefit from partnerships in terms of professional development. For example, they may improve their communication skills whilst carrying out their role as ambassadors to schools (STEMNET, 2010).

Universities collaborate with schools for a number of reasons. They use partnerships to promote the study of science, to encourage future careers in the field and to provide an enriching experience for their students in teacher education programmes. Student teachers benefit from being in contact with pupils and teachers, they are able to develop their teaching skills and gain direct knowledge of the teaching profession. Academic researchers, on the other hand, can use partner schools as a laboratory for developing innovative learning approaches (Paris, Yambor and Packard, 1998).

Teachers benefit from partnerships with universities by being in contact with applied research and, in consequence, they may improve their skills particularly with regard to teaching science in specific contexts (see Chapter 5). In fact, collaborating with businesses or university science departments can support inquiry-based teaching. Not only do teachers have access to more resources and materials for their inquiry-based activities, but through a partnership they can also become agents for instigating changes in teaching approaches within their schools.

Furthermore, when a scientific project carried out at the local level actively involves a school in its work, the final project results can have a more significant impact. By having committed pupils and teachers involved in the process, a project may extend its reach to the whole local community to which a school belongs (Fougere, 1998; Paris, Yambor and Packard, 1998).

Collaboration is therefore beneficial for all. However, it is students who are at the heart of a school partnership in science education. School partnerships can bring positive experiences for pupils and students by increasing their interest in and motivation to learn science and thus making their learning process more effective. By showing the relevance of science in everyday life, learning experiences within a partnership might encourage pupils to continue their career in science branches at secondary level and later on in higher education (James et al., 2006). Well-conducted projects with partners from outside the formal school setting might have positive effects on girls' participation in science activities by increasing their motivation and achievement in this curriculum area.

Despite the various benefits a partnership can offer, the parties involved in collaborative activities might face shared difficulties. Organisational aspects such as time management and physical distance represent the first obstacles that partners can encounter in their collaboration, while a lack of funding can jeopardise an entire project in its execution and results. Teachers might also struggle to establish links between the partnerships's learning activities and the normal curriculum. Furthermore, accurately assessing pupil progress in terms of knowledge, attitudes and skills can be problematic when participating in innovative learning activities (Paris, Yambor and Packard, 1998).

Centres dedicated to science education, such as museums, also play a significant role in improving motivation among pupils and students in this field. A museum can be defined as 'a non-profit, permanent institution [...], open to the public, which acquires, conserves, researches, communicates, and exhibits, for purpose of study, education and enjoyment, material evidence of people and their environment' (ICOM, 2007). A science museum, therefore, imbues all these characteristics but with the added focus on science and technology. Science centres, however, which have been established mainly since the 1960s, are a new form of science museum that emphasise a hands-on approach, feature interactive exhibits which focus on scientific topics without collecting or investigating objects as such. They encourage visitors to have a playful but at the same time critical approach to scientific topics and sensitise the younger generation in particular to science, technology and their links to societal developments (Science Centre Netzwerk, 2011).

The effective influence these centres can have on a student's career in science has been confirmed by a project carried out by the Norwegian Centre for Science Education. According to the preliminary results of the project called *Vilje-con-valg* (willingness and choice), '20 % of all students who started studies in science in 2008 referred to science centres as a ‘source for motivation and inspiration to choose science studies’. Students mentioned science centres as being ‘more motivating for their choice than school counsellors and advertising campaigns’ (Norwegian Ministry of Education and Research 2010, p. 17). In the United Kingdom (England), the evaluation of the National Network of Science Learning conducted in 2008 reached similar findings. The survey revealed that three quarters of science educators who have used Science Learning Centre services reported impact upon pupils learning, interest, motivation and achievement (GHK 2008, p. 48).

2.2.1. Programmes, projects and initiatives to encourage school partnerships

Over the last five years, around two thirds of European countries have developed programmes, projects and initiatives to encourage the setting up of school partnerships in the field of science. All school partnerships are established with the same main aim which is to increase interest in science. Based on the examples reported by countries, at first glance, it appears that there are various types of organisations from a wide range of science-related fields taking part in partnerships. However, some common themes emerge when we consider the main partner collaborating with the school.

In a significant number of countries, it is higher education institutions (HEI) which are largely responsible for organising activities targeted at schools. The aims are generally to raise awareness of the world of scientific research and to attract students to the field. In addition, by collaborating with pupils, students and teachers, HEIs have an opportunity to consolidate their research on science education. In turn, findings from research might improve science teaching, learning and resources in schools.

> In the **Czech Republic**, the Technical University of Liberec launched, as part of the three-year initiative, STARTTECH – Begin with Technique, the 'Children’s University' programme ([31]). Within this programme, there is the project 'Fundamentals of Robotics and Electrical Engineering' which is intended to be fun, with practically-oriented content designed for pupils of the first and second stage of basic school without prior experience in the field. The Technical University of Liberec has been running this project since August 2010 with the support of more than CZK 11 million from the European Union operational programme Education for Competitiveness.

([31]) http://www.starttech.cz/

In **Germany**, under a Resolution of the Standing Conference of 2005 of the Ministers of Education and Cultural Affairs on activities of the *Länder* for the development of mathematics and science education, several programmes focused on partnerships have been carried out. The City of Science, Technology, and Media in Adlershof – Berlin organises activities targeted at secondary students. One of these activities 'School labs: learning by doing' involves laboratory experiments on different science-related topics ([32]). Under the ELAN project – *Experimentierlabor Adlershof für naturwissenschaftliche Grundbildung* (experimental laboratory for scientific literacy), chemistry experiments have been run since 2008 with sponsorship from the Department of Chemistry, Humboldt University of Berlin. The project is aimed at teachers and students from the 5th grade (ISCED 2).

In **Lithuania**, the project 'Development of the System for the Identification and Education of Pupils as Young Researchers' *(Mokinių jaunųjų tyrėjų atskleidimo ir ugdymo sistemos sukūrimas)* was launched in the 2009/10 school year for a two-year period. The Young Researchers Club is responsible for implementing the project. Its main objectives are to create conditions for scientists to provide counselling to young researchers; to enable students as young researchers to organise their scientific activities and to provide pupils with the knowledge and skills necessary for scientific research. The main partners of schools are universities and state research institutes; 600 pupils and students participated in 2009/10.

In **Austria**, the Federal Ministry for Education, Arts and Culture collaborates with the Federal Ministry of Science and Research within the programme 'Sparkling Science' launched in 2007 ([33]). Under this ten-year programme, pupils and students are actively involved in the research process by supporting scientists in their work and by communicating the joint research results to the public. Within this programme, primary and secondary schools might work along with universities and research institutions as well as universities of applied sciences and university colleges of teacher education. The pivotal point in the projects is the ethnographical research process of the students in real research environments at university. The scientists are, on the one hand, 'the ones under scrutiny' but are also actively involved in the research process. Secondary students, teachers and student teachers all take part in the planning and analysis of data and the final results are presented by both students and scientists. It is hoped that the programme will result in a shift in beliefs from all participants regarding the nature of science and role of scientists, particularly with respect to gender stereotyping; it will also hopefully motivate more students to study physics.

'Physics in the forefront of 21st Century Challenges' (2009-2014) and the 'National Laboratory of Quantum Technologies' (2009-2011) ([34]) are two examples of partnerships in **Poland** carried out by the Faculty of Physics at the University of Warsaw under the government programme 'Ordered fields of study'. In both projects, the Department of Physics promotes science by organising workshops and displays (for more information, see Section 2.4 on guidance.) A third interesting example in Poland is the 'Children's University' ([35]), a joint programme developed by four universities: Jagiellonian University of Krakow, University of Wrocław, University of Warsaw and University of Warmia and Mazury in Olsztyn. Under this programme, a project called 'Master and Student' ([36]) is being implemented. It consists of interactive sessions based on observation and experiments in the field of physics, genetics and biotechnology. Such activities are targeted at pupils at ISCED 1 (grade 6) and 2.

In Spain, France, Italy and the United Kingdom, it is the ministries with responsibility for education as well as other official bodies committed to supporting science education, working in close cooperation with the research and science community, which are behind the existing partnerships.

In **Spain,** the Department of Education of the Aragon Government, through the Innovation Unit of the Directorate General for Educational Policy has run the Science Alive *(Ciencia Viva)* programme over the last twenty years ([37]). It is

([32]) http://www.adlershof.de/schulen/?L=2

([33]) http://www.sparklingscience.at/en/infos/

([34]) http://fizykaxxi.fuw.edu.pl/ and http://nltk.home.pl/

([35]) http://www.uniwersytetdzieci.pl/uds?dc1

([36]) http://www.uniwersytetdzieci.pl/lecturegroups/show/8

([37]) http://www.catedu.es/ciencia/

a partnership between science research centres, about a half of Aragon's secondary schools and some primary schools. These schools are given opportunities to participate in various scientific activities such as talks, exhibitions, visits to research centres, laboratories, workshops, conferences and seminars for teachers. The main partners are the Foundation for Science and Technology of the Ministry of Science and Innovation (FECYT – *Fundación Española para la Ciencia y la Tecnología*), the University of Zaragoza, the Science Park of Granada, Spanish research centres, European research centres and scientific associations. In 2010/11, about 10 000 students from 58 secondary schools took part. The budget allocated was about EUR 50 000.

The High Council for Scientific Research in Schools – HSRC ([38]) (El CSIC – *Consejo Superior de Investigaciones Científicas - en la Escuela)* has, as its two partners, the High Council for Scientific Research (CSIC – *Consejo Superior de Investigaciones Científicas)* – an agency of the Ministry of Science and Innovation, and the BBVA Foundation established by the BBVA bank. The programme, which started in 2000, consists of a collaborative project between researchers and teachers with the aim of introducing and promoting the teaching of science from primary to upper secondary education. The main objective is to put the pupil in the role of researcher by conducting simple experiments. The project also intends to foster school science education as an effective method for addressing problems such as gender differences and cultural integration. Teachers' centres in the different Autonomous Communities support the project by inviting teachers to undertake initial scientific training provided by HSRC researchers. Up to now, this project has been carried out in seven Autonomous Communities reaching 300 schools.

In **France**, the organisation *Sciences à l'Ecole* ([39]) is set up by the Ministry of National Education and the Ministry of Higher Education and Research. Funded by the government and the industry foundation *C.Genial*, *Sciences à l'Ecole* supports and organises scientific projects carried out in secondary schools but outside the teaching of science subjects, such as during workshops and clubs. At national level, *Sciences à l'Ecole* establishes school networks such as *Sismo à l'Ecole* ([40]), *Météo à l'Ecole* ([41]) and soon *Genome à l'Ecole*. The national steering committee of *Sciences à l'Ecole* is chaired by eminent researchers and includes members of the general directorates of research and innovation, of school teaching and of higher education. A permanent group of four teachers and engineers is in charge of the implementation of the various projects. In each *académie*, a representative, usually, a regional inspector, assures the link between secondary schools and *Science à l'Ecole*.

In **Italy**, EneaScuola ([42]) is a partnership between schools and ENEA, the National Agency for New Technology, Energy and Sustainable Economic Development *(Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile)*. EneaScuola supports the dissemination of scientific and technological culture to schools. Under this partnership, the 'Educate for the Future' project *(Educarsi al futuro)* ([43]) involves a school research trip for every school grade focusing mostly on the sustainability of the human activities.

In **Latvia**, under the national programme on improving the quality of teaching and learning in MST at secondary level, a school network was established in 2005 ([44]) to pilot and support the implementation of the new curricula and teaching materials in secondary schools. Various partners cooperate in this programme: the Centre for Curriculum Development and Examinations, higher education institutions, local government and regional development agencies. During the period 2008-2011, three types of schools are participating: pilot schools with or without previous experience (12 and 14 schools respectively) and 33 support schools. In practice, schools ensure the piloting of the new materials and organise activities for teacher professional development while universities support the collaborative work in schools. Entrepreneurs and scientific institutions also contribute to improving student engagement.

([38]) http://www.csic.es/web/guest/el-csic-en-la-escuela
([39]) http://www.sciencesalecole.org
([40]) www.edusismo.org
([41]) www.edumeteo.org
([42]) http://www.eneascuola.enea.it/
([43]) http://www.eneascuola.enea.it/progetto_enea.html
([44]) http://www.dzm.lv/

In the **United Kingdom**, SCORE (Science Community Representing Education) ([45]) is a partnership between the Association for Science Education, the Institute of Physics, the Royal Society, the Royal Society of Chemistry and the Society of Biology. The partnership provides a coherent voice for the science education community on the long-term issues in science education. It was established to support improvement in the quality of practical work in science. Among the many activities carried out within this partnership, there is the 'Getting Practical' ([46]) project, led by the Association for Science Education, with an emphasis on extending good practice and focusing on the quality, rather than just the quantity, of practical work.

In some countries, non-governmental organisations and foundations are the main organisations responsible for coordinating and organising science education activities for schools.

In **Poland**, the Youth Palace in Katowice *(Pałac Młodzieży w Katowicach)* ([47]) is an educational institution run under the auspices of the association 'With Science to the Future'. Its purpose is to support schools lacking well-equipped science laboratories by offering a variety of supervised chemistry workshops based on chemical experimentation for ISCED 2 students. Experiment-based classes in physics are also designed in compliance with the new core curriculum at ISCED 2 as well as biology classes based on observation, experimentation and field work.

In **Portugal**, the Champalimaud Foundation in cooperation with the Ministry of Education launched the project 'Motivation of Young People for Science – *Champimóvel '* ([48]) in 2008. This project aims to promote biomedical research in Portugal and to stimulate interest and talents in the field of biomedical sciences. The first action, directed at pupils of second and third cycles of basic education (ISCED 1 and 2), consists of an interactive exhibition on the functioning of the human body which is presented in a transportable simulator, the *Champimóvel*'. A wide range of information and teaching materials supplement the exhibition in order to help students and teachers become familiar with biotechnology-related topics such as genetic therapy, stem cells and nano-technologies.

In **Slovakia**, the non-governmental organisation *Schola Ludus* ([49]) promotes science, research and scientific knowledge in a user-friendly way to a wide public including children and young people from pre-primary to lower secondary level. *Schola Ludus* cooperates with various partners such as universities, science centres and museums as well as private companies. In addition to providing in-service training for teachers, *Schola Ludus* supports schools in developing educational programmes in science subjects. *Schola Ludus* also organises exhibitions and non-formal educational activities for summer camps.

In the **United Kingdom** (**Scotland**), the Edinburgh Science Foundation, an educational charity created in 1989, develops activities directed to people of all ages such as the annual Science Festival but also has an educational programme. The foundation has been running for 20 years the Generation Science project which aims to bring science to life in classrooms through educational and entertaining performances and workshops. In 2010, 56 000 pupils participated from 553 schools across 30 local authorities in Scotland ([50]).

The partnerships reported above mostly involve stakeholders from either publicly-funded bodies or non-profit-making organisations. But in three countries, the main partner collaborating with schools is from the private sector, i.e. industry and business.

([45]) SCORE, ACME and the Royal Academy of Engineering are the Lead Organisations for Action Programmes 5 - 7 respectively. Together with STEMNET, these Lead Organisations work with a large number of STEM Enhancement and Enrichment (E&E) providers to ensure that all schools and colleges have better access to information on the activities available to them, and how these activities may benefit their students.

([46]) http://www.gettingpractical.org.uk/

([47]) http://www.pm.katowice.pl/

([48]) http://www.fchampalimaud.org/education/en/champimovel2/

([49]) http://www.scholaludus.sk/new/?go=projektova_skupina&sub1=teplanova1

([50]) http://www.sciencefestival.co.uk/education

In the **Netherlands**, Jet-Net – Youth and Technology Network Netherlands ([51]) – was established in November 2002 as a partnership between Dutch industry, the government, and the education sector. Jet-Net was created in order to assist secondary schools to enhance the appeal of their curriculum and science teaching. Since 2008, the network has comprised thirty national and international companies, representatives of the ministries of Education and Economic Affairs, trade organisations and the national Science and Technology Platform. Almost a third of upper general secondary (HAVO) and pre-university (WVO) schools currently participate in the network (for more information, see Section 2.3 on guidance).

In the **United Kingdom**, STEMNET ([52]), the science, technology, engineering and mathematics network creates opportunities to inspire young people in science, technology, engineering and mathematics (STEM) which, in turn, enables them to develop their creativity, problem-solving and employability skills, widen their choices and support the UK's future competitiveness. STEMNET helps encourage young people to be well informed about STEM, able to engage fully in debate, and make decisions about STEM-related issues. It is funded by the Department for Business, Innovation and Skills (BIS) and Department for Education (DFE) and runs three programmes to help realise its vision: STEM Ambassadors ([53]) where people from STEM backgrounds volunteer as inspiring role models for young people; Brokerage of STEM Enhancement and Enrichment on which STEMNET co-ordinates 52 organisations to fulfil a brokerage role to schools. Through strong links with business organisations the brokerage service aims to ensure that all schools and colleges can offer their students programmes which support the curriculum and increase the quality and quantity of students moving into further STEM education, training and development. STEMNET also oversees the coordination of the network of After School Science and Engineering Clubs (ASSECs). In **Scotland**, Determined to Succeed (DtS) is the Scottish Government's strategy for enterprise education. Partnerships between business organisations and schools are helping make learning work-relevant, experiential and engaging.

In **Norway**, the programme developed by the Confederation of Norwegian Enterprise (NHO) 'Business and Industry', was created in order for students to understand what science is used for and to see science as a possible option for them. The programme allows schools to have regular contact with trade and industry and permits the development of partnership agreements between schools and local businesses, allowing students to experience the role of science in the real world. Similarly, in order to enable the business community to help strengthen education in mathematics, science and technology, trials of the *Lektor 2* ([54]) scheme have been initiated. The aim of this scheme is to encourage employees to teach part-time in primary and secondary education and training specifically in subjects where schools need extra help. The scheme contributes to increased recruitment to MST subjects, creates good relationships with the business community and provides better training in science. Furthermore, through collaboration between schools and local employers, schools can access modern technical equipment and receive more relevant and practical training.

In only two countries, do local authorities play an active role in their partnership with schools. However, such contributions from the local level are, in both cases, provided under the umbrella of a government initiative.

In **Denmark**, 25 municipalities were chosen from five regions including 250 431 primary and secondary pupils (almost a third of the national school population) to take part in the project *Sciencekommuner* ([55]) (Science Municipalities) between 2008 and 2010. This project, which involved setting up a learning network, is based on the vision that children and young people's interest in science and technology could be enhanced if all positive forces within town boundaries acted together. The Danish Science Communication (*Dansk Naturvidenskabsformidling* – DNF), an independent non-profit organisation with experience in new initiatives in science communication, supports the project while the Ministry of Education also provides some funding. To become a Science Municipality, municipalities must have a long-term

([51]) http://www.jet-net.nl/

([52]) http://www.stemnet.org.uk/home.cfm. Further information on the size and scale of this project in the 2009/10 annual report available online: http://www.stemnet.org.uk/_db/_documents/STEMNET_Annual_review_FINAL.pdf

([53]) For information on this programme in Scotland, please see the specific website: www.stemscotland.com

([54]) http://www.lektor2.no/

([55]) http://www.formidling.dk/sw7986.asp strategy for developing science which links with their strategy for business. Each municipality has to appoint a science coordinator who keeps in contact with schools. The particular objectives are primarily to provide extra opportunities for inquiry-based learning, but also to address subjects that take different learning strategies into account.

In the **United Kingdom** (**Scotland**), the new curriculum framework for Scotland – Curriculum for Excellence – has been designed to foster more effective partnership working within schools as well as between schools and their local communities. This includes science projects.

The programmes and initiatives reported above, promote science education through school partnerships which involve a huge variety of activities. However, there are other school partnerships which are dedicated to a specific topic or type of activity.

In Belgium and the United Kingdom, partnerships have been established for the purpose of enabling pupils and students to carry out hands-on activities; they provide mobile centres which visit a number of schools during the school year, irrespective of their location.

In **Belgium (French community)**, the *Camion des Sciences* (Science truck) is a laboratory truck which visits schools in order to provide teachers and students with a real laboratory in which to perform experiments in eight different scientific fields. It is an initiative of the Museum of Natural Sciences and a private chemical company, with the support of the Ministry of Education.

In **the United Kingdom**, the Institute of Physics is responsible for the project 'Lab in a Lorry', a mobile science laboratory in a converted lorry that takes hands-on physics experiments to secondary schools. Similarly in **Scotland,** the University of Edinburgh set 'The Sci-Fun Roadshow' which takes the experience of a mobile science centre for secondary schools across Scotland, particularly to rural areas without easy access to a science centre. It has received Scottish Government funding for several years, including £ 25 000 in 2010/11. Both projects are carried out under the 'Science Engagement' funding programmes for public and schools audiences with the objective of complementing the Curriculum for Excellence, strengthening science learning and supporting teaching.

In Denmark and France, two partnerships in science education are focused, in particular, on curriculum development and the design of teaching materials for science subjects.

In **Denmark**, *Anvendelsesorientering* (Applied Science methods) is a programme coordinated by the Danish Science Communication (*Dansk Naturvidenskabsformidling* – DNF). The programme started in 2007, has continued in its present form since 2009 and will do so for at least another two years. All projects must be designed with the objective of rethinking the teaching of science subjects at upper secondary level in order to make it more applied. Teaching approaches must emphasise both professional and pedagogical aspects and students must actively investigate a case study. The Ministry of Education strongly supports the projects and recommends that participating schools work together with industry or science education centres. In this way, students can also experience how science is applied in practice, for example, by allowing them to meet role-models from universities or businesses.

In **France**, *La main à la pâte*, which means collaborative and hands-on work in French, was founded in 1996 by Georges Charpak, a Nobel prize winner, and the French Academy of Sciences / Institute of France with the support of the French Ministry of Education. The programme started in 1997 with a partnership between the French *Académie des sciences* and INRP (National Institute for Pedagogical Research). Agreements in 2005 and 2009 reinforced the partnership between the *Académie des sciences*, the Ministry of National Education and the Ministry of Higher Education and Research and extended it until at least 2012, while also widening the programme to include students at ISCED 2. The main objectives are to promote science and technology teaching at school, to train and support teachers as well as to spread inquiry methods at an international level. *La main à la pâte* has an international dimension with direct partners in 30 countries ([56]). In France, the programme is managed by a directorate strongly linked to the *Académie des sciences* and run by a team established in the *Ecole normale supérieure* at Montrouge. There is a

([56]) http://www.lamap.fr/international/1 network of 14 steering centres which implement the programme and five associated centres responsible for building projects and partnerships with schools ([57]). Based on ten principles, the strategy of *La main à la pâte* stresses science, language and social skills. Pupils and students progressively appropriate science concepts and methods and improve their oral and written communication. Different professionals from the field of science and education, for example, teachers, teacher educators, inspectors, students, engineers and scientists participate in the development of the various teaching materials produced.

In Germany and Norway, partnerships are focused on girls in particular and address their participation in science education activities and their take-up of science as a career.

In **Germany**, the National Pact for Women in MINT (mathematics, informatics, natural sciences and technology) careers called 'Go MINT!' ([58]), launched in 2008, is based on partnerships. The 'pact partners' together with the Ministry of Education and Research support and promote specific measures for encouraging girls to take up careers in science. Pact partners might be universities and colleges and higher education associations; employers' and employees' associations; media; clubs and associations; research organisations and research consortia; enterprises and foundations and the federal states (for more information, see Section 2.3 on guidance).

In **Norway**, under the national strategy for Strengthening Mathematics, Science and Technology (MST) for the period 2010-2014, three projects focusing on science education have been carried out with a strong involvement from universities and companies. Girls and Technology is a collaborative project of the University in Agder (UiA) with the Confederation of Norwegian Enterprise (NHO), the Norwegian Society of Engineers and Technologists (NITO), the Norwegian Society of Graduate Technical and Scientific Professionals (Tekna), the Norwegian Confederation of Trade Unions (LO) and the two county municipalities, Øst- and Vest-Agder (for more information, see Section 2.3 on guidance).

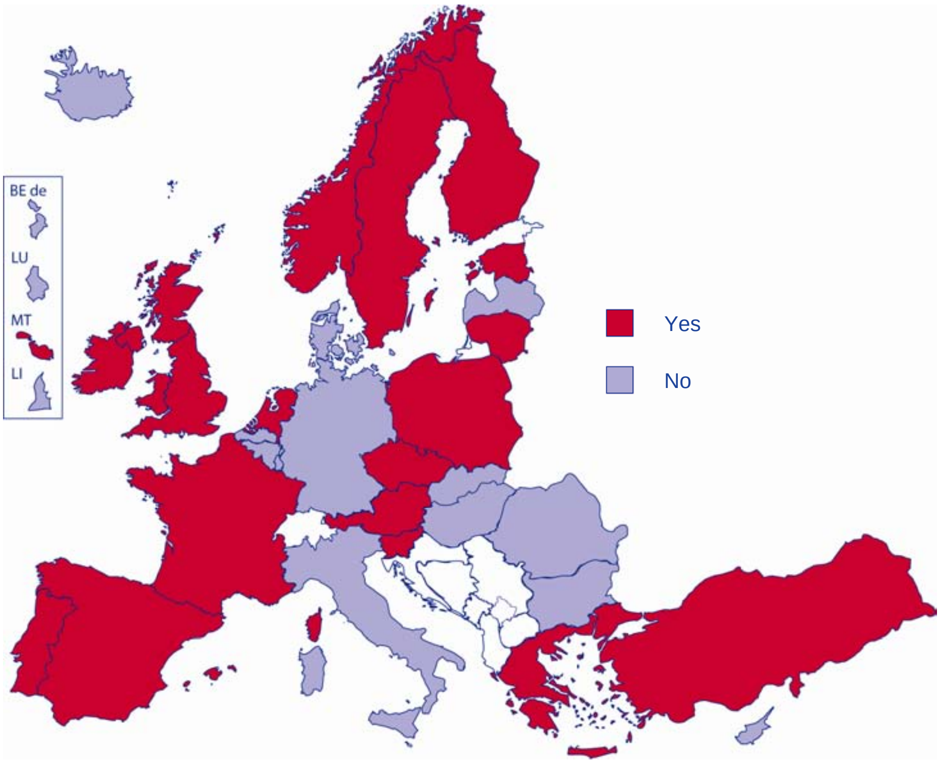
2.2.2. Science centres and similar institutions promoting science education

Promoting science education outside school through collaboration with pupils and teachers involves a wide range of activities from disseminating innovative learning materials to organising professional development activities for teachers. Two-thirds of Eurydice countries have institutions devoted to the promotion of science education.

([57]) For further information, see the 2010 evaluation report: http://www.lamap.fr/bdd_image/RA2010.pdf.

([58]) www.komm-mach-mint.de

Figure 2.2: Existence of national science centres or similar institutions promoting science education, 2010/11



Source: Eurydice.

Explanatory note

Only national science centres and similar institutions are taken into account. Local and small-scale science centres and other small institutions are not included.

In Ireland, Portugal, Finland, Norway and Turkey, these centres are official umbrella-organisations with a mission to promote science at national level. They are either established in universities or have them as a main partner.

In **Ireland**, the National Centre for Excellence in Mathematics and Science Teaching and Learning (NCE-MSTL) (59) has the mission to enhance the teaching of science and mathematics at all levels of the education system in Ireland. Its activities include conducting research in the teaching of mathematics and science, collaborating with universities and other institutions in relation to such research, the development and delivery of CPD for teachers and the development of resources for teachers of mathematics and science. The centre is funded by the Government and works in partnership with a number of third level institutions, including the University of Limerick which hosts the centre.

In **Portugal**, the agency *Ciência Viva* (science alive) (60) was created in 1996 as a unit of the Ministry of Science and Technology; its role is to promote scientific and technological education in Portuguese society, particularly among younger pupils from in pre-primary upwards but including the whole school population (ISCED 1, 2 and 3). The agency collaborates with 11 different partners such as state bodies, *Agência da Inovação* (Innovation Agency), *Fundação para a Ciência e Tecnologia* (Foundation for Science and Technology), research centres, *Instituto de Estudos Sociais* (Science Studies Institute), non-profit-making organisations, *Instituto de telecomunicações (*Telecomunications institutes*)*, higher education institutes, *Instituto de biologia molecular e cellular* (Cell and Molecular Biology Institute). *Ciência Viva*'s programmes comprise three main types of activity. The agency runs a programme which supports the

(59) http://www.nce-mstl.ie/
(60) http://www.cienciaviva.pt/home/

use of experimental science teaching methods and the promotion of science education in schools. Under this programme, an annual national competition of science education projects is organised and science inquiry and laboratory activities are provided during holidays. The agency also coordinates and manages the national network of regional centres *Ciência Viva*.

In **Finland**, the national LUMA centre [61] (LU stands for *luonnontieteet*, natural science in Finnish, and MA for mathematics) is an umbrella organisation for the cooperation of schools, universities, business and industry, coordinated by the Faculty of Science, University of Helsinki. The goal is to support and promote the teaching and learning of science, mathematics and technology, at all levels. The LUMA Centre works together with schools, teachers, students of education and several other partners in order to achieve its goals. The main activities are CPD activities for teachers including an annual LUMA science day; the national LUMA activation week for schools; MST camps for children; resource centres for mathematics and science. The LUMA Centre is governed by a management team comprising representatives of various institutions: the Ministry of Education, the National Board of Education, the Faculties of Biosciences, Behavioural Sciences and Science, the Helsinki University of Technology as well as the City of Helsinki Education Department, as well as a representative of Finnish municipalities and various Finnish Industry associations. The centre cooperates with, for instance, the Palmenia Centre for Continuing Education, government agencies, NGOs, associations, science centres and textbook publishers.

The **Norwegian** Centre for Science Education [62] at the University of Oslo's Faculty of Mathematics and Natural Sciences, is a national resource centre for all education levels. Beside schools, the Centre has various collaborators from universities and university colleges to museums and industry. Its main objectives are to enable pupils and teachers to consolidate their skills and to encourage interest in the natural sciences. The Centre develops working methods and teaching materials which help to make natural science teaching more varied, as well as lively and exciting for pupils and students. The centre contributes to the development and the testing of computer based learning materials and the organisation of web-based learning environments in natural science. It also provides teacher professional development activities. Many other activities are carried out by the centre, including providing information and disseminating research results; contributing to the development of positive attitudes and a thoughtful view of natural sciences in society; supporting and advising the Ministry of Education and Research and the Directorate for Education and Training regarding curriculum development and pupil assessment in the natural sciences; and promoting equal opportunities education regardless of gender, socio-economic differences and race.

Science centres have also been established at regional level in Norway with the specific objective of raising interest in mathematics, science and technology. In 2009, the Ministry allocated a total of NOK 20.3 million to these regional science centres. They operate as learning centres and received more than 164 000 pupils as part of organised school visits in 2008. They support teacher education and collaborate with the existing local stakeholders involved in scientific information within their region, such as science museums.

In **Turkey**, the Science Centres' Foundation [63] was established in 1995 as a result of the consolidation of existing science centres. Among its objectives, the Foundation seeks to increase society's knowledge about social and applied sciences and create an environment that encourages enthusiasm for learning; opportunities to carry out exciting experiments; and fosters the joy of discovery. The Foundation is also responsible for strengthening communication between industry, schools and society. The Science Centres' Foundation organises specific projects, contests, workshops and exhibitions. Among its founders are several universities, the National Ministry of Education, the Scientific and Technological Research Council of Turkey (TÜBİTAK), the Turkish Academy of Sciences (TÜBA) and many non-profit and non-governmental organisations.

([61]) http://www.helsinki.fi/luma/english/index.shtml

([62]) http://www.naturfagsenteret.no/ For more information on the mandate, please see the web page in English: http://www.naturfagsenteret.no/c1442967/artikkel/vis.html?tid=1442390

([63]) http://www.bilimmerkezi.org.tr/about-us.html

In a few countries, there are also centres devoted to promoting science education which are either based in higher education institutions or collaborate closely with them. They support schools in teaching science and are ideal places for contributing to research in the field of science education.

In **Ireland**, the Calmast – Centre for the Advancement of Learning of Mathematics, Science and Technology ([64]) aims to promote the study of science and related subjects in schools in the south-east of Ireland. The centre publishes science-related resources for schools and organises local science promotion activities such as science fairs. Another centre which plays a relevant role is the Castel – Centre for the Advancement of Science and Mathematics Teaching and Learning ([65]). This organisation has a multidisciplinary research team involving scientists, mathematicians and educationalists from Dublin City University and St Patrick's College, Drumcondra. Apart from the aim of improving the learning of science at all levels of education, the centre is involved in promotional activities in partnership with local and national organisations.

In **Spain**, at the regional level, the *Centre de Reçerca per a l'Educació Científica i Matemàtica* – CRECIM (the Science and Mathematics Education Research Centre) at the Universidad Autónoma de Barcelona (UAB) in the Autonomous Community of Catalonia ([66]) plays a significant role in promoting and supporting science education. The Centre defines its goals as improving teachers' professional development in order to promote scientific and technological literacy as well as to contribute to science communication and dissemination. The objectives of CRECIM are implemented through research projects as well as seminars and professional development courses. Its work is carried out through a network made up of teachers and researchers called REMIC (*Reçerca en Educació Matemática e Científica* – Mathematics and Science Education Research) which has been active since 2006 and is funded by the Autonomous Government ([67]).

In **Poland**, the Centre for Innovative Bioscence Education, BioCEN *(Biocentrum Edukacji Naukowej)* ([68]) has been promoting biology experiments for ISCED 2 and 3 students and teachers through classes and workshops offered in the educational laboratories at the International Institute of Molecular and Cellular Biology and at the Warsaw University of Life Sciences (SGGW). One of the statutory objectives of BioCEN is to promote experimental biology in Poland and to develop this area of biology in schools by organising various activities such as lectures, seminars, workshops, conferences and by preparing biology teaching materials for primary and secondary schools. The BioCen is supported by two higher education institutions as well as three research institutes in Warsaw.

In **Sweden**, there are three resource centres devoted to supporting the teaching of science subjects. Established by the government, these centres are run by universities and play a role at national level. One of the three centres located at Uppsala University is the National Centre for School Biology and Biotechnology ([69]). Its mission is to support and inspire teachers at all levels of education, from pre-school to upper secondary schools, including adult education. The activities offered include supporting discussion and the exchange of ideas between teachers; raising competence at all levels of biology teaching; giving advice for practical work in the laboratory; promoting the development of outdoor education; supporting an integrated view of life science; giving information about current developments within the biology field; supporting and promoting contacts between research, school and industry; and stimulating discussions about sustainable development and ethical questions.

The National Resource Centre for Chemistry Teachers ([70]) located at Stockholm University aims to promote and encourage the teaching of chemistry in compulsory and upper-secondary schools. It carries out various activities including: developing new experiments for schools and giving advice on issues concerning the teaching of chemistry; encouraging children and young people to become involved in scientific activities; offering continuing professional

([64]) http://www.calmast.ie/
([65]) http://www.castel.ie/
([66]) http://crecim.uab.cat/
([67]) http://crecim.uab.cat/xarxaremic/
([68]) http://www.biocen.edu.pl/; http://www.biocen.edu.pl/en/
([69]) http://www.bioresurs.uu.se/aboutus.cfm.
([70]) http://www.krc.su.se/

development to chemistry teachers and informing them about new legislation and reforms; and initiating and fostering contacts between schools and the chemical industry. The National Centre for Physics Education ([71]) run by Lund University has similar objectives and is an important resource centre for all teachers from pre-school to upper secondary level.

In Estonia, Malta, Norway and Turkey, specific bodies have been established by official authorities to coordinate measures for supporting science education.

In **Estonia**, a separate unit for science communication (The Science Popularisation Unit – SCU) was created in 2010 within the Archimedes Foundation ([72]) which is an independent body established by the Estonian government. Its objective is to coordinate and implement programmes and projects in the field of training, education, research, technological development and innovation. The SCU manages eight different programmes with a yearly budget of approximately EUR 0. 2 Million from the state budget and has more than 1 300 participants yearly.

The **Malta** Council for Science and Technology (MCST) is a public body established by the central government in 1988. Its mandate is to advise the government and other bodies on science and technology policy. The MCST also organises various science popularisation events on a national basis such as the Science and Technology Festival and the Researchers' Night. There is also the Science Centre which cooperates with the Department of Curriculum Management and eLearning within the Ministry of Education, Employment and the Family. The Science Centre collaborates closely with schools in the area of science education. It is also the headquarters of a team of 21 peripatetic primary science teachers who visit primary schools and deliver the science syllabus on a day-to-day basis.

In **Norway**, the mission of the team for MST (mathematics, science and technology) at the Ministry of Education and Research ([73]) is to implement science, mathematics and technology policies by coordinating work towards the strengthening of these subjects in Norwegian education. The team comprises members from the Ministry of Education and Research as well as representatives from all educational levels and from the research community. The role of the team is to keep track of existing initiatives and ensure that new initiatives are in line with the overall aims of government policy. Among its other responsibilities, the team supports the work of the three national science centres.

The Scientific and Technological Research Council of **Turkey** (TÜBİTAK) established in 1963 is an autonomous institution with a mission to advance science and technology, conduct research and support Turkish researchers. TÜBİTAK is responsible for research and development in line with national targets and priorities. It runs several annual activities in the field of science education for pupils and students and also supports municipalities wishing to establish science centres in their cities.

In many countries, science museums and centres organise programmes and activities to raise pupils and student interest in science. These organisations also help to consolidate what is taught and learnt at school and provide teachers with advice and support on their professional practice. The specific activities which science museums and centres provide can make a significant difference to how young people view and understand science as well as to how motivated they are to study and work in this field.

In the **Czech Republic**, two science centres were recently opened: the iQpark ([74]) in 2007 and one year later, the Techmania Science Centre ([75]). The iQpark is located in the former facility of the state Textile Research Institute in Liberec and incorporates more than a hundred interactive exhibits. This centre was founded by the non-profit organisation Labyrint Bohemia and is co-financed by the European Regional Development Fund (ERDF). The Techmania Science Centre was founded by the Skoda Holding joint-stock company and the University of West

([71]) http://www2.fysik.org/
([72]) http://archimedes.ee/index.php?language=2
([73]) http://odin.dep.no/ufd/engelsk
(74) http://www.iqpark.cz/en/
([75]) http://www.techmania.cz/lang.php?lan=1

Bohemia in Pilsen *(Západočeská univerzita v Plzni)* with the intention of building an interactive centre on the Skoda industrial estate. The aim of its founding bodies was to respond to the decline in interest in technical fields. The Centre provides exhibits which explain mathematical or physical principles through games and interactive activities.

In **Estonia**, the Ministry of Education and Research, the University of Tartu and the city of Tartu together founded the AHHAA Science Centre ([76]) in 1998. It specialises in developing new methods for explaining science and technology to the public and in particular to young people at all educational levels. The Science Centre is supported from the state budget, from European Structural Funds and private sector funding. It includes interactive educational exhibitions, ‘science theatre’ shows, planetarium lectures and fun laboratory experiments.

In **France**, *la Cité des sciences* and *le Palais de la découverte* merged in 2010 into one organisation, *Universciences* ([77]), a public, industrial and commercial institution. The main aim of *Universciences* is to make scientific and technical culture accessible to everyone. The role of *Universciences*, therefore, is to develop scientific and cultural products as well as to set up educational programmes and create new educational activities for primary and secondary education. The institution operates on a regional, national and international level. From September 2010, seven state-sector teachers have been seconded to *Universciences* to manage, for example: the scientific and technical coordination and support for visits; activities and programmes for primary and secondary teachers such as training courses; the production of teaching materials; and the linking of teachers with the science community through digital networks.

In **Greece**, the educational department of Goulandris Natural History Museum ([78]) is open to collaboration with teachers, students, volunteers, museum-pedagogues and animators for the implementation of programmes, projects and children's workshops. The department has been monitoring the new teaching approaches introduced through the Interdisciplinary Curricula of the 2006/07 school year and has created educational programmes for visiting groups of primary school pupils.

In **Lithuania**, the Lithuanian Young Naturalists Centre *(Lietuvos jaunųjų gamtininkų centras)* ([79]) established by the Ministry of Education is responsible for non-formal education and training in the fields of nature, environment and human health. Its activities include: the organisation of national and international events for children and young people and the creation of conditions which allow them to acquire skills developed through non-formal education; the dissemination of information; the organisation of CPD activities for teachers; and the development of teaching materials. The Lithuanian Student Information and Technical Creativity Centre, also established by the Ministry of Education, plays a similar role in non-formal education and training in the area of science and technology.

In **Spain**, the mission of the National Museum of Science and Technology (MUNCYT) ([80]), located in Madrid and very soon also in La Coruña (Galicia), is to contribute to science education in Spanish society. Educational programmes are one of the museum's current priorities within its two-fold objective of enhancing scientific culture and highlighting the importance of the history of science and technology. The museum, which is dependent on the Ministry of Science and Innovation, is managed by the FECYT *(Fundación Española para la Ciencia y la Tecnología)* within the action line ‘Spanish Network of Science and Technology Museums’. In 2008, the MUNCYT began to create a network of partner institutions through which it can carry out activities in different parts of the country.

At regional level, the Science Park ([81]) located in the Autonomous Community of Andalusia is an interactive museum which houses various exhibitions, both permanent and temporary. It is funded by the Autonomous Government and other public and private institutions. It was created in order to promote science and technology in education and to foster interactive approaches and hands-on experiments. Its work is carried out through a range of activities including summer workshops for children and adolescents from 5 to 13 years old.

([76]) http://www.ahhaa.ee/en/
([77]) http://www.universcience.fr/fr / education
([78]) http://www.gnhm.gr/Museaelect.aspx?lang=en-US
([79]) http://www.gamtininkai.lt/
([80]) http://www.muncyt.es
([81]) http://www.parqueciencias.com/

The **Malta** Council for Science and Technology will be building a National Centre for Interactive Science in 2013. This will serve as an educational and entertainment platform for students, parents and professionals with the objective of increasing the interest in science, engineering and technology.

In **Poland**, the Copernicus Science Centre *(Centrum Nauki Kopernik)* ([82]) is a joint institution established and funded by the City of Warsaw and the State Treasury, represented by the Minister of National Education and the Minister of Science and Higher Education. It disseminates information on national and world achievements in science and technology, explaining the nature of phenomena around us through the use of interactive classes and facilities. The Copernicus Centre's mission is to arouse interest, to support understanding of the world and the learning process as well as to inspire social discourse on science. It organises events promoting science (physics in particular), primarily among pupils at ISCED 1 and 2. In addition, a permanent exhibition of interactive models is being prepared along with laboratories for experiments and research. The Science Experiment Centre *(Centrum Nauki Eksperyment)* ([83]) established within the Gdynia Innovation Centre at the Pomeranian Park of Science and Technology ([84]), is a non-formal education centre comprising 40 different laboratory stands, including interactive ones, adapted to different age groups which enable pupils to familiarise themselves with a particular scientific phenomenon. The Laboratory of Biotechnology and Environment *(Wdrożeniowe Laboratorium Biotechnologii i Ochrony Środowiska)* ([85]) is an integral part of a biotechnological module at the Pomeranian Park of Science and Technology in Gdynia. The laboratory is equipped with high-tech facilities and provides laboratory classes in biology and chemistry for groups of pupils.

In the **Netherlands**, the Nemo Science museum ([86]) welcomes people of all ages but its primary target group is children and young people aged between 6 and 16. It provides an interactive non-classroom-based learning environment for the fields of science and technology. The Nemo Science Museum is part of the National Centre for Science and Technology (NCWT); its goal is to use scientific and technological phenomena and developments to inform, inspire and captivate the general public and school children of every age.

In **Slovenia**, several science centres play a role in supporting science education. For example, the House of Experiments ([87]) welcomes visits from groups of students and teachers as well as the general public to hands-on exhibits and other activities such as workshops and competitions. The Natural Sciences Educational Centre for Sustainable Development (FNM-UM) ([88]) also provides educational courses and workshops using modern laboratory equipment aimed at teachers and students. The ICJT – Educational Centre for Nuclear Technology ([89]) – coordinates similar activities targeted at schools at all levels of education.

The **United Kingdom (Scotland)** has four Science Centres: the Glasgow Science Centre ([90]), Our Dynamic Earth ([91]), Sensation' ([92]) and Satrosphere ([93]) which together make up the Scottish Science Centres' Network (SSCN). These four centres have various aims: to promote Scotland's science, education and innovation capability; to communicate the role of leading edge science and technology in shaping Scotland's future; to build partnerships to develop the national role in science communication and education; to create interactive experiences that inspire, challenge and engage; to increase awareness of science; to enhance the quality of science and technology learning; to promote education and life-long learning in science; to spark renewed interest in university science courses.

([82]) http://www.kopernik.org.pl/index.php
([83]) http://www.experyment.gdynia.pl/pl/dokumenty/main_page
([84]) http://www.ppnt.gdynia.pl/en.html
([85]) http://www.ppnt.gdynia.pl/lekcja-biologii-molekularnej.html.
([86]) http://www.e-nemo.nl/?id=5&s=85&d=551
([87]) http://www.h-e.si/index.php?lang=en
([88]) http://www.fnm.uni-mb.si/default.aspx
([89]) http://www.icjt.org/
([90]) http://www.gsc.org.uk/
([91]) http://www.dynamicearth.co.uk/
([92]) http://www.sensation.org.uk/
([93]) http://www.satrosphere.net/

Many institutions engaged in the science field might also be in position to support science education in schools. To this end, networks intended to connect organisations, individuals and schools have been established in Spain, Austria and in the United Kingdom (England and Wales).

In **Spain**, the Foundation for Science and Technology (FECYT) established as part of its programme for Scientific Culture and Innovation a network of Scientific Culture Units – the CCU+i network – which links universities and research centres. The CCU+i network acts as a communication channel between science researchers from 70 CCU+i centres and the whole population. Some of the activities carried out by the centres are specifically designed to promote and support science education.

In **Austria**, the Science Centre Network ([94]) is an association of Austrian organisations and persons working to further the understanding of science and technology. The Science Centre Network aims to inspire and to stimulate thinking as well as to encourage a casual, light-hearted approach to science and technology for all ages. It also wants to encourage young people in their choice of career. The educational concept is based on individual and self-directed learning processes. Almost 100 partners have currently joined the network and contribute actively to the community by developing, offering or using interactive science activities. Network partners come from various backgrounds from all over Austria, among them more than 70 institutions and 24 individuals. Their fields of expertise are very diverse, including education, science and research, design, arts, media and industry.

In the **United Kingdom (England and Wales)**, the Institute of Physics and the science learning centres have formed a partnership to establish and run a support network for teachers and physics students. Known as the Stimulating Physics Network ([95]), it supports both pupils and teachers, with particular emphasis on schools where the number of students studying physics is not high and where there is a low take-up by girls. The network provides professional development for teachers and careers resources and activities designed to motivate students. Support is offered to all schools through network coordinators who work closely with universities and STEMNET, which has links with local and specialist schools.

2.2.3. Other science promotion activities: national events and competitions

Apart from school partnerships and activities developed in specific institutions and centres, other types of events such as science festivals, contests and competitions have been set up in some European countries with a view to promoting science education.

National science education events

Nationwide events for the promotion of science are held annually in some countries. Although these are usually open to the general public, pupils and students are often the main target and specific activities are arranged for them. Some events focus solely on the school population. They may be either one-day events or they may last a full week. Activities are intended to make science lively and accessible and so a fun, practical and interactive approach is taken.

In **Spain**, the Science Week ([96]) has been carried out each year since 2002 within the action line 'Regional Network of Innovation and Science Communication' of the FECYT ([97]) and, at regional level, by the departments or bodies designated as official coordinators of these kinds of actions in each participating Autonomous Community.

In **France**, *la Fête de la science* ([98]) takes place each year during the last week of October under the auspices of the Ministry of Higher Education and Research which is the main funder. Regional authorities and sponsors also contribute to the initiative.

([94]) http://www.science-center-net.at/
([95]) http://www.stimulatingphysics.org/overview.htm
([96]) www.semanadelaciencia.es
([97]) http://www.convocatoria2010.fecyt.es/Publico/Bases.aspx

In **Malta**, each year there is a week-long festival devoted to science and technology called 'Science is Fun' ([99]) held at the University of Malta Campus and coordinated by the Malta Council for Science and Technology (MCST). Another annual event is the 'Science Week' which is organised by the NSTF (National Students Travel Foundation) at which are held an exhibition of students' creative works, experiments, research findings and original projects, as well as a forum for the promotion, explanation and discussion of various selected themes.

In **Poland**, the 'Science Picnic' ([100]) organised jointly by Polish Radio and the Copernicus Science Centre, is a large outdoor science-popularisation event, organised every year since 1997 in Warsaw. The event is open to all visitors, but focused, in particular, on pupils from primary and secondary schools. Around 250 institutions from Poland and abroad take part in the event, presenting their achievements and revealing 'behind-the-scenes' aspects of their work. Most of the participating organisations are higher education institutions, research institutes, museums and cultural bodies, science-related foundations and other interest groups. In addition to this event held in the capital, regional science festivals take place each year in all the main cities of Poland and involve science-related organisations including higher education institutions, science and cultural centres and research institutes. These festivals reach and attract students as well as the general public ([101]).

In **Slovenia**, since 2009, the 'Sciencetival of Adventures' (*Znanstival dogodivščin*) ([102]) has been organised by the House of Experiments. Experiments, workshops, exhibitions and other science promotion activities are held over several days in Ljubljana and Piran.

In the **United Kingdom**, the British Science Association runs an annual National Science and Engineering Week, with a different theme each year ([103]).

In some countries, science promotion events are targeted specifically at schools.

In **Belgium (French Community)**, the annual event *le Printemps des Sciences* (Science Spring) ([104]) is aimed at primary pupils as well as at secondary and tertiary students. This event was launched in 2000 under the initiative of the Ministry of Higher Education, and is organised by the universities and the *hautes écoles* which play an important role along with the sixty other partners which include museums, laboratories and research centres. The *Printemps des Sciences* seeks to stimulate the interest of the youngest pupils in science and to encourage careers in science among older students. Activities carried out during the event are consistent with the curriculum.

The Nordic and Baltic countries taking part in the Nordplus Framework Programme ([105]) i.e. Denmark, Estonia, Latvia, Lithuania, Finland, Sweden, Iceland and Norway, share an initiative called the Nordic Climate Day. Launched by Education Ministers in 2009, this event is designed to provide a boost to the teaching of climate issues and to promote co-operation between teachers and students from primary and secondary education in the participating countries. The Nordic Climate Day gathers together a large number of stakeholders and gives schools the opportunity to carry out various activities and to use tools and materials made available on a specific web portal ([106]).

Science contests and competitions

Other types of activities for raising interest and enthusiasm for science which have been developed in several countries are contests and competitions. As they are not compulsory and because they combi-

([98]) http://www.fetedelascience.fr/
([99]) http://www.mcst.gov.mt/
([100]) http://www.pikniknaukowy.pl/2010/en/
([101]) One example among the annual regional science festivals: http://www.festiwal.wroc.pl/english/
([102]) http://www.znanstival.si/index.php
([103]) http://www.britishscienceassociation.org/web/NSEW/index.htm
([104]) http://www.printemps-des-sciences.be
([105]) http://www.nordplusonline.org/
([106]) http://www.klimanorden.org

ne competition with fun, these events can raise interest in science topics already taught at school and/ or motivate students to deepen their knowledge and to devote more time to experimental activities.

The biggest competition at European level is the Olympiads organised at regional, national and international level. There are also two other European competitions held in the field of science which complement the Olympiads: the European Union Contest for Young Scientists which started in 1989 ([107]) and the European Union Science Competition ([108]) launched in 2002. Almost all European countries participate in these competitions and contests.

Initiatives for organising contests in the field of science can also come from the private sector or from not-for-profit-organisations. In Italy, ENEL, an electricity company organises an annual 'Energy in Play' contest for students in all grades. Similarly, in Latvia, the electric energy company 'Latvenergo' holds an annual physics competition called 'Experiments' ([109]) which is directed at students in grade 9 (ISCED 2). In the United Kingdom, the British Science Association ([110]), a voluntary organisation, provides information and offers a range of activities including competitions.

School science contests and competitions are usually organised under the initiative of the Ministry responsible for education or by other bodies with responsibility for promoting science education such as science centres. This is the case in the French Community of Belgium, the Czech Republic, Spain, Estonia, Latvia, Lithuania, Malta, Hungary, Portugal, Slovenia and Turkey.

The greatest number of contests and competitions are aimed at secondary students while a few are directed at primary pupils. However, activities aimed at promoting science education sometimes start earlier. In Norway, the Science Seeds Prize *(Forskerfrøprisen)* contest is specifically directed at kindergarten children and is run each year by the Norwegian Centre for Science Education. The kindergartens applying for the award are those which show good practice in stimulating scientific exploration, and 'preserve children's curiosity, wonder and focus' in teaching science subjects in kindergarten ([111]).

2.3. Encouraging young people to choose scientific careers through specific guidance

Students' low or diminishing interest in the field of science and the relatively low take-up of science subjects at university level are areas of concern for policy-makers at European level (European Commission, 2007). Studies on students' attitudes and perceptions conclude that students' do not see the relevance of their science studies to their future working lives (Bevins, Brodie and Brodie, 2005; Cleaves, 2005). In addition, they often have stereotypical and narrow views about science careers, or sometimes no information at all about what it means to be a scientist or an engineer (Ekevall et al., 2009; Krogh and Thomsen, 2005; Lavonen et al., 2008; Roberts, 2002). As a result, the majority of students in Europe do not aspire to become scientists or engineers (Sjøberg and Schreiner, 2008). Gender issues also affect career aspirations, with girls being much less interested in choosing careers in science (Furlong and Biggart, 1999; Schoon, Ross and Martin, 2007; van Langen, Rekers-Mombarg and Dekkers, 2006).

In addition to ensuring that science is taught in context (see Chapter 3), other suggestions to remedy this situation include inviting experts from scientific fields into schools, organising workplace visits, as

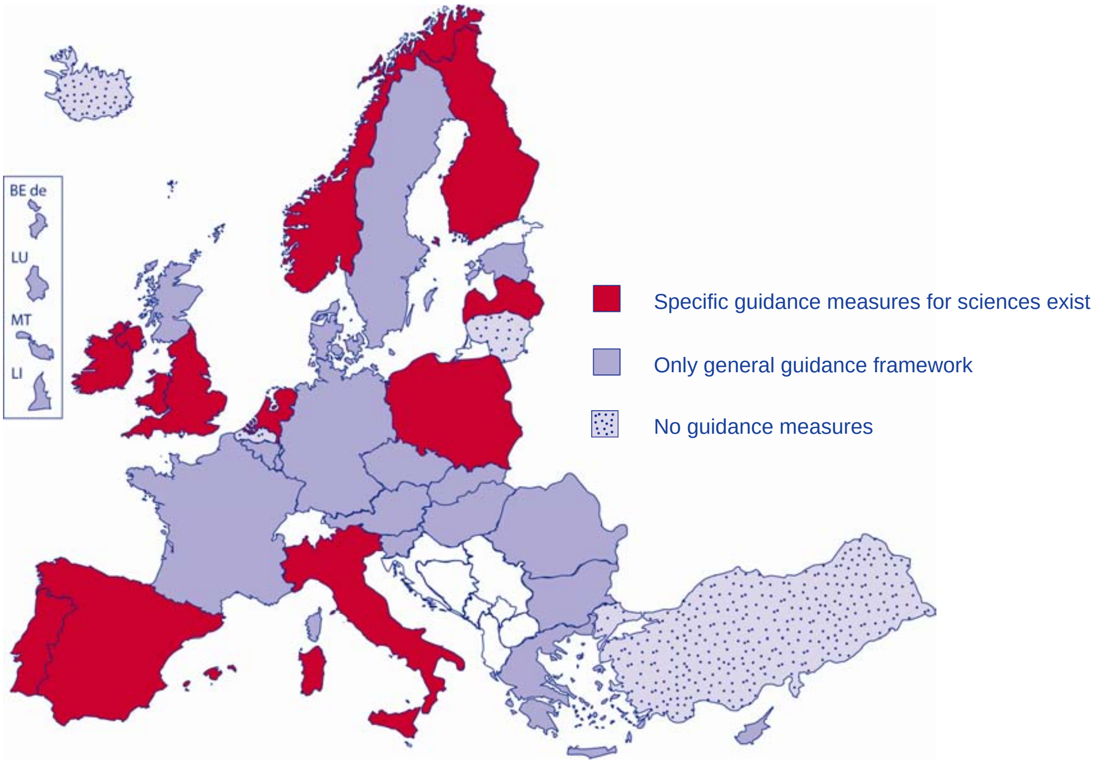
([107]) http://ec.europa.eu/research/youngscientists/index_en.cfm
([108]) http://www.euso.dcu.ie
([109]) http://www.latvenergo.lv/portal/page?_pageid=73,1331002&_dad=portal&_schema=PORTAL
([110]) http://www.britishscienceassociation.org/web/AboutUs/index.htm
([111]) http://www.naturfagsenteret.no/c1557812/artikkel/vis.html?tid=1514469&within_tid=1557824

well as providing focused career guidance and counselling services. Student surveys indicate that science professionals could provide valuable information on possible careers in science as well as acting as positive role models for students (Bevins, Brodie and Brodie, 2005; Lavonen et al., 2008; Roberts, 2002).

With respect to careers guidance, research often concludes that careers advisors are not well-informed about science careers themselves and are therefore not well-equipped to advise students on these issues (Lavonen et al., 2008; Roger and Duffield, 2000). It is therefore important to strengthen high-quality career advice in schools, paying special attention to the needs of girls. Careers advisors need to understand how to counteract the perception that science is a male activity and be able to reassure girls that choosing science does not constitute a loss of their femininity, which is often one of their concerns (Roger and Duffield, 2000). This latter suggestion is based on the assumption that identity plays a strong role in career choices; and that science is construed as a masculine discipline, and that this contributes to discouraging women's interest in the subject (Brotman and Moore, 2007; Gilbert and Calvert, 2003).

There is, therefore, a need for both science-related and gender-sensitive educational and vocational guidance to increase motivation and encourage the interest of both girls and boys in science subjects and careers.

Figure 2.3: Specific guidance measures to encourage careers in science for pupils and students in ISCED 2 and 3 in Europe, 2010/11



Source: Eurydice.

Country specific note

Italy: Specific guidance measures concern only pupils in ISCED 2.

As Figure 2.3 shows, in the majority of European countries, careers-related guidance on opportunities in science are included within the general guidance framework. In these countries, schools and/or other relevant bodies are generally required to ensure the availability of educational and vocational guidance. They must provide information as well as advice to pupils, students and their parents on the availability of various educational pathways and career choices. In addition, in some of these countries, several small-scale projects or initiatives devoted to raising and enhancing pupils' interests in science exist.

> In **Denmark**, there are opportunities for practical training at the University of Copenhagen with certain companies. In **Estonia**, the Science Popularisation Unit manages the programme 'TeaMe' with the main objective of encouraging young people's interest in careers in science and technology (see Section 2.2 for similar projects). In **Austria**, 'Generation Innovation' ([112]), an initiative of the Ministry of Transport, Innovation and Technology and the Ministry of Education, Arts and Culture, aims to inspire children and young people's interest in research and innovation in science and technology. One of the three main activities of the initiative is assisting students to take part in internships. The activity *ForschungsScheck* (research voucher) provides grants for innovative science projects from pre-primary to upper secondary level.

When specific science subjects and career-related guidance measures are in place, they generally involve girls and boys in both lower and upper secondary education. The principal reason for the development of specific guidance in sciences noted by almost all of these countries is the need to avoid a potential shortage of skilled scientific staff by increasing the number of students choosing science-related subjects. Generally, their main aims include increasing the number of young people choosing science-related subjects and careers by improving their engagement in sciences. In certain countries (e.g. the Netherlands and Poland), this goal is explicitly linked to the Lisbon Strategy objectives. Norway highlights the importance of competence in maths, science and technology in the context of solving the global challenges related to energy and climate change, health, poverty, and empowerment.

Depending on the country, these measures take various forms, such as nationwide or regional programmes (i.e. in Spain) or projects (i.e. In Italy). Different stakeholders, such as educational authorities at national and/or regional level; schools; higher education institutions (HEIs) and their students, teachers, academics; as well as employers are involved. The content of programmes and/or projects also varies from country to country. In the majority of cases, the activities consist of visits to universities, study visits to workplaces, interactions with university teachers, students and/or employers. Role models and mentoring are often included. Pupils and students are given the opportunity to apply the knowledge acquired in school in real work situations or research activities. Schools and teachers are also helped to introduce educational innovations that encourage students to consider scientific careers.

> In **Spain**, scientific vocations as well as innovation and entrepreneurship are encouraged through two different nationwide programmes: The 'Programme for the promotion of scientific and innovation culture' is managed by the Spanish Foundation for Science and Technology, an agency of the Ministry of Science and Innovation and the Ministry of Education.
>
> Another programme, the *Campus Científicos de Verano* (the Summer Science Campus) involves ten universities from six autonomous communitiesnamely Andalucía, Asturias, Cantabria, Cataluña, Galicia and Madrid; it is intended to promote the interest of pupils and students in science, technology and innovation. Grants are available especially for students who have shown special skills in science in the fourth (last) year of lower secondary education and in the first year of scientific upper secondary education *(Bachillerato)*. The activities proposed within this programme allow students to have a first experience of research through participation in scientific projects designed and conducted by academics in collaboration with secondary school teachers.

([112]) http://www.generationinnovation.at/

The project called *Rutas Científicas* (Scientific Routes) ([113]), running since 2006 under the responsibility of the Ministry of Education, in cooperation with the Education Departments in the Autonomous Communities involves upper secondary students who study science subjects. They are given the opportunity to participate in short, one-week internships in laboratories, research centres, technology industries, natural parks or science museums. The objective is to complement the scientific knowledge acquired in the classroom by discovering its application and usefulness in everyday life. In 2010/11, around 1 500 students participated in the programme.

At regional level, the annual collaboration programme between secondary schools (ISCED 2 and 3) and the Faculty of Science of the University of Zaragoza aims to give first and second year *Bachillerato* students the opportunity to become familiar with the Faculty of Science. The selected applicants spend a week within the departments of the Faculty in order to learn and participate in research tasks. Students also participate in cycles of conferences and exhibitions throughout the year and are provided with role models through the visits of university lecturers to secondary schools.

In **Italy**, the project 'Degrees in Natural Sciences' *(Il Progetto Lauree Scientifiche)* is the result of collaboration between the Ministry for Universities and Education, the *Conferenza Nazionale dei Presidi di Scienze e Tecnologie* (National Conference of Science and Technology Deans) and of *Confindustria* (Industrial Federation). The project started in 2004, initially to increase the number of participants in chemistry, physics, and mathematics degree programmes. Between 2005 and 2009 around 3 000 schools and 4 000 secondary level teachers, as well as around 1 800 university teachers participated in the different activities. With the support of the Ministry's Technical Science Committee (*Comitato Tecnico Scientifico* – CTS), a network has been set up to link the partners at national, regional and local levels.

In **Latvia**, various initiatives for schools and students are available within the project 'Science and Maths' ([114]). Within this project, the event 'Think Differently – be More in Science and Mathematics!' is held. Students participate in this two-day event, meeting Latvian scientists and visiting different laboratories and industrial companies. This new initiative was started in August 2009 and will be repeated.

In the **Netherlands**, the *Platform Bèta Techniek* ([115]) commissioned by the government, education and business sectors delivers the *JetNet* (Youth and Technology Network) continuing programme for secondary education. It makes an important contribution in encouraging students to choose scientific careers. *Jet-Net* companies help schools enhance the appeal of their science curriculum by using a great variety of activities as well as allowing pupils to gain a better understanding of their future career prospects in industry and technology. Major national events organised within the programme are: the *Jet-Net* Career Day, the National *Jet-Net* Teachers' Day and Girls' Day (25 companies involved). In addition, a range of smaller programmes and activities has been developed, e.g. mentoring activities, company-assisted research, guest lectures, expert meetings and teacher workshops.

In **Poland**, the government programme 'Ordered Fields of Study', launched in 2008, targets mainly students in departments of science, maths and technology (ISCED 4 and 5). However, within the programme's activities individual HEIs and universities organise promotional activities in science-related fields for their prospective students i.e. pupils and students in lower and upper secondary education (ISCED 2 and ISCED 3). Science festivals and picnics are organised during which HEIs and universities present their activities and achievements. During university open days, potential students are informed about the courses offered by the institution and are allowed to participate in meetings, lectures and workshops with professors and students. An example of good practice is the Summer School of Physics ([116]) organised at the Faculty of Physics, University of Warsaw in cooperation with the Polish Physical Association and the City of Warsaw.

([113]) http://www.educacion.es/horizontales/servicios/becas-ayudas-subvenciones/centros-docentes-entidades/no-universitarios/becas-rutas-cientificas.html. Specific information regarding Andalusia available on this website: http://www.juntadeandalucia.es/educacion/nav/contenido.jsp?pag=/Contenidos/OEE/planesyprogramas/PROGRAMASEDUCATIVOS/VIAJES_ESCOLARES/CIENTIFICAS

([114]) http://www.dzm.lv/skoleniem/events_for_students

([115]) www.platformbetatechniek.nl or www.deltapunt.nl

([116]) http://www.fuw.edu.pl/wo/lsf/ (in PL)

In the **United Kingdom**, the STEM Careers Action Programme managed by the Centre for Science Education (CSE) at Sheffield Hallam University was aimed at 11- to 16-year-old pupils. The CSE created and delivered a wide range of resources to support the curriculum, the careers workforce and continuing professional development, under the theme of 'enthusing students, equipping professionals, supporting employers'. An integrated communication campaign involving TV and cinema advertising accompanied the programme.

In the **United Kingdom (Northern Ireland)**, in 2008 the Department of Education launched the STEM careers Education, Information, Advice and Guidance (CEIAG) programme, aimed at improving young people's knowledge and understanding of the opportunities for entering careers which require a background in STEM subjects. This work is focused on developing materials to inform young people about STEM-related careers and the benefits of seeking employment in these areas.

In **Norway**, the ENT3R nationwide motivation programme (117) was initiated by the Ministry of Education and is implemented, coordinated and evaluated by the National Centre for Recruitment to Science and Technology (RENATE). Within this programme young people aged 15 to 18 years old meet mentors who are university and college students. The mentors are meant to be role models with the ability and mission to make science and technology more attractive and to inspire teenagers in their choice of education and careers. In addition, RENATE's website is providing the 'Role Models' database which has the profiles of a variety of people with scientific or technological training. Since 2011, it has been possible to book a 'role model' to come to the school. Another activity proposed within the ENT3R programme involves monthly presentations to pupils and students by science- and technology-based enterprises on the relevance and importance of maths and science education. It also allows students to meet possible future employers.

As mentioned at the beginning of this section, there is a specific need to redress gender differences in pupils' attitudes towards sciences and their motivation to study these subjects, with girls being much less interested in choosing scientific careers. Nevertheless, these issues are not often explicitly addressed within the existing science-related guidance measures. A few countries have developed specific science-related guidance programmes which focus on young women and/or have integrated female-oriented guidance initiatives within existing guidance programmes or science projects.

In **Germany**, the National Pact for Women in MINT (mathematics, informatics, natural sciences and technology) Careers – 'Go MINT!' (118), launched in 2008, tries to interest female pupils in MINT subjects by offering assistance in deciding on a course of study and facilitating contacts with the working environment. In one of the several Go MINT projects, called 'Cyber mentor', women working in MINT careers are put in touch with female students via e-mail in order to answer questions on MINT topics. In other projects, such as 'taste MINT', female secondary school graduates are given a chance to assess their potential for MINT study areas. Various partners participate in MINT projects (for more information on partners, see Section 2.2).

In **France**, where the need for scientific vocations, especially for girls, is mentioned within the general framework for guidance *(socle commun)*, a small project 'Pour les Sciences' (119) was launched in 2006 in the *Académie* of Versailles. It is intended to motivate young people, especially girls, to take up scientific careers and supports any initiative in the field of science and technology.

In the **Netherlands**, girls in primary and secondary education constitute one of the target groups defined in the framework of the *Platform Bèta Techniek*. The aim is to allow girls to become aware of their own talents and to acquire positive science-related experiences. Some specific actions of the *Jet-Net* programme (e.g. the Girls' Day – see above) focus specifically on girls who are provided with female role models and a broad overview of career opportunities in science.

In **Finland**, the GISEL (gender issues, science education and learning) Project being carried out by the Department of Applied Sciences of Education at the University of Helsinki has sought to find ways to influence girls' attitudes towards

(117) http://www.renatesenteret.no/ent3r/h
(118) www.komm-mach-mint.de
(119) http://www.pourlessciences.ac-versailles.fr/

science and technology when choosing a career, as well as influencing the attitudes of the professionals involved. In practice, within the project's framework and in cooperation with teachers, science teaching methods have been developed which demonstrate the attractiveness of science and promote young people's interest in science, particularly girls. The intention is to motivate them to study science and to choose advanced science courses in upper secondary school.

In the **United Kingdom**, there are national initiatives to counter the gender imbalance in science and engineering. One of the best known is Women into Science, Engineering and Construction (WISE). The WISE campaign collaborates with a range of partners to encourage girls of school age to value and pursue science-, technology-, engineering- and construction-related courses in school or college as well as to move on into related careers ([120]).

In **Norway**, girls' lack of self-esteem in maths and science constitutes one of the reasons for launching the ENT3R programme (see above). 'Girls and Technology' is another collaborative project of the University of Agder. Every year since 2004, the project has transported hundreds of girls from lower and upper secondary schools in the Agder counties to the University of Agder for a technology adventure day. 'Girls and Technology' gives girls the opportunity to meet female role models from trade and industry, laboratory work is demonstrated and they are entertained with a science show and musical performances. UiA has directly benefited from this career guidance by a significantly increasing the number of female applicants to their engineering and technology studies. In 2004, 45 female students started courses in engineering at UiA, after four years of focusing on girls as a target group in general, and on girls and technology in particular, in 2008 this number had increased to 114.

The project *Realise,* which started in 2010, aims to develop measures to increase the recruitment of girls to science. The target group for the project is grades 8 to 13. The measures are aimed at students, teachers, counsellors, school administrators and school owners. The focus is on the recruitment of girls to science, especially mathematics, physics, technology, earth science and ICT ([121]).

2.4. Support actions for gifted and talented students in science subjects

In nine countries, specific attention is paid to pupils and students who are gifted and talented or particularly interested in science subjects. Support actions reported by these countries involve designing and providing activities specifically adapted to the needs of these students. The objective is to encourage them to maintain their interest in studying science subjects and to choose this area for their further studies and career. Most of these support activities are provided outside normal curriculum time during breaks in the school day, after school and in school holidays.

Denmark, Spain and the United Kingdom are the only countries with specific guidelines or regulations on supporting gifted and talented pupils.

In **Denmark**, education legislation requires the organisation of specific activities for talented students at upper secondary level. Guidelines provided to schools contain examples on how to support talented students individually or in groups. This covers the provision of extra-curricular activities devoted to science education. Students and the education institution together decide which science subjects the activities will focus on ([122]).

In **Spain**, the 2006 Act on Education (LOE) states that particularly gifted and motivated pupils must be given attention appropriate for their educational needs. Consequently, the educational authorities of the Autonomous Communities must take appropriate measures and develop action plans to meet those needs.

([120]) http://www.wisecampaign.org.uk

([121]) http://www.naturfagsenteret.no/c1515373/prosjekt/vis.html?tid=1514707

([122]) http://www.uvm.dk/Uddannelse/Gymnasiale%20uddannelser/Love%20og%20regler/Bekendtgoerelser.aspx

In the **United Kingdom** (England, Wales and Northern Ireland), there are policies and guidelines regarding support for talented students ([123]). The guidance in Northern Ireland includes specific guidelines for science teaching ([124]).

In other countries, support measures for gifted students are provided within the framework of either a programme or a project.

In **Bulgaria**, within the 'With Care for Each Pupil' programme, one of the two modules offered provides training for talented pupils in sciences from the fifth to the twelfth grade in order to prepare them for participating in school competitions. The module covers 50 classes per year. The subjects involved are physics and astronomy, chemistry, environmental protection, biology and health education. The module is delivered in schools, at the end of the normal school day or at weekends.

In the **Czech Republic,** two relevant projects are currently in operation under the initiative of the NIDM – National Institute of Children and Youth of the Ministry of Education, Youth and Sports ([125]) (*Národní institut dětí a mládeže Ministerstva školství, mládeže a tělovýchovy)*.

In the first project, 'Support System for the Development of Talented Children in Science and Technical Fields' ([126]), the NIDM works in close collaboration with external experts to run a survey which is focused on employers and their readiness to participate in developing talented students with an interest in science and technology. It looks in detail at employers' requirements of these young people as prospective employees in their companies. The aim is to determine, amongst other things, under what conditions and how willing employers are to support the work with gifted and talented students.

The other project *Talnet* ([127]) is targeted at talented young people aged 13 to 19 years who are interested in sciences. The project seeks to identify talented students and offer them a systematic increase in educational opportunities in the natural sciences and technology. It also provides an online environment tailored to meet the needs of these students.Talnet collaborates with industry specialists, teachers, parents and psychologists. Although the project is provided under the auspices of the NIDM, it is delivered by the Department of Physics Education, Faculty of Mathematics and Physics, at Charles University in Prague.

In **Estonia**, the Gifted and Talented Development Centre (GTDC) at the University of Tartu ([128]) has developed and collected various teaching resources that help support individualised learning in class and are also useful for extra-curricular activities, for example, contests in schools. The main aim of the GTDC is to provide opportunities and possibilities for the development of pupils who have a deeper interest in science. The GDTC offers both the facilities to enrich pupils' knowledge beyond the usual school curriculum and also the resources they need to spend their leisure-time more meaningfully. The GDTC organises enrichment courses in several MST fields: mathematics, physics, chemistry, and life sciences. In the 2009/10 academic year, 1 450 students participated in 36 courses. These activities are mainly funded by the Ministry of Education and Research.

In the **Netherlands**, a multi-disciplinary research program 'Curious Minds' *(TalentenKracht)* ([129]) was launched in 2005 with the aim of mapping, preserving and developing the talents of children between the ages of three and six years, in the STEM (science, technology, engineering and mathematics) fields. The Curious Minds program not only consists of scientific research activities carried out by various Dutch universities, it also concentrates on the influence of children's

([123]) Please see more information on Effective Provision for Gifted and Talented Children in Secondary Education on https://www.education.gov.uk/publications/standard/publicationDetail/Page1/DCSF-00830-2007. See also for Wales the document 'Quality Standards in Education for More Able and Talented Pupils' available at http://wales.gov.uk/topics/educationandskills/publications/circulars/qualitystandardseducation/?lang=en

([124]) http://www.nicurriculum.org.uk/docs/inclusion_and_sen/gifted/Gifted_and_Talented.pdf

([125]) http://www.nidv.cz/cs/

([126]) http://www.nidm.cz/projekty/priprava-projektu/perun/system-podpory-kognitivne-nadanych-deti

([127]) www.talnet.cz

([128]) http://www.teaduskool.ut.ee/

([129]) http://www.talentenkracht.nl/

social surroundings with a special attention paid to parents. The Curious Minds program is supported by the Dutch Ministry of Education and the Program VTB (Broadening Technology in Primary Education) which is part of the *Platform Bèta Techniek* (see Section 2.1.1).

In **Poland**, the Ministry of National Education announced the 2010/11 school year as the 'Talent Discovery Year' *(Rok Odkrywania Talentów)* ([130]) which includes the fields of natural sciences and research. During the implementation of this year, the Ministry of National Education granted a status of 'Talent Discovery Centre' to various educational institutions. At present the initiative is continued by the Centre for Education Development *(Ośrodek Rozwoju Edukacji)* ([131]).

In **Turkey**, *Bilim ve Sanat Merkezleri* (Science and Arts Centres) are designed to give further support to talented pupils and students from primary and secondary schools. By providing supplementary education, these centres intend to reach the key targets of enhancement. In addition, students enrolled in science pathways at upper secondary level may study science and mathematics to an advanced educational level.

In Denmark, Spain and Poland, support measures for gifted and talented students are specifically targeted at upper secondary education when students are ready to choose options for their further education and careers.

In **Denmark**, the project Scientist Sprouts *(Forskerspirer*) ([132]) is targeted at talented students at ISCED level 3 who want to gain experience in the world of research. The University of Copenhagen administers the project while the Ministry of Education and Ministry of Science, Technology and Innovation provide financial support. The project started in 1998, and, since then, 60 to 80 schools volunteer each year and between 120 and 180 students are admitted to the programme. The project aims to let talented students experience research and attempts to demystify the work of universities. Pupils participate in this project for almost a year and have time to focus on a particular topic, visit universities, participate in seminars, achieve close contact with a researcher as mentor, and obtain training in academic work on a particular subject.

In **Spain**, the Autonomous Community of the region of Murcia established a pilot research project in 2007 which is now a full-scale *Baccalaureate* project ([133]). In this project, different teaching methods are applied allowing research, new information and communication technologies as well as laboratory practice and field work to be enhanced in all subjects. This project focuses on two branches of the *Baccalaureate*: Science and Technology, and Humanities and Social Sciences. The main objective is to provide students with excellent training and a more rigorous knowledge of various subjects as well as to make them familiar with research methodology in a practical and agreeable way. The *Baccalaureate* is offered to students who complete 4 º ESO *(Educación Secundaria Obligatoria)* studies (ISCED level 2) with good marks and are motivated to improve their personal learning. Similar projects are initiated in other Autonomous Communities such as Madrid ([134]).

In Poland, the Education Office of the City of Warsaw with the support of the Warsaw Network of Support for Talented Pupils (*Warszawski System Wspierania Uzdolnionych*), for the period 2008-2012 ([135]) has set up a programme which includes a module devoted to mathematics and science for talented students at ISCED level 3. The module consists of extra-curricular classes given by teachers of Warsaw schools.

The Netherlands and Hungary have addressed the topic of gifted and talented, and particularly motivated students by launching nationwide programmes to establish networks between schools and other stakeholders, at all levels of education, including primary.

([130]) http://www.roktalentow.men.gov.pl/projekt-strona-glowna

([131]) http://www.ore.edu.pl/odkrywamytalenty

([132]) http://forskerspirer.ku.dk/

([133]) http://www.carm.es/web/pagina?IDCONTENIDO=4772&IDTIPO=100&RASTRO=c1635$m

([134]) http://www.madrid.org/dat_capital/deinteres/impresos_pdf/InstruccionesBExcelencia.pdf

([135]) http://www.edukacja.warszawa.pl/index.php?wiad=3025

In the **Netherlands**, the Orion programme (136) for talented students at primary level aims to encourage the establishment of regional science nodes. A science core node consists of a university, several basic schools and an intermediate body such as a centre providing CPD or a science centre. The objective of creating a science node is to offer a range of substantive activities and to develop educational packages for primary pupils in order to inspire them more in science. Several activities are provided, including courses for teachers, development of teaching methods and materials, lessons from scientists for students, internships and education camps.

In **Hungary**, the National Talent Programme (137) also targets children and young people (ISCED 0 to 3) gifted in science. The core organisation is the National Talent Support Council *(Nemzeti Tehetségsegítő Tanács)* and its role is to promote and support organisations and initiatives dealing with the recognition, selection and support for gifted young people in Hungary and across the borders. The programme is based on a network of various organisations such as schools and NGOs. The funding sources are from the European Union, national co-financing and the National Talent Fund financed from the central budget, the Labour Market Fund and private sector sources. The main activities of the programme include supporting the continuous professional development of science teachers and talent development in the field of science education. Short training courses are offered to teachers and psychologists as well as to staff members of the talent network in schools, NGOs, etc.

Summary

In conclusion, this review of strategies and policies for the promotion of science education reveals that only a few countries have overall strategic frameworks in place. Where they do exist, these frameworks all have a number of action lines and comprise various smaller-scale programmes and projects. Although organised differently in each country, they have, in most cases, a multitude of stakeholders. The aims expressed in these strategies are either linked to broad educational goals for society as a whole, or have a clear focus on schools. The areas usually considered important and in need of improvement in the field of school education are the curriculum, teaching methods and teacher education.

School partnerships in the area of science education are organised very differently in each European country. Partners may vary and range from government agencies, higher education institutions, and science associations to private companies. Some partnerships focus on a specific topic but the vast majority embrace various aspects of science education. Very few partnerships seem to focus their attention on raising girls' interest in science.

Although partners come from various fields and provide a specific contribution to projects, they are usually seeking to achieve one or more of the following aims:

- to promote scientific culture, knowledge and research by familiarising pupils and students with scientific procedures and by disseminating scientific research results to schools (this also supports researchers’ work in the field of science education);
- to make pupils and students understand what science is used for, namely through contact with companies in science-related fields;

(136) http://www.orionprogramma.nl/
(137) http://www.tehetsegprogram.hu/node/54

- to strengthen science education by:
    - enhancing and supporting the implementation of the science curriculum, subjects and teaching;
    - providing teachers with CPD focusing on practical work and inquiry-based learning;
    - supporting pupils and students at school in science activities;
- to increase recruitment to MST by encouraging talented pupils and motivating students to choose MST careers by making school science more work-relevant.

Two thirds of countries report the existence of national science centres and similar institutions which have formal responsibilities for science promotion activities targeted at pupils and students. School partnerships and science centres often complement each other by sharing the aims and objectives mentioned above.

Most countries do not provide specific science-related career guidance measures for every student. However, in many countries there are programmes and projects with a guidance remit which try to reach as many students as possible.

For most countries with a science promotion strategy in place, science-oriented guidance is an integral part of the strategy. Only some countries provide specific initiatives which seek to encourage more girls to choose scientific careers.

Only a few countries have implemented specific programmes and projects to support talented pupils and those students who are particularly motivated to study science. Normally, these students are offered additional and more suitable science learning activities as extra-curricular activities. Stakeholders outside school from research, higher education and private sector organisations are encouraged to support these initiatives.

CHAPTER 3: CURRICULUM ORGANISATION AND CONTENT

Introduction

The way in which science subjects are taught greatly influences students' attitudes towards science as well as their motivation to study and, consequently, their achievement. This chapter discusses how science teaching is organised in schools in Europe.

The first section presents the main research arguments surrounding the issue of whether science should be taught as separate subjects or as a single, integrated programme. Current practice in European countries is examined with respect to the length of time science is taught as a general subject, and in which countries science teaching is subsequently split into separate subjects. In addition, we investigate which subjects are taught separately and consider the names associated with science subjects in different countries.

Section 3.2 focuses on the contextualisation of science in schools; it examines the theoretical arguments behind this principle and looks at evidence from steering documents on the context-related issues recommended in European countries. An overview of science learning theories and research indicating which teaching approaches are considered to provide effective science teaching is provided in Section 3.3; examples of the types of science activities recommended in steering documents are given. Section 3.4 briefly examines the measures in place in to support low achievers while Section 3.5 addresses the provision of science teaching in upper secondary education. The final sections provide information on textbooks and specific teaching materials for science as well as the organisation of extra-curricular activities (Section 3.6) before concluding with a review of recent, on-going or forthcoming reforms to science teaching in European countries (Section 3.7).

3.1. Integrated versus separate-subject science teaching

Science education in primary school begins as a single, integrated subject. However, there is an ongoing debate as to whether science teaching should be organised in distinct subject areas or as a single, integrated programme during later school years.

The labels *integrated, interdisciplinary, multi-disciplinary,* and *thematic teaching* are usually used to describe a variety of curricular arrangements and degrees of integration. In this study, however, the term *integrated science teaching* is used for all the various curriculum arrangements that merge elements from a minimum of two science disciplines.

There are several clusters of arguments in support of the integrated approach to science teaching. Firstly, integration seems to make 'common sense' or have 'face validity' (Czerniak, 2007) since in real life knowledge and experience are not separated into distinct subjects. This line of argument usually stresses that traditional discipline boundaries do not reflect contemporary needs, and that scientific research itself is becoming increasingly integrated and interlinked (James et al., 1997; Atkin, 1998). The second line of arguments stresses the process of knowledge construction. Teaching science in a holistic approach and making connections between different disciplines is seen as a process leading to new ways of thinking and knowledge (Riquarts and Hansen, 1998) that links various abilities (Ballstaedt, 1995), develops critical thinking, and forms the 'big picture' and deeper understanding (Czerniak, 2007). Finally, there is an underlying belief that integrated teaching motivates both teachers and students (St. Clair & Hough, 1992).

The critique of integrated science teaching centres on the lack of empirical evidence of its positive impact on student motivation and achievement. Due to the vague or varied use of definitions, research tends to conflate different levels and objectives of integration. Moreover, it is often impossible to isolate the effects of integrated teaching from other variables that affect student learning. Lederman & Niess (1997) even argue that students following integrated approaches develop less foundational and conceptual understanding since certain discipline-specific topics are covered in less detail or are even omitted.

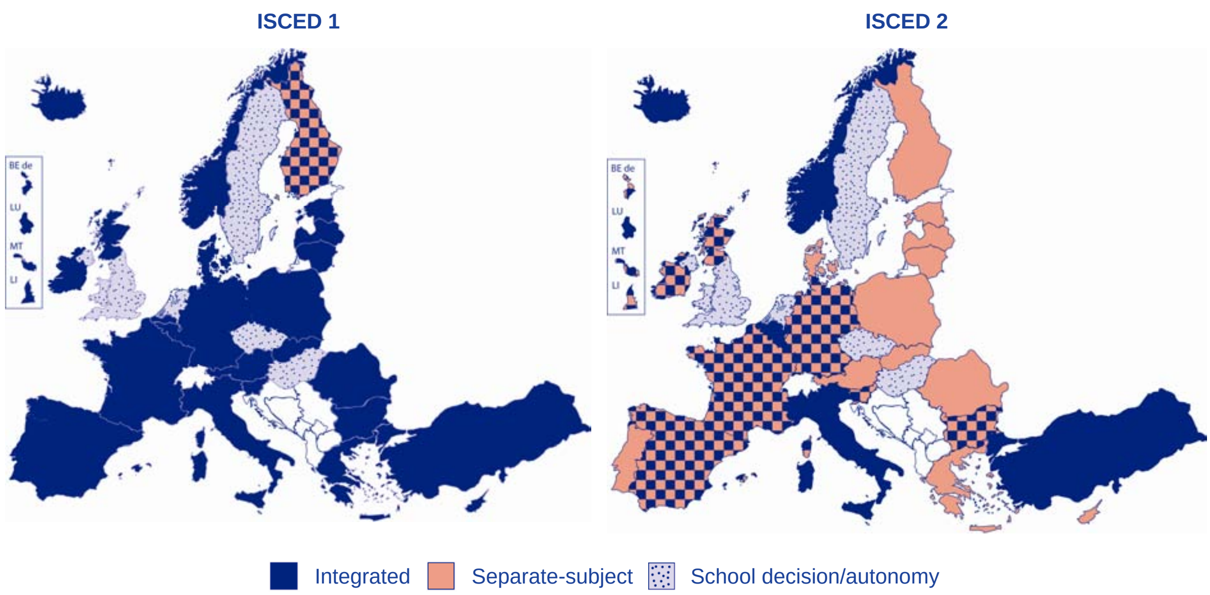
Teachers' skills and knowledge of subject matter is another concern when using integrated approaches. Teachers are usually trained in a limited number of academic disciplines and feel uncomfortable integrating a subject into their lessons for which they were not originally trained or qualified (Geraedts, Boersma & Eijkelhof, 2006; Wataname & Huntley, 1998). Teaching in a team, on the other hand, may result in conflicts over time in the school day and content coverage.

Even though there are many theoretical arguments that support either integrated or separated science teaching, little empirical evidence of their influence on student achievement has been produced (Czerniak, 2007; Lederman & Niess, 1997; George, 1996). Both integrated and separate-subject science teaching can be found in European countries.

Organisation of science teaching in primary and lower secondary education

In all European countries, science education begins as a single, general, integrated subject area which is intended to foster children's curiosity about their environment providing them with basic knowledge about the world and giving them the tools with which they can investigate further. Integrated science subjects promote a questioning and investigative approach to the environment and prepare children for more detailed studies in later grades. Teaching is usually organised in broad themes, for example 'living things respond to the environment' (Belgium – German-speaking Community), 'Diversity of living beings' (Spain) or 'Life and living beings' (Turkey).

Figure 3.1: Integrated or separate-subject science teaching, as recommended in steering documents, ISCED 1 and 2, 2010/11



Source: Eurydice.

Country specific notes

Czech Republic and **Netherlands**: In practice, integrated science teaching dominates in ISCED 1, separate-subject teaching in ISCED 2.
Luxembourg: Last year of ISCED2 – school autonomy.
Hungary: 75 % of schools teach integrated science in ISCED 1.
United Kingdom (ENG/WLS/NIR): Steering documents treat science as an integrated subject, but schools have the autonomy to organise their teaching as they choose. In practice, integrated science teaching dominates in ISCED 1, but there is more variation in ISCED 2.
United Kingdom (SCT): Science is taught as integrated lessons in ISCED 1 with pupils specialising in ISCED 2, but the curriculum levels (and time) at which they do so vary considerably.

Figure 3.1 gives an overview of the common forms of organisation for science teaching in primary (ISCED 1) and lower secondary (ISCED 2) education. In almost all European countries, science is taught as an integrated subject throughout the entire period of primary education. The exceptions are Denmark and Finland, where the separation of science teaching into several subject areas begins during the last year or two of ISCED 1.

In contrast, in lower secondary education, science teaching is usually split into separate subjects. In several countries the teaching of science as an integrated programme continues at ISCED 2 level, but it is split into separate subjects by the end of ISCED 2 (Belgium – German-speaking Community), Bulgaria, Estonia, Spain, France, Malta, Slovenia and Liechtenstein). In only seven European education systems (Belgium – French and Flemish Communities), Italy, Luxembourg, Iceland, Norway and Turkey) is science taught as an integrated subject throughout the entire period of ISCED 1 and ISCED 2.

As the cut-off between integrated and separate-subject teaching of science does not align clearly with education levels, Figure 3.2 provides information by grade or school year. In all European countries, except Liechtenstein and Turkey, science education begins in the first grade of ISCED 1. In Liechtenstein, science is not taught during the first grade, while in Turkey science teaching starts only at grade four.

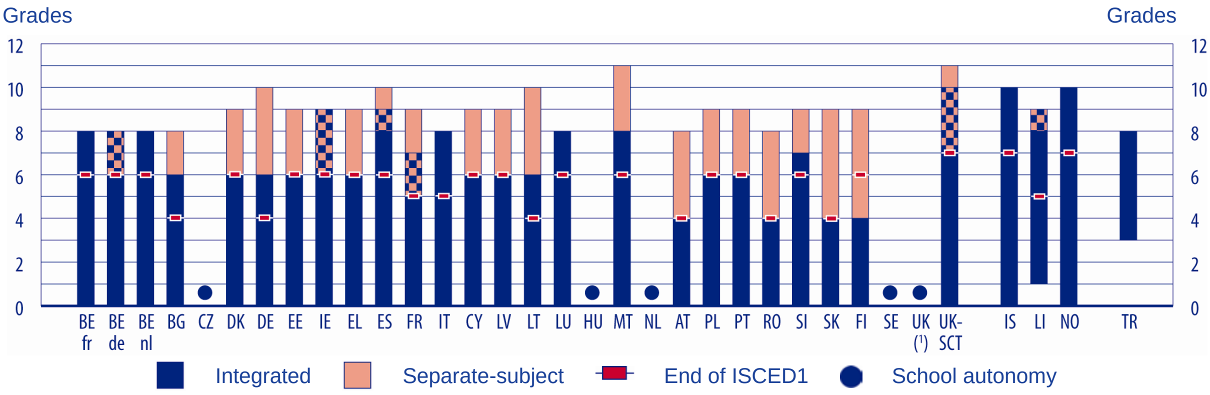
In most European countries, integrated science teaching lasts six to eight years. The duration of science teaching as a single, general, subject in ISCED 1 and 2 varies from four years (in Austria, Romania, Slovakia and Finland) to ten years (in Iceland and Norway).

In some countries, either integrated or separate-subject science teaching may take place at the same grades. For example,

> In **Ireland**, in grades 7-9, science is a single subject. However, the science syllabus is presented in three distinct sections corresponding to the three subjects: biology, chemistry and physics. Teachers have the option of teaching the three subjects separately or in a co-ordinated or integrated manner.
>
> In **France,** in grades 6-7, about 50 schools are experimenting with science taught as an integrated subject: EIST (integrated teaching of science and technology) ([138]).
>
> In **Spain,** in the third year of Lower Secondary Education (9th grade of compulsory education), the integrated subject 'Natural sciences' may be split into two subject areas ('Biology and geology' and 'Physics and chemistry') if the Autonomous Communities so decide.

([138]) See more at http://science-techno-college.net/?page=317

Figure 3.2: Integrated and separate-subject science teaching by grade (ISCED 1 and 2), 2010/11



Years of teaching	BE fr	BE de	BE nl	BG	CZ	DK	DE	EE	IE	EL	ES	FR	IT	CY	LV	LT	LU
Integrated	8	6	8	6	●	6	6	6	6	6	8	5	8	6	6	6	8
Integrated and separate-subject		2							3		1	2					
Separate-subject				2	●	3	4	3		3	1	2		3	3	4	

Years of teaching	HU	MT	NL	AT	PL	PT	RO	SI	SK	FI	SE	UK (1)	UK-SCT	IS	LI	NO	TR
Integrated	●	8	●	4	6	6	4	7	4	4	●	●	7	10	7	10	5
Integrated and separate-subject	●		●								●	●	3		1		
Separate-subject	●	3	●	4	3	3	4	2	5	5	●	●	1				

Source: Eurydice.

UK (1) = UK-ENG/WLS/NIR

Country specific notes

See Figure 3.1

Even when science is taught as separate subjects, many countries emphasise the links between the different subjects. Denmark, Spain, Latvia and Poland define common educational goals (teaching objectives) and/or educational standards for biology, chemistry, physics and geography or geology. In France, the steering document describing the ISCED 2 curriculum starts with a common introduction to mathematics, technology and science subjects. Moreover, in several countries, the teaching of separate science subjects is organised as common themes, building blocks or learning activities.

> In **Lithuania,** the axes of integration between biology, chemistry and physics are concepts of movement, energy, system, evolution, macro- and micro-systems and change. All science courses deal with issues of sustainable development in ecology, environmental protection, and health and hygiene; they also focus on the place and role of man in the world.
>
> The **Romanian** National Curriculum contains specific objectives/competences linking separate science subjects; also, the methodological part of each syllabus focuses on the need for planning integrated learning activities.

Titles used for the integrated science curriculum area

The title by which the integrated science curriculum area is known varies considerably across European countries, but as one might expect, separate science subjects are usually called biology, chemistry and physics (see Table 1 in annex).

Generally, the integrated science curriculum area is either simply called 'science' or has a name related to the world, environment or technology. The aim to stimulate pupils' curiosity in the **world** around them is highlighted by naming the curriculum area 'World orientation' (Belgium – Flemish Community, grades 1-6), 'Homeland' (Bulgaria, grade 1), 'Outside world' (Bulgaria, grade 2), 'People and their world' (the Czech Republic), 'Exploring the natural world' (Greece, grades 5-6), 'Discovering the world' (France (grades 1-2) and Lithuania (grades 1-4)), 'Knowledge and understanding of the world' (the United Kingdom – Wales, grades 1-2) or 'The world around us' (the United Kingdom – Northern Ireland).

Other countries stress the **environment** or **nature** as the most appropriate way to develop pupils' interests, calling the curriculum area 'Nature and man (or people)' (Bulgaria (grades 3-6), Hungary and Lithuania (grades 5-6)), 'Environmental studies' (Greece, grades 1-4), 'Environmental education' (Slovenia, grades 1-3), 'Humans and the environment' (the Netherlands, ISCED2), 'Knowledge of the natural, social and cultural environment' (Spain), 'Nature education' (Poland, grades 1-3), 'Studying the environment' (Romania, grades 1-2), 'Study of the environment' (Portugal, grades 1-4), 'Sciences of the nature' (Portugal, grades 5-6), 'Nature and society' (Slovakia) or 'Natural history and environmental education' (Iceland).

In a few countries the title shows links with **technology**: 'Nature and technology' (Denmark and the Netherlands, ISCED1), 'Experimental sciences and technology' (France, grades 3-5), 'Natural sciences and techniques' (Slovenia, grades 4-5), 'Science and technology' (Italy (grades 6-8), the United Kingdom (Northern Ireland, Key Stage 3) and Turkey). The links with technology are usually highlighted in the later grades of teaching science as an integrated subject.

The curriculum area is just called 'Science' in Estonia, Cyprus, Latvia and the United Kingdom (England, Wales Key Stages 2-3 and Scotland) and 'Natural science' in Norway. In Belgium (Flemish Community), Spain, Poland, Romania and Slovenia, the title changes to 'Natural sciences' in the last 2-3 years of teaching science as an integrated programme.

Separate science subjects taught

When science is taught as separate subjects, in almost all countries, the subjects are called simply biology, chemistry and physics (see Table 1 in annex). In some countries, geography (or earth science) is also taught as a separate subject. In most countries, all of these three or four subjects are introduced immediately following the period of integrated science teaching. However, in a few countries (Greece, Romania and Slovakia), only biology is taught in the first year(s) of separate-subject science teaching, while in Estonia, Cyprus and Latvia, science teaching starts with biology and geography. Lithuania postpones chemistry teaching by one school year and initially teaches only biology and physics.

Some countries have a semi-integrated approach at ISCED 2 level. In Spain, science is divided into two joint subject areas: biology and geology are taught together as are physics and chemistry. Similarly in France, life and earth sciences are taught together, while physics and chemistry make up another subject. However, the new French science programme (March 2011) encourages schools to teach life and earth sciences, chemistry, physics and technology as a single integrated subject in grades 6-7.

Interdisciplinary approaches to science teaching

Science has many natural links with other subjects and interdisciplinary topics. Moreover, science education is intrinsically related to personal and societal issues. In European countries' steering documents, these connections are often highlighted and teachers are usually encouraged to apply cross-curricular approaches whenever possible.

> In the Act on the **Danish** *Folkeskole* (ISCED 1 and 2), there is a requirement to teach interdisciplinary topics and problems.

One of the aims of secondary education in **Spain** is that students should 'view scientific knowledge as integrated knowledge which is structured into different disciplines'; they should also be able to understand and apply problem-solving methods to various fields of knowledge and experience ([139]).

In the **United Kingdom** (**Northern Ireland**), curriculum guidance talks about the importance of 'connected learning', highlighting that 'young people need to be motivated to learn and see the relevance and connections in what they are learning. An important part of that process is being able to see how knowledge gained in one area can connect to another and how similar skills are being developed and reinforced right across the curriculum' ([140]).

Often science is taught as part of wider cross-thematic programmes/frameworks or includes cross-curricular themes. It can be also linked with other subjects by applying the same transversal skills.

In **Liechtenstein**, the integrated science subject belongs to the curriculum area 'people and their environment', which includes topics on 'responsible/sustainable ways of living', 'key questions on being human', man's 'relationship with the environment' and 'cultural and moral virtues'.

In **Poland,** grades 1-2, which follow the new core curriculum, are organised around eight key transversal skills. Later, in grades 4-6 (which still follow the old curriculum), it is compulsory for a pupil to follow one of the educational paths (ecological education and health education) which integrate various elements of different sciences.

Some countries' steering documents specify the subjects with which science teaching should be linked. The usual cross-references are reading (or language of instruction), mathematics, design, technology, ICT and social sciences or moral education.

3.2. Context-based science teaching

Many researchers conclude that students' low or declining interest in science is partly due to its presentation as a collection of detached, de-contextualised and value-free facts that are not connected to students' own experiences (Aikenhead, 2005; Osborne, Simon & Collins, 2003; Sjøberg, 2002). In this sense, traditional school science is perceived to present difficulties in awakening students' curiosity about the natural world, mainly because they do not see its relevance for their own lives and interests (Aikenhead, 2005; Millar & Osborne, 1998).

While neither boys nor girls tend to be motivated by traditional school science, this lack of interest seems to be more apparent in girls (Brotman & Moore, 2008). This is partly due to the fact that boys' and girls' science-related interests can differ, with boys often being more interested in the technological aspects that usually form part of traditional curricula. In contrast, girls' interests are generally under-represented in science teaching, especially in the case of physics (Baram-Tsabari & Yarden, 2008; Häussler & Hoffman, 2002; Murphy & Whitelegg, 2006). Gender differences in attitudes should be taken into account when trying to raise motivation levels in science learning.

A potential way of improving student motivation and interest in the subject is to use social and real-life contexts and practical applications 'as the *starting point* for the development of scientific ideas' (Bennett, Lubben & Hogarth 2007, p. 348, emphasis original). This method is referred to as context-based science teaching or the science-technology-society (STS) approach.

Context-based science teaching emphasises the philosophical, historical or societal aspects of science and technology, as well as connecting scientific understanding with students' everyday experiences. This approach is considered by some researchers to increase students' motivation to

([139]) December 29th, Royal Decree 1631/2006, establishing the national core curriculum for ISCED2 (BOE 5-1-2007), for full text see http://www.boe.es/boe/dias/2007/01/05/pdfs/A00677-00773.pdf

([140]) http://www.nicurriculum.org.uk/key_stages_1_and_2/connected_learning/

engage in scientific studies, and possibly lead to improved scientific achievement and increased up-take (Bennett, Lubben & Hogarth, 2007; Irwin, 2000; Lubben et al., 2005).

The science-technology-society approach requires science to be embedded into its social and cultural context. From a sociological perspective, this includes examining and questioning the values implicit in scientific practices and knowledge; looking at the social conditions as well as the consequences of scientific knowledge and its changes; and studying the structure and process of scientific activity. From a historical perspective, changes in the development of science and scientific ideas are studied. From a philosophical perspective, context-based science teaching raises questions regarding the nature of scientific inquiry and evaluates the grounds of its validity (Encyclopædia Britannica Online, 2010). It also recognises science as a 'human endeavour' where imagination and creativity play a role (Holbrook & Rannikmae 2007, p. 1349).

Both context-based and STS science teaching incorporates students' everyday experiences and contemporary societal issues such as ethical or environmental concerns, and should develop their critical thinking skills and social responsibility (Gilbert, 2006; Ryder, 2002). STS science courses aim to promote 'practical utility, human values, and a connectedness with personal and societal issues, taught from a student-centred orientation' (Aikenhead 2005, p. 384). The goal of science education is to make students responsible future citizens who 'understand the interactions between science-technology and their society' (Ibid.).

As mentioned above, many research studies find that girls' scientific interests differ in some respects from those of boys, which means that special attention needs to be paid to incorporate girls' interests into science teaching through ‘female-friendly’ science education (Sinnes, 2006). Based on evidence from ROSE (for further details see Chapter 1), researchers conclude that girls are especially interested in science content related to human aspects such as the human body, health or wellbeing, while boys are more interested in technological applications and their social dimension (see e.g. Baram-Tsabari & Yarden, 2008; Christidou, 2006; Juuti et al., 2004; Lavonen et al., 2008). However, as there is a considerable overlap between girls’ and boys' interests, context-based science teaching which focuses on the human and social aspects of science can be interesting for both sexes. This means that a female-friendly curriculum can be also advantageous for boys (Häussler & Hoffmann, 2002).

Emphasising the overlap between girls’ and boys' interests, some researchers criticise the idea of a female-friendly curriculum and the strong girls vs. boys categorisation. Instead, they talk about ‘gender-sensitive’ (Sinnes, 2006) or ‘gender-inclusive’ (Brotman & Moore, 2008) science education, recognising ‘the difference between all individuals’ and their diverse experiences and interests (Sinnes, 2006, p. 79). It is argued that redefining curricula in such a way enables it to accommodate the diverse perspectives and experiences of all students.

Recommended contextual issues in the science curriculum

As Figure 3.3 shows, steering documents in European countries typically recommend a range of contextual issues to be addressed in science classes in primary and lower secondary schools (for definitionsn see Glossary). As science teaching in many countries is separated into several subjects at ISCED 2 (see Figure 3.1), interesting differences between the subjects emerge and these are highlighted in the notes and text. It is important to mention at the outset that steering documents can only provide indications as to which contextual dimensions should be incorporated into science teaching; they do not tell us what actually happens in schools.

Science and the environment/sustainability addresses the environmental implications of scientific activity and is recommended for inclusion in science teaching by the steering documents of almost all European countries both at primary and at lower secondary levels; it usually applies to all science subjects (biology, chemistry and physics).

The second most widely recommended contextual issue is **science and everyday technology**. Linking science and technology to everyday life is recommended in primary level steering documents in 29 European countries. At lower secondary level, the everyday technological applications of scientific phenomena are suggested in all countries for all science subjects.

Contextualising scientific phenomena through examples relating to the **human body** and its functioning is recommended at primary level in the steering documents of 27 European countries and at lower secondary level in 29 countries. When science is taught as separate subjects, the human body is an obvious topic in biology; this context was therefore only investigated in relation to chemistry and physics teaching. We were interested in topics such as forces acting in muscles when using them in sports; heart, blood pressure and blood flow; how radiation from solariums and the sun might affect the skin; the influence of electric shock/electricity on muscles and the body; how radioactivity affects the human body, pharmaceutical products and their effects on the body/skin, etc. ([141]). Providing a context for chemistry and physics teaching through examples relating to the human body is recommended in less than half of European countries (Bulgaria, Estonia, France, Latvia, Lithuania, the Netherlands, Austria, Poland, Portugal, Romania, Slovenia and Finland).

Science and ethics or examining the ethical considerations raised by advances in science and technological innovations is recommended in fewer countries at primary level than at lower secondary level. Ethical considerations are more often recommended for discussion in biology than in physics lessons.

The last three contextual dimensions presented in Figure 3.3 relate to scientific method, the nature of science and the production of scientific knowledge. Not surprisingly, these more abstract issues are more often recommended at lower secondary rather than primary level.

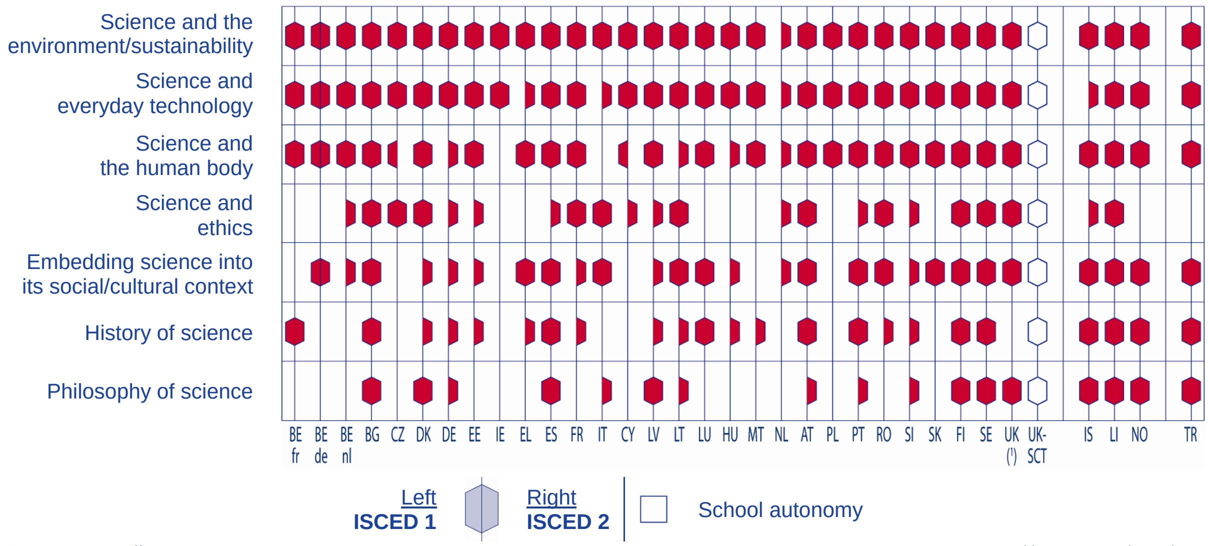
Embedding science into its social/cultural context is considered important when teaching because the development of scientific knowledge may be viewed as a social practice which is dependent on the political, social, historical and cultural realities of the time. The process involves examining/questioning the values implicit in scientific practices and knowledge; looking at the social conditions as well as the consequences of scientific knowledge and its changes; and also studying the structure and process of scientific activity. At primary level, this approach is recommended in approximately half of European education systems. At lower secondary level, embedding science into its social and cultural context is suggested in 27 educational systems.

The **history of science** is recommended in less than half of European education systems at primary level. At lower secondary level, the history of human thought about the natural world (from its beginnings in prehistoric times to the present) is suggested in more than half of European countries.

The least common contextual dimension in science teaching at ISCED 1 and 2 is the **philosophy of science**. Only about one third of European education systems at primary level, and about a half of countries at lower secondary level suggest addressing questions regarding the nature or validity of scientific inquiry.

([141]) The examples are mostly based on the ROSE questionnaire.

Figure 3.3: Contextual issues to be addressed in science classes, as recommended in steering documents (ISCED 1 and 2), 2010/11



Source: Eurydice. UK (¹) = UK-ENG/WLS/NIR

Explanatory note

At ISCED 2 a particular contextual issue is marked as 'recommended' if it is recommended in an integrated science course or in at least one of the three individual science subjects – biology, chemistry or physics. When a certain issue is *not* recommended in *all* science subjects, the subjects are mentioned below.

Science and everyday technology – **Greece** and **Lithuania**: chemistry and biology. **Poland**: physics.
Science and human body - (biology not considered – see text above)). **Denmark, Hungary** and **Slovakia**: chemistry. **Greece**: physics.
Science and ethics – **Slovenia**: biology and chemistry. **Denmark, Spain, France, Cyprus** and **Latvia**: biology.
Social/cultural context of science – Austria: physics and biology. **Denmark**: biology.
History of science – Estonia: chemistry and physics. **Austria:** biology and chemistry.
Philosophy of science – Austria: biology.

Country specific notes

United Kingdom (ENG/WLS/NIR): History of science only in England and Northern Ireland.
United Kingdom (SCT): No recommendations are made in steering documents. However, strong emphasis is placed on interdisciplinary learning within contextualised frameworks and all of the above could be included in teaching and learning.

3.3. Science learning theories and teaching approaches

It is not the purpose of this section to present a thorough review of the enormous amount of research literature on the theoretical basis of science teaching and nor is it the remit of this study to evaluate the wide range of teaching methods. The aim here is to briefly discuss those teaching approaches which are most commonly considered by researchers in the field as 'effective' in terms of improving student motivation and/or learning achievement.

Scott et al. (2007, p. 51) point out that although teaching is a responsive activity depending on several external factors, there are some teaching approaches which might be more effective than others; these would be 'tightly linked to clear teaching objectives, or involve… a motivating activity …, or challenging students' thinking in an engaging way, or allow… students the opportunity to articulate their developing understandings'.

Of course, the approaches described below are not mutually exclusive but rather build on each other. There is considerable overlap between them and, more importantly, they are potentially complementary. Harlen (2009) argues, therefore, for a combination of these approaches to produce a 'best pedagogy' for science education.

Aims of good science education

What can be considered a good teaching approach is evidently linked to the aim(s) of what is considered to be 'good science education'. Harlen (2009) summarises these aims as developing scientific literacy and the ability to continue learning. She defines scientific literacy as 'being comfortable and competent with broad scientific ideas, with the nature and limitations of science and with the processes of science, and having the capacity to use these ideas in making decisions as an informed and concerned citizen' (Harlen 2009, p. 34).

For achieving these goals of scientific literacy and continuity of learning, a large variety of teaching approaches and underlying learning theories is available. There are, consequently, many potential ways to categorise them. Following Harlen's grouping, we distinguish the following approaches: individual and social constructivism; discussion, dialogue and argumentation; enquiry; and formative assessment (Harlen 2009, p. 35).

Although teaching approaches and assessment methods are clearly interconnected, the issue of formative assessment will not be treated here, but in the theoretical introduction to Chapter 4 on assessment.

Changing children's ideas

Constructivism or *conceptual change* in the context of science education has a long history and 'the most influence within the science education community' (Anderson 2007, p. 7). It basically generates the idea that children form their own understanding of certain natural phenomena (called 'misconceptions', 'naïve conceptions', etc.) which, however, most often conflicts with real scientific understanding (for a more extensive review of theories of learners' construction of common sense conceptions, see Eurydice (2006)).

The aim of conceptual change is, therefore, to reorient pupils' understanding of certain phenomena and replace their 'naïve' concepts by scientific ones. To achieve this aim, teachers may help children to test ideas, make them link ideas gathered from diverse experiences and expose them to different ideas (Harlen, 2009). The research summary of this approach proposed by Appleton (2007) identifies teachers' questions, interviews and observations as well as pupils' drawings and concept maps as typical methods to introduce within this approach of identifying students' initial ideas.

Although Anderson in his review of science learning theories acknowledges the importance of conceptual change theories for improving overall science learning, he claims that teaching approaches generated by this theory do not show a positive impact on reducing the achievement gap between high and low achievers (Anderson 2007, p. 14).

The importance of language

Discussion, dialogue and argumentation as part of science teaching are propagated based on the evidence that spoken and written discourse is fundamental in the process of (science) learning. Evidently, this is not a stand-alone approach as discourse is inevitably as much part of conceptual change teaching approaches as of inquiry-based learning.

Argumentation skills in the context of science teaching mean 'to persuade colleagues of the validity of a specific idea… Scientific argumentation is ideally about sharing, processing and learning about ideas' (Michaels, Shouse and Schweingruber 2008, p. 89). Evidently, in this sense the development of such skills should also form part of the teaching content in science classrooms.

Indeed, the analysis of science classroom teaching situations as done by Lemke shows that ‘learning science means learning to communicate in the language of science and act as a member of the community of people who do so’ (Lemke 1990, p. 16). He analysed how teachers communicate science in the classroom and how scientific reasoning is learned by talking. Later, he went further in his reflections on linguistic interactions in science teaching evoking the importance of multimedia literacy in this context (Lemke, 2002). Beyond written and spoken language, there are pictures, diagrams, and all kinds of symbols to be read and understood within science teaching.

Building on Lemke’s theories and investigations, Hanrahan investigated teacher discourse practices in science classrooms. Her focus was on aspects of discourse practice that seem most likely to be implicated in making science accessible to students regardless of their socio-cultural background or ability (Hanrahan, 2005). The researcher argues that if equity in education is a goal, the prevailing ‘interpersonal climate’ has to change in many subjects as ‘teachers may inadvertently communicate attitudes that alienate most students’ (ibid, p. 2). Based on classroom observations in Australian schools, she found out that it is important how difference is addressed during science lessons in order for students to feel in- or excluded. The positive practices included lessons in which teachers tended to apply practices that would enhance 'dialogicality’ with students; they took over a variety of roles and allowed students some flexibility in their corresponding roles; they tried to have a balance between formal and informal talk as well as ‘the expression of scientific detachment and subjective experience’ (ibid, p. 8). However, she points out that single lessons would, in themselves, not have a lasting effect on the attitudes towards school science. Only by the consistent repetition of such discourse practices, multiplied over time, may students feel included as 'legitimate' science learners (ibid, p. 8).

Aguiar, Mortimer and Scott (2010) analysed how student questions can have an impact upon the subsequent development of the classroom discourse. Specifically, they explored how student questions influence the ‘teaching explanatory structure’ and modify the form of the ongoing classroom discourse. From data collected in a Brazilian secondary school, their analysis shows that student questions provide important feedback to the teacher and so enable adjustments to the teaching structure. The data therefore suggest the need to consider students' active verbal participation in the negotiation of both the content and structure of classroom discourse (Aguiar, Mortimer and Scott, 2010).

The socio-cultural approach, including the analysis of classroom discourse, allows insights into the interplay between language, culture, gender and social norms. It shows that science learning is also a linguistic, cultural and emotional process (Anderson, 2007).

Inquiry

The report 'Science Education Now' (European Commission, 2007, p. 9) points to the existence of two historically contrasted approaches in science education: the 'deductive' and the 'inductive' approach. In this sense, the first one would be the more traditional approach, with the inductive one more oriented towards observation and experimentation. The authors argue that the notion evolved and is today commonly referred to inquiry-based science education.

From this very broad definition soon arises the main problem when talking about inquiry teaching approaches: a lack of clarity in terminology. This issue has been addressed by many researchers: (Anderson, Ch. 2007; Anderson, R., 2007, Appleton 2007; Brickman et al., 2009; Minner et al., 2009). As Minner et al. (2009, p. 476) point out in their recent and thorough research review on the topic:

> 'The term inquiry has figured prominently in science education, yet it refers to at least three distinct categories of activities – what scientists do (e.g., conducting investigations using scientific methods), how students learn (e.g., actively inquiring through thinking and doing into a phenomenon or problem, often mirroring the processes used by scientists), and a pedagogical approach that teachers employ (e.g., designing or using curricula that allow for extended investigations)'.

A model to deal with different forms of inquiry approaches is proposed by Bell et al. (2005). They describe a model that includes four inquiry categories which vary according to the amount of information provided to the student. The first category, 'confirmation inquiry', is the most strongly teacher-directed in which the student is provided with the most information, the other levels are known as 'structured inquiry', 'guided inquiry', and 'open inquiry'. At the 'confirmation' level, students know the expected outcome; at the other end of this scale ('open inquiry'), students formulate questions, choose methods and propose solutions themselves.

In Minner et al.'s (2009) major research synthesis of 138 studies ([142]) on the impact of inquiry-based science teaching, the authors blame this lack of a common understanding of the term for making it difficult to investigate its effects. In their investigation, they therefore included studies on teaching which showed the following features of inquiry instruction: engagement of students with scientific phenomena, student active thinking, student responsibility for learning and involvement in the investigation cycle. This is their conceptual framework for inquiry-based learning. The researchers found out that the majority of the studies examined showed positive impacts of inquiry instruction on student content learning and retention. Similarly, positive effects of inquiry-based hands-on activities on conceptual learning could be found. Overall, the results indicated that 'having students actively think about and participate in the investigation process increases their science conceptual learning' (p. 493). However, intensive use of inquiry instruction did not show better learning outcomes. But the researchers conclude that this aspect would need to be further analysed.

Brotman and Moore (2008) reviewing multiple empirical studies, point out that inquiry-based science education, especially if introduced at an early stage, is said to have particularly positive effects on girls' interests and attitudes towards science. Other recent studies, such as Brickman et al. (2009) showed that students working in inquiry laboratories demonstrated a significant improvement in scientific literacy skills.

Recommended science learning activities

This section addresses the issue of whether steering documents (for a definition, see Glossary) in European countries recommend the use of specific learning activities which might be considered as particularly motivating for students learning science. These activities may be based on inquiry methods, dialogues, discussions, verbalisation of problems, collaborative and independent working and the use of ICT.

As shown in Figure 3.4, the activities grouped in the categories 'discussions and argumentations' and 'project work' are very frequently recommended in steering documents at both primary and lower secondary level. This is not so for the use of specific ICT applications.

The most frequently recommended activity in steering documents for primary level is to make scientific observations. More hands-on practical activities such as designing experiments as well as conducting and presenting them are also taken into consideration. However, also activities linked to discussions and argumentations are mentioned in steering documents of most countries, such as formulating

([142]) The analysed studies were mainly conducted in the United States and cover the period from 1984 to 2002.

potential explanations. Collaborative project-work is a recommended activity in more than half of European countries. However, fewer countries recommend debating current scientific and societal issues, self-directed project work and the use of ICT for simulations or video conferences for this level of education.

At lower secondary level, apart from the activities already recommended for pupils at primary level, more reflective activities such as designing and conducting experiments; describing or interpreting phenomena scientifically; or framing a problem in scientific terms are recommended in virtually all countries. Debating current scientific and societal issues and self-directed project work are mentioned in the steering documents of a majority of countries. The use of ICT in terms of computer simulations or video conferences is recommended far more often for secondary students than for primary level pupils, although these activities are still only mentioned in the steering documents of less than half of European countries.

Interestingly, in almost all countries where science is also taught as several separate subjects at lower secondary level (see Figure 3.2), there are no differences between subjects (physics, biology or chemistry) in the recommended activities.

From the above, we can see that activities based on inquiry methods, dialogues, discussion and collaborative working are frequently recommended in European countries' steering documents. However, it must be borne in mind that however detailed these documents may be, they do not attempt to provide any information on actual classroom practice.

Figure 3.4: Science learning activities, as recommended in steering documents (ISCED 1 and 2), 2010/11

Source: Eurydice.

UK (¹) = UK-ENG/WLS/NIR

Country specific notes

Italy: Information shown for ISCED 2 applies to physics only.
Lithuania: Information shown for ISCED 2 applies to science taught as separate subjects.
Austria: Information shown for ISCED 2 applies to physics only.

3.4. Support measures for low achievers

Support measures for pupils and students at risk of not achieving the expected level of attainment in science subjects are regulated and organised in various ways.

Only two countries have defined national targets for tackling low achievement in science.

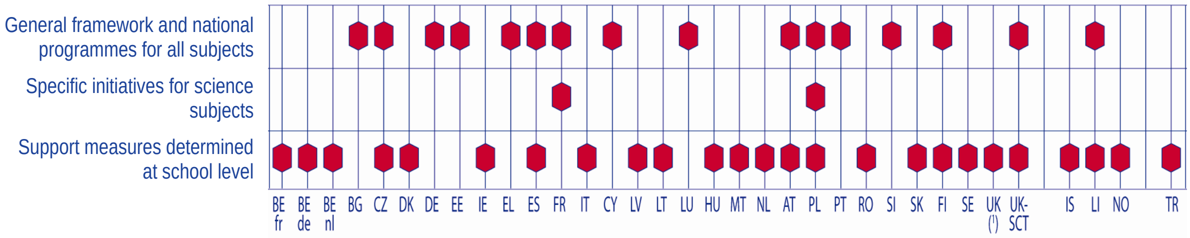
In **Lithuania**, the Strategic Plan of the Ministry of Education and Science for 2010-12 includes a target of 45 per cent of grade 8 students (ISCED 2) to achieve the Advanced and High Benchmarks (550 points) in the 2012 TIMMS survey in the field of natural sciences ([143]).

In the **Netherlands**, under the *Platform Bèta Techniek*, a target of 15 per cent more of students in science and technical programmes has been established for secondary education.

No countries have a policy or strategy for providing specific support to low achievers in science. However, most countries underline that it is the responsibility of schools or teachers themselves to make decisions about support measures for pupils with difficulties in science.

In half of the countries, there are general policies on student support provision but no distinction is made between subjects. The measures and procedures in place to detect learning difficulties are the same for science as for other subjects. However, two countries (France and Poland) have specific initiatives in place to provide support for students with difficulties in science.

Figure 3.5: Provision of support for students in science subjects (ISCED 1 and 2), 2010/11



Source: Eurydice.

UK (1) = UK-ENG/WLS/NIR

In most countries, schools are responsible for identifying low achievers and for supporting them in their learning. The support given to students depends on their particular circumstances and may vary from one school to another within the same country. This is particularly the case in Lithuania, Sweden, the United Kingdom (except Scotland) and Norway.

In **Lithuania**, based on the Curriculum Framework, schools and teachers develop school-specific and grade-specific curricula by adjusting them to the needs of specific grades and pupils. Pupils' achievements are described at the end of each two-year period according to a scale which comprises a minimum level, a basic level, and a higher level of achievement. Two documents (teaching and learning guidelines and curriculum content guidelines) define the required minimum subject content to be learnt by pupils in order to achieve the minimum level.

In **Sweden**, for all subjects, the main principle is that schools must provide pupils with the support needed to achieve the goals set for the school level in question. Schools decide what kind of extra support should be made available and how it should be provided (e.g. teacher, institution or company). Any support must be funded from the school's budget. The situation is similar in **Norway**. However, it is worth noting that in Sweden, in 2011, a new curriculum and syllabus for the compulsory school will be introduced where the goals and content are more distinct. One aim is to make it possible for schools to detect problems early in the student's school life and take appropriate action.

([143]) http://www.smm.lt/veikla/docs/sp/2010/3_LENTELE.pdf

The same applies to **the United Kingdom** (except Scotland) where according to a fundamental principle enshrined in regulations, education should be suitable for a child's age, ability and aptitude. In line with this, the structure of the curriculum is designed to accommodate differences in pupil ability and performance. The curriculum separates programme content from attainment targets which set out national standards for pupil attainment. These are defined, not in terms of progress through grade-related content, but in terms of a single scale spanning primary and secondary education. In **England**, for pupils whose attainments fall significantly below the expected levels at a particular stage, teachers may need to use the content of programmes of learning as a resource or to provide a context, in planning learning appropriate to the requirements of their pupils. In **Wales**, the national curriculum in science at Key Stages 2 to 4 states that: "Schools should use material in ways suitable for the learners' age, experience, understanding and prior achievement to engage them in the learning process. For learners working significantly below the expected levels at any key stage, schools should use the needs of the learner as a starting point and adapt the programmes of study accordingly" (DCELLS/Welsh Assembly Government 2008, p. 5). In **Northern Ireland**, the situation is similar.

In most countries, a general framework covering all subjects regulates the provision of support measures to low achievers at school. The types of activities to be provided and methods for identifying students with learning difficulties as well as the duration of any support are normally defined within the framework.

In the **Czech Republic**, the most common support measures for low achievers are tutor classes or any other form of tutoring which are organised and provided under the full responsibility of the school.

In **Spain**, all schools must include a 'diversity measures plan' in their educational plan. Attention to the diversity of educational needs of individual pupils is one of the basic principles of compulsory education. Schools are free to select and implement any measures established by national legislation, according to their pupils' needs. The measures might be, for example, minor curriculum modifications or flexible grouping.

In **France**, the procedures to detect learning difficulties in any subject include using the results of the national examinations in French and mathematics (primary years 2 and 4) and the portfolio designed for assessing the competences of the *Socle commun* as well as using assessment materials developed by teachers. It is the class teacher who provides support. In 2009/10, a specific in-service training course was organised for primary teachers. At both educational levels, support measures are based on the pupil's individual learning plan (*programme personnalisé de réussite educative* – PPRE) ([144]). This programme is designed to address the needs of a pupil who is at the risk of not achieving the objectives of the *Socle commun*. The programme is based on a small number of objectives, mainly in mathematics and French and, in rare cases, science subjects. The support measures comprise differentiated learning and small group instruction and sometimes ability grouping. Support usually lasts a few weeks but varies according to the pupil's difficulties and progress made. At the end of the programme, a project-based assessment allows a decision to be taken on the need for any additional support.

In **Greece**, ISCED level 2 students are offered a daily remedial teaching programme of one to three hours in the afternoon. Students are able to attend just one or all of the remedial support classes with a maximum of 15 hours per week. Likewise, a supplementary support teaching programme is provided to ISCED 3 students, with a maximum of 14 hours per week. The teaching of each subject does not last more than the hours allowed by the Curriculum. Support programmes at ISCED 2 and 3 involve small groups of students and a variety of teaching methods. They are provided either by the school's special unit teachers or by other supplementary specialist teachers.

In **Cyprus,** two frameworks exist for each educational level. At primary level, extra taught time is centrally allocated to each school by the Ministry of Education and Culture at the beginning of each school year. When low achievers are identified by schools, the extra taught time available to teachers is used to provide support to these pupils, through either one-to-one tutoring or tutoring in very small groups. As this support is offered during curriculum time, this means that they have to leave the class in order to attend the sessions. At secondary level, the Ministry of Education and

([144]) http://eduscol.education.fr/cid50680/les-programmes-personnalises-de-reussite-educative-ppre.html

Culture encourages teachers to use learning strategies such as differentiation, peer instruction, cooperative methods and inquiry-based activities to help low achievers individually or in groups. When providing support for low achievers, classes should not normally exceed 20 pupils; if this does happen, the class should be divided in half during the experimental investigation part of the science class.

In **Slovenia**, at ISCED level 2, supplementary lessons are provided in any individual subject by the subject teachers. Students with difficulties can attend a 45-minute lesson once a week in each science subject. Other common support measures implemented in the classroom are differentiated teaching and peer-assisted learning.

In the **United Kingdom** (**Scotland**), all pupils qualify for support. Strategies vary from school to school and are determined by teachers**.** Support might be provided through differentiated materials and ability groupings and is based on a staged intervention model. Teachers might be advised about strategies to support pupils within the classroom. In cases of more severe learning difficulties, support is provided either through a pupil support assistant or learning support teachers working co-operatively with the class teacher.

In **Liechtenstein**, as from the 2011/12 school year, assistant teachers will be in place at the *gymnasium* (ISCED 3) to support teachers in science subjects, for example, to help conduct experiments.

Five countries have launched a nation-wide programme for tackling low achievement at school in all subjects including science.

In **Bulgaria**, within the national programme 'Caring for Each Pupil', the module called 'Providing further training for pupils to improve their level of achievement' covers all subjects in general education, including natural sciences. Classes are conducted in school at the end of the school day.

In **Germany**, the Resolution of the Standing Conference of 4 March 2010 is a national strategy which aims to accompany pupils in all subjects during a period of several years in order to avoid school failure and promote the acquisition of qualifications.

In **Spain**, in line with the principle of diversity, there are three types of provision available in schools at ISCED 2. Firstly, 'specific educational compensation groups' are intended to help combat early school drop-out by tailoring educational provision for pupils under 16 who, due to socio-educational disadvantages or a migrant background, significantly lag behind in most curriculum subjects, including natural sciences. Secondly, the 'curriculum diversification programme' is aimed at pupils who need support in order to achieve the learning objectives of general compulsory secondary education and so obtain the corresponding qualification. The educational authorities of the Autonomous Communities are responsible for establishing the curriculum of these programmes – one of the two specific areas is in the field of science and technology. Thirdly, there are other educational compensation measures which are directed at students in the last two years of compulsory education who, in addition to being significantly behind in most subjects, have negative attitudes to school and serious adjustment problems, or have had delayed or irregular schooling. Among the subjects concerned are natural sciences, and biology, physics and chemistry.

In **France**, there is a national policy initiative in certain areas of the country for addressing social and educational issues. Its aim is to tackle the impact of social, economic and cultural inequalities by improving education in areas where school performance is very low. This priority education policy involves connecting some primary and lower secondary schools into 'Ambition and Success Networks' (*Réseaux ambition réussite* – RAR). The number of schools involved is 254 lower secondary schools and 1 750 primary schools ([145]). A RAR comprises a lower secondary school and its neighbouring primary and pre-primary schools. A four- or five-year contract between the *Académie* (regional education authority) and the RAR guarantees increased funding and supervision. Schools are responsible for implementing coherent projects and improving teaching as well as evaluating results. Although the RAR tackles low achievement in general without devoting particular attention to science, there are some specific projects which do seek

([145]) http://www.gouvernement.fr/gouvernement/l-education-prioritaire-et-les-reseaux-ambition-reussite to improve achievement in this subject, particularly through the inquiry-based learning approach ([146]). Two interesting examples can be mentioned: the project *'J'aime les sciences*' (I like science) implemented in April 2010 by the *RAR* Pierre Mendès-France in La Rochelle (Poitiers *Académie*) ([147]) and the project 'How to Develop Inquiry-based Learning in Sciences' carried out by the *RAR* Gérard Philipe in Paris ([148]).

In **Poland**, a national set of regulations targeted at talented pupils as well as pupils with learning and/or social difficulties was adopted in 2010. The new regulations emphasise the use of a personalised approach intended to foster the development of pupils' talents and interests, as well as to support pupils and students in overcoming any learning problems. The measures also limit the use of grade retention. Important changes introduced are that support measures are to be provided at the request of either pupils or their parents and the limit on the minimum number of pupils participating in the classes has been abolished. The forms of support recommended to be used most frequently are remedial and compensation classes. These new regulations are being implemented gradually, first at ISCED levels 1 and 2 in 2010/11 and then at ISCED level 3 in 2011/12.

Finally, only two countries reported specific initiatives for supporting low achievers in science subjects.

In **France**, as part of projects carried out between 2006 and 2009 support for low achievers in science branches was provided by a secondary school in Besançon in the last two grades of ISCED 3 ([149]). The support included an assessment through a 'confidence-based contract' *(évaluation sur contrat de confiance)*. The objectives were to identify problems in each subject, to personalise the monitoring of students by structuring the support given, re-motivating them for learning and restoring their self-confidence. Four subject-teachers were involved in this initiative to support 158 students in five classes. The time devoted to each pupil was two-and-a-half to five hours per week.

Poland referred to three different projects covered by the action on 'Equalising educational chances for pupils with limited access to education and reducing differences in quality of education' within the Human Capital Investment Operational Programme under ESF funding. These three projects refer specifically to support for science education.

One of the projects 'Everybody has a Chance of Success' ([150]) (run in a primary school located in the county of West-Pomerania since the first half of 2010) comprises remedial science classes for pupils enrolled at the fifth grade. These classes consist of activities to develop and preserve science skills in such as the use of a microscope, and the reinforcement of knowledge learned in science classes.

A second project 'Dreams to Realise – Equalising Educational Chances' has been running in a *gymnazjum* (ISCED 2) in Głogów between September 2009 and August 2011 ([151]). As part of the project additional remedial classes are held in chemistry and physics. Early results at the end of the first year show high levels of performance from students in science and chemistry school contests.

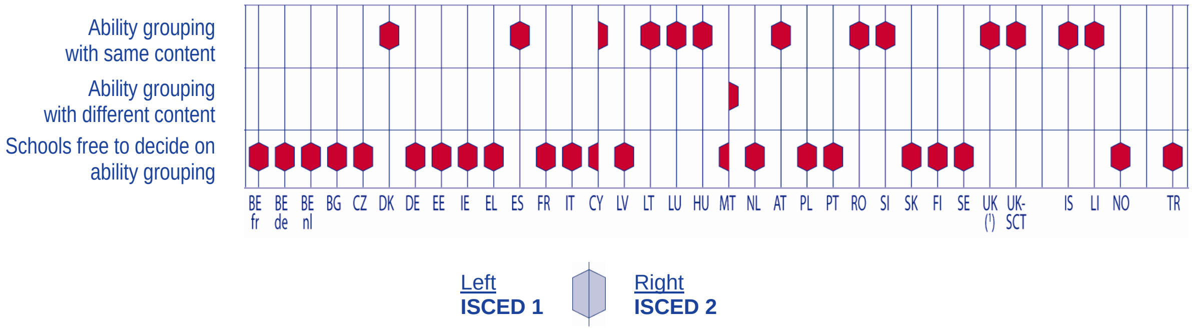
A similar project 'Raising Educational Achievements of ISCED 1 *Pupils' (Podnoszenie osiągnięć edukacyjnych uczniów szkół podstawowych województwa kujawsko-pomorskiego)* ([152]) has been carried out in the region of Kuyavia and Pomerania. This project is run by the regional Centre of Teacher Education in Bydgoszcz and involves 225 primary schools in the region with a total number of 7 000 pupils at 6th grade. Remedial and compensation classes in science are provided in these schools for these pupils.

([146]) http://www.educationprioritaire.education.fr/index.php?id=43
([147]) http://ww2.ac-poitiers.fr/ed_prio/spip.php?article94
([148]) http://www.ac-paris.fr/portail/jcms/p1_137774/rar-g-philipe-un-projet-au-service-de-l-acquisition-de-la-demarche-experimentale?cid=p1_90908andportal=piapp1_64152
([149]) http://www.ac-besancon.fr/spip.php?article1317
([150]) http://www.sp6.szkola.pl/pages/program_gosiak.pdf
([151]) http://www.marzenia.gim5.glogow.pl/viewpage.php?page_id=1
([152]) http://projektunijny.cen.bydgoszcz.pl/index.php?option=com_content&view=article&id=3&Itemid=7

Ability grouping

Ability grouping is the practice of grouping students by their ability or achievement level so that the ability levels of a class are more uniform. Various forms of ability grouping are used in schools, the most common being ability grouping within a single class (Slavin, 1987). Although ability grouping might also be used with pupils and students with special educational needs, this type of provision is not taken into consideration in this section.

Figure 3.6: Within-class ability grouping in science subjects, as recommended in steering documents (ISCED 1 and 2), 2010/11



Source: Eurydice. UK (¹) = UK-ENG/WLS/NIR

Country specific note

United Kingdom: Ability grouping is not officially recommended but is often used in schools.

In the majority of countries, at both educational levels (ISCED 1 and 2), steering documents either prescribe or recommend that all students should be taught the same subject content irrespective of their level of ability. In Cyprus, this applies only to primary education; at lower secondary level, ability grouping is used and the same content is recommended for all students, but it is taught to different levels of difficulty. In Italy, although ability grouping is not recommended, Ministry of Education documents require personalised plans to be developed in order to take into account the learning rhythm of each student. Each school is free to decide how to implement the requirements.

Thirteen countries (including Cyprus as mentioned above) report that recommendations state that students should be grouped by ability level in science subjects but should be taught the same content at both ISCED levels 1 and 2.

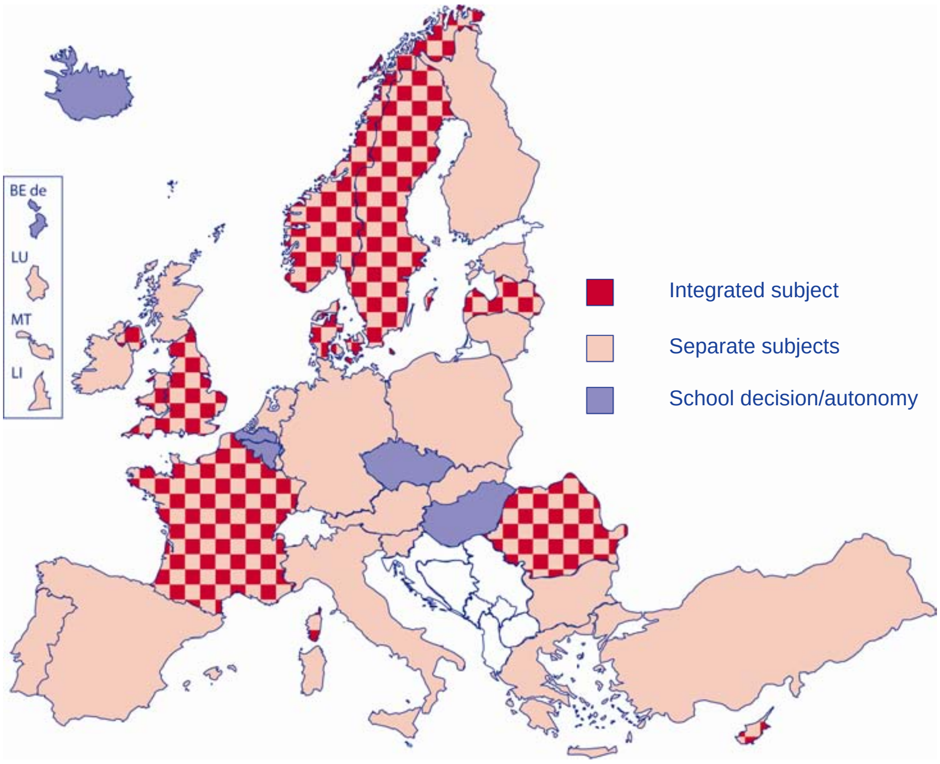
> In **Spain**, at ISCED 1 and 2, schools implement actions and programs designed to prevent and overcome minor learning difficulties by adjusting the mainstream curriculum without changing any of its basic elements, so that all pupils may achieve the general objectives for their year, stage and/or level. Support measures might affect the organisation of teaching or the curriculum. For instance, one of these measures allows schools to operate flexible grouping so that students may join groups appropriate to their ability level during the school year depending on their progress. Teachers can also make minor curriculum modifications for one or more pupils, such as variations in the timing of objectives or the teaching of subject content, and changes to teaching methods. Modifications such as these should not alter the basic elements of the curriculum (objectives, content and assessment criteria).

Malta is the only country where students may be grouped according to their ability level and be taught different subject content as a result. However, this practice is only carried out at ISCED level 2 and will be phased out in the coming years.

3.5. Organisation of science teaching in general upper secondary education

As with compulsory education, the way science subjects are taught in upper secondary education varies from country to country (see Figure 3.7). Moreover, since this level of education is often delivered in different branches/streams of education, different ways of organising science teaching may be found depending on the branch of school. As might be expected, there is less study of science in the branches focusing on arts and humanities than in the specialist science branches.

Figure 3.7: Science teaching in general upper secondary education, as recommended in steering documents (ISCED 3), 2010/11



Source: Eurydice.

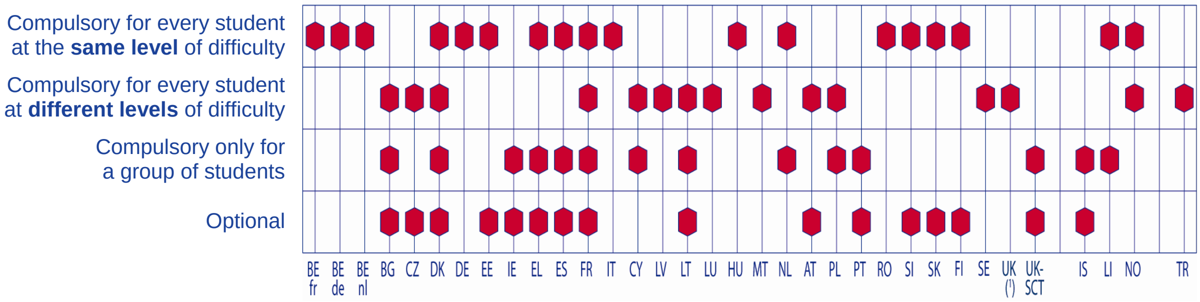
Country specific notes

Italy: The information only refers to the *Liceo* specialised in science education.
United Kingdom: In line with the new Key Stage 4 programmes of study, the new General Certificate of Secondary Education (GCSE) subject criteria in science subjects were published in 2009. Awarding bodies are currently developing subject specifications based on these criteria for teaching from 2011.

As shown in Figure 3.7, in almost all European countries or regions, national curricula for general upper secondary education consider science as separate subjects. In some countries (Denmark, France, Cyprus, Latvia, Romania, Sweden, the United Kingdom (England, Wales, Northern Ireland) and Norway), an integrated approach to science has also been adopted. For example, in France, under the *lycée* reform launched in 2010, the integrated optional course, *enseignement d'exploration,* has progressively been introduced in addition to separate science subjects. It contains some thematic areas related to science and aims to help students in their educational and career orientation. In Romania, the integrated approach to science teaching is practised only in some branches. In Cyprus and Norway, science is taught as an integrated subject only in the first grade of ISCED 3. Subsequently, it is delivered as separate subjects. In other countries, namely Belgium, the Czech Republic, Ireland (for the first grade), Hungary and Iceland, schools decide for themselves how to teach science. For example, in the Czech Republic, science is included in the national curriculum under the ‘People and nature’ thematic area, but each school is free to organise science education either as an integrated curriculum area or as separate subjects.

In almost all European countries, science subjects in the national curriculum are compulsory for all students at ISCED 3. Nevertheless, not all students are taught science at the same level of difficulty. It usually depends on grades and/or educational streams chosen by students (for more information on different subjects taught, see Table 2 in the annex).

Figure 3.8: Status of science subject(s) in upper secondary education (ISCED 3), as recommended in steering documents, 2010/11



Source: Eurydice.

UK (1) = UK-ENG/WLS/NIR

Country specific notes

Greece: Science subjects are compulsory for every student at the same level of difficulty only in the first grade of ISCED 3.
Spain: Optional subjects are regulated by the Autonomous Communities and schools, in accordance with the regulations established by the Ministry of Education, which stipulate that it is up to schools to programme their optional subjects according to students’ demands and taking into account their teaching staff.
Italy: The information refers to the *Liceo* specialised in science education.
Poland: Science education at basic level ends after the second grade of the three-year general upper secondary education programme. When science is taught at the extended level, it lasts throughout the entire period of upper secondary education.
Slovenia and Finland: In general, upper secondary education students have compulsory courses in biology, geography, physics and chemistry, but they can choose optional specialisation courses as well.
Slovakia: Science subjects are optional in the last grade of ISCED 3 for students who do not choose a science subject for the school leaving examination.

However, in several countries (for example, Denmark, Greece, Hungary, Liechtenstein and Norway), not every science subject is compulsory throughout all grades of ISCED 3. In Malta, at ISCED 3, all students must choose at least one subject from a series of science subjects but it may be at a different level of study.

In several cases (Bulgaria, the Czech Republic, Greece, France, Cyprus, Poland, Slovenia and the United Kingdom), science subjects are compulsory for every student only during the first years of upper secondary education. In some countries (Ireland, Austria, Portugal, the United Kingdom (Scotland), Liechtenstein and Iceland), these subjects are either compulsory only for certain students in specialist branches of general upper secondary education or considered as non-compulsory/optional.

3.6. Textbooks, teaching material and extra-curricular activities

The quality of science teaching is influenced not only by the choice of teaching approaches and appropriate subject content, but also by the types of teaching material used during lessons. Extra science activities organised outside normal curriculum time may also contribute to raising motivation and levels of achievement.

3.6.1. Textbooks and teaching material

In general, in all countries school textbooks have to comply with the educational aims requirements or recommendations set out in steering documents. Consequently, there are no specific guidelines for authors of science textbooks in any country. As with other subjects, teachers and schools at all levels of education are normally free to choose which textbooks they use, although they might be obliged to make their choice from an approved list drawn up by the ministry.

In Lithuania, a survey to examine the suitability of textbooks for the development of competences has been carried out. All sets of science textbooks published between 2004 and 2009 for grades five to eight have been examined. The survey report was published in November 2010 ([153]).

In Ireland, a revision of the syllabuses in the three main science subjects – physics, chemistry and biology – at ISCED 3 is currently under way. The reasons for undertaking the reform of these syllabuses include the need to bring the syllabuses into line with the ISCED 2 science syllabus introduced in 2003; the low take-up of the physical science subjects; and the need for an element of practical assessment in the final examination to complement the paper-based assessment. The main objectives of the reforms include re-drafting the syllabuses in terms of learning outcomes; introducing an inquiry-based approach to teaching and learning; establishing a valid and reliable model of practical assessment; introducing a greater emphasis on student attainment in the key skills of critical and creative thinking, information processing, communicating, being personally effective and working with others. An implementation date for the revised syllabuses has yet to be agreed.

In several countries, the development of science teaching materials is the subject of particular initiatives or forms part of specific science education promotion activities. Science centres, such as in Portugal and Norway, also provide teaching materials (for more information on science centres, see Chapter 2).

In **Norway**, the Ministry of Education and Research together with the Ministry of the Environment launched in 2008 'The Natural Satchel'. This package is rooted in the curricula for the common core subjects of natural science, social studies, food and health and physical education. It helps to foster curiosity and knowledge of natural phenomena, awareness of sustainable development and increased environmental commitment by pupils and teachers in primary and lower secondary school.

The **French** partnership *la Main à la pâte* is very much focused on the development of teaching materials to promote inquiry-based learning. The website gives free access to teaching units recommended for specific educational levels on a large variety of topics relating to natural sciences ([154]).

Similarly, the **German** version of the French *la Main à la pâte* project *(Sonnentaler)* provides material organised in the same form free of charge to teachers and schools ([155]).

([153]) http://mokomes5-8.pedagogika.lt/images/stories/Vadoveliu_analizes_failai/Vadoveliu%20tyrimo%20ataskaita%202011-01-14.pdf

([154]) http://lamap.inrp.fr/?Page_Id=2

([155]) www.sonnentaler.org

In **Latvia**, under the national programme Science and Mathematics ([156]), teacher support material (e-material, printed works, educational films) has been developed for secondary schools.

In the **United Kingdom**, the website created for the Triple Science Support Programme (introducing GCSE courses in physics, chemistry and biology) provides teaching material and allows practitioners to share ideas and resources, and to access knowledge and information.

European projects also provide guides on inquiry-based learning procedures as well as teaching resources in English, which can be downloaded free of charge. For example, inquiry-based science education was a primary objective of *Pollen* ([157]). The project focused on the creation of 12 Seed Cities throughout the European Union. (A Seed City is an 'educational territory' that supports primary science education.)

3.6.2. Extra-curricular activities

Extra-curricular activities are defined as activities designed for young people of school age which take place outside normal curriculum time. Some education systems or schools offer publicly-funded or publicly-subsidised activities during lunch breaks, after school, at weekends or in school holidays (EACEA/Eurydice, 2009a).

In less than half of European countries, central guidelines or specific recommendations encourage schools to provide extra-curricular activities in science. In seven countries, educational authorities recommend that schools offer science-related activities outside curriculum time. The most common aim in organising such activities is to supplement the science curriculum and help pupils to achieve the defined targets. This is the case in Estonia, Slovenia, Finland and Norway. In Belgium (German-speaking Community) and Turkey, where, as well as reinforcing what is taught in the classroom, extra-curricular activities provide an opportunity to promote inquiry-based learning approaches for students. In Lithuania, extra-curricular activities have a third aim which is to motivate students to learn science. In six other countries, guidelines and recommendations specify that existing extra-curricular activities in science should target specific students groups.

In **Spain**, extra-curricular activities are offered on a voluntary basis in publicly-funded schools and might be devoted to science-related content. In parallel, the Ministry of Education launched a Reinforcement, Guidance and Support Plan (*Programas de Refuerzo, Orientación y Apoyo* – PROA) ([158]). This plan aims at improving academic performance of students with learning difficulties by offering them additional extra-curricular activities and individualised support. The PROA also aims at supplementing the curriculum as well as helping pupils to achieve the curriculum targets defined.

In Bulgaria, the Czech Republic, Estonia and Lithuania, the projects and programmes providing extra-curricular activities in science are specifically designed for gifted and talented students (for more information, see Section 2.4).

Finally, in the Czech Republic and Spain, guidelines and recommendations on the provision of extra-curricular activities exist but they do not specify whether such activities should focus on science education. In Spain, where each Autonomous Community has developed its own legislation regulating the organisation of extra-curricular activities, any curriculum subjects might be covered as well as any areas not included in the normal curriculum.

Although in the majority of the countries no guidelines on extra-curricular activities exist, schools have the right to offer activities outside of curriculum time and might therefore decide to devote them to science subjects. Some countries mention examples of good practice in promoting science education

([156]) http://www.dzm.lv/
([157]) www.pollen-europa.net
([158]) http://www.educacion.es/educacion/comunidades-autonomas/programas-cooperacion/plan-proa.html

outside curriculum time. The most common activity reported is the science club. Provided during the mid-day break or after classes, these are devoted to fostering science literacy. Pupils and students develop research projects on topics which interest them. Science clubs are offered in France, Latvia, Malta, Austria, Poland, Portugal, Romania and the United Kingdom.

> In **Poland**, science classes are provided outside curriculum time within the programme 'Pupil Academy – Mathematical-scientific Projects in Lower Secondary Schools' *(Akademia uczniowska. Projekty matematyczno-przyrodnicze w gimnazjach)* ([159]) implemented by the Centre for Citizenship Education (CEO). The main aim of the programme is to promote laboratory methods in science subjects. Over 300 lower secondary schools in Poland will provide these extra-curricular science classes within school science clubs. The programme will involve ca. 35 000 students in the 2010/11 school year.
>
> In the **United Kingdom,** schools are free to run their own school science activities in ISCED 1 and 2. In addition, there are two separate initiatives within the framework of STEMNET. One in **England**, which is the programme After School Science and Engineering Clubs (ASSEC) which aims to inspire key stage 3 students aged 11 to 14 (ISCED 2) to learn and enjoy science and engineering. And the other in **Scotland**, a two-year project which established in 2008 STEM Clubs in some Scottish secondary schools and their feeder primaries. Clubs were established with a mix of pupils from the last ISCED 1 grade and the first ISCED 2 grade. They provide opportunities for additional science-based activities to help strengthen science learning in the classroom. The project was maintained in 2010/11.

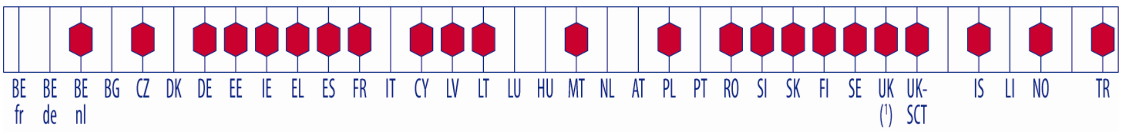
Only Spain provides extra-curricular activities aimed at raising girls' motivation to study sciences.

> Schools and teachers organise extra-curricular science activities with the specific intention of motivating girls to participate in science and encouraging them to pursue science careers. As an example, in the Autonomous Community of Galicia, schools invite female scholars belonging to the University Women's Seminar (*Seminario Mulleres e Universidad* – SMU) from the University of Santiago de Compostela to share their experiences as women participating in science research with ISCED 3 students ([160]).

3.7. Curriculum reform

Several countries are currently, or have recently been engaged in curriculum reform; between 2005 and 2011 more than half of European countries either reformed their primary and secondary education curricula or started planning reforms. Most of these reforms were triggered by the need to bring curricula (including science subjects) more closely in line with the EU key competences approach (Council Recommendations, 2006).

Figure 3.9: Countries engaged in curriculum reform, including science (ISCED 1-3), between 2005-2011



Source: Eurydice.

UK (¹) = UK-ENG/WLS/NIR

Some of these reforms are, however, particularly focused on science. Very comprehensive reform of the science curriculum has been taking place in Estonia, Latvia and Poland covering all three levels of education.

([159]) http://www.ceo.org.pl/portal/b_au_o_programie

([160]) http://193.144.91.54/smu/

In **Estonia**, the new national curriculum for ISCED 1, 2 and 3 was approved by the government in January 2010. It emphasises inquiry-based science education and recommends that special attention is paid to foster positive attitudes towards mathematics, science and technology. Topics for all science subjects (general science, biology, chemistry, physics) incorporate a list of practical activities, laboratory work, and guidelines for their implementation. The main goals in renewing the curriculum were to promote students' scientific and technological literacy, to modernise curriculum content, to reduce students' study load, and to include student-directed approaches and active learning methods. Additional opportunities for using ICT are also indicated. The learning outcomes are formulated more specifically, which provides a good basis for the development of materials for teachers and students. More emphasis has been put on the development of students' personal motivation and the implementation of active learning methods. A very important change has also been the opportunity to divide classes into smaller groups in science lessons. The new national curriculum for upper secondary schools states that schools have to develop their fields of study (altogether 3 fields of study should be developed by each school); one of the fields must be focused on science and technology and provide compulsory and optional courses. The new curricula will be implemented from the start of the 2011/12 academic year.

In **Latvia**, the national programme for the development of the science and mathematics curriculum for upper secondary education was implemented with financial support from the European Union in the period from 2005 to 2008. As a result of the project, all secondary schools received new, modern study materials for chemistry, biology, physics, mathematics and sciences for grades 10 to 12. Secondary school students have been studying science and mathematics according to the new standards since the 2008/09 school year.

In developing the new curriculum, project experts have tried to change the philosophy of education in schools: they have tried to move away from imparting knowledge towards the learning of skills; from the acquisition of scientific knowledge and algorithms towards students' own discoveries and skills; from the student as a passive participant of the teaching-learning process towards the student as an active participant; and from the teacher as a source of knowledge towards the teacher as a consultant. One of the results of the project is the implementation of a contemporary curriculum which meets the demands of the modern world in grades 10-12 in biology, chemistry, physics and natural sciences.

The reforms for ISCED 3 are in the implementation phase; ISCED 2 (grades 7 to 9) reforms are still in the pilot phase. The analyses of the results of the pilot phase as well as the monitoring system are in preparation.

In **Poland,** the curricular reform in science subjects focused on teaching both practical skills (carrying out laboratory experiments and field work) and intellectual skills (cause and effect reasoning, deduction, processing and creation of information, etc.); restoring the significance of the laboratory method; providing greater differentiation between knowledge levels within the basic programmes at the third and fourth stages of education while maintaining their coherence; ensuring continuity in science teaching from ISCED 1 to ISCED 3 while retaining proper levels of knowledge and skills and using suitable teaching methods at each stage. The core curriculum includes European recommendations for science teaching at ISCED level 2 and is intended to motivate, evoke interest and provide students with skills for further study of these subjects and everyday life. In 2010, the Central Examination Board announced a reformulation of the lower secondary school leaving exam for 2011/12, in which the science part (geography, biology, chemistry, and physics) has been separated from the previously combined mathematics and science part.

Belgium (Flemish Community), Greece, and Cyprus are also currently undergoing important reorganisations of their science curricula.

In **Belgium** (**Flemish Community**), the Department of Education organised a survey in 2005 to find out to what extent pupils in primary education obtain the final objectives in the learning area 'world orientation'. In 2006, a similar survey was organised for biology at lower secondary level. The results of both surveys triggered a quality debate between all stakeholders on these final objectives. Consequently, changes have been made in the first stage of secondary education. The final objectives for biology have been expanded with a number of objectives for physics and some approaches to chemistry. They were brought into force on the 1st September 2010. Improved science literacy was the basic underlying principle. In the next few years an update of the final objectives for natural sciences in the second and third stages of secondary education is planned as a sequel to the changes that have already taken place in the first stage.

In **Greece**, in 2009/10 the Ministry of Education, Lifelong Learning and Religious Affairs set up committees which limited the material to be taught and prepared new teaching materials for various subjects including sciences. The intention has been to avoid repetition and ensure improved coordination between the different grades. The Ministry of Education also announced radical changes to curricula and systematic in-service training for teachers with a view to optimising the quality of the education offered as well as providing better continuity between ISCED levels 1 and 2.

In **Ireland**, a major review of the whole curriculum is underway for ISCED level 2. It is proposed to make science one of four compulsory core subjects. Currently science is not compulsory though it is taken in the final examination by close to 90 % of the cohort.

In **Cyprus**, within the framework of a broader educational reform introducing the concept of key competences, the main changes in the new science curriculum relate to the modernisation of content. This includes the use of real everyday life situations as a tool and object of study, relating scientific skills to the development of pupils' key-competences and to the requirements for democratic citizenship, promoting problem solving and the use of ICT. Increased attention has also been paid to incorporate everyday life scenarios into assessment. The changes involve ISCED levels 1 and 2. Staff training and the piloting of material is currently in progress, with the gradual implementation of the new curricula scheduled to commence at the end of 2011.

Slightly earlier reforms in the Czech Republic, Spain and the United Kingdom focused on the introduction of wider curriculum reforms and special school leaving examinations in science (UK).

In 2007, curriculum reform in the **Czech Republic** allowed different models of science education to be implemented according to the needs of students and schools. Science education is rooted in the area of 'People and nature' ('People and their world' at the first stage of basic school (ISCED 1)); schools may draw on this area to form specific subjects, either integrated or separate. This represents an opportunity to create a variety of compulsory and optional subjects and to use projects and other educational activities; however, the expected educational outcomes laid down in the curriculum must be met.

In **Spain**, in 2006, the most significant curriculum (apart from the introduction of key competences in compulsory education) changes affected ISCED 3: the introduction of the new compulsory subject 'Science for the contemporary world' (first year of Baccalaureate) for all students was a development highlighting that scientific culture is also part of basic literacy. The subject 'Geology' in the last year of ISCED 3 (12th grade) was replaced by 'Earth and environmental sciences', covering the content of both disciplines.

In the **United Kingdom**, since 2007/08, the curriculum and the examinations system have been revised including increasing young people's entitlement to separate science GCSE courses and reducing the factual content of the curriculum to allow for more engaging and innovative teaching during ISCED 2 and 3. For example, in England, there is now a new non-statutory entitlement to triple science (biology, physics and chemistry) teaching at GCSE for those who reach at least level 6 in science at Key Stage 3 (the expected level of performance at age 14). The Learning and Skills Network (LSN) Triple Science Community has developed a generic programme to help all schools plan, develop and implement triple science; it will provide more intensive support to a small number of schools in need of additional assistance.

A similar development can now be observed in Sweden and Norway. In **Sweden**, a trial project with upper secondary programmes focusing on mathematics and natural science – 'top competence education' – has started and will be evaluated. A new type of upper secondary school, with differentiated subject content for different programs, will start in 2012 and support development in various subjects, including sciences.

In **Norway**, two new subjects 'Technology and theory of research' and 'Geosciences' have been introduced into the natural science and mathematics branch of upper secondary education.

Discussions on innovative science teaching have been held in Italy; and in Malta, a national plan for science education is currently being drafted.

In **Italy**, a study on the use of innovative methods in science teaching has been recently proposed by the Ministry and the Berlinguer Group. The study was initiated by a workshop held in Rome in 2010 which was followed by an online discussion between experts in the field with a view to developing proposals for innovative teaching methods in science, including the use of new technology. The proposals are expected at the end of 2011 and will apply to ISCED levels 1, 2 and 3.

In **Malta**, within the framework of the new science education strategy, the proposed curriculum reforms touch upon a greater emphasis on primary science education in terms of both quantity and quality of teaching; an improved hands-on approach at ISCED level 1 and an integrated approach to science in ISCED level 2.

Summary

From the available data it would appear that science education begins with one general, integrated subject in all European countries. Science is taught this way throughout the entire period of primary education almost everywhere, and continues in this vein for one to two years in lower secondary education, generally lasting six to eight years in all. In six education systems, science is taught as an integrated subject throughout lower secondary as well as primary education. Generally, science as an integrated subject is called simply 'science' or by a name referring to the world, environment or technology.

By the end of lower secondary education, therefore, in the majority of countries, science teaching starts to be split into the separate subjects of biology, chemistry and physics. However, many countries continue to emphasise the links between different science subjects, with steering documents often highlighting the connections between subjects and encouraging teachers to apply cross-curricular approaches whenever possible.

In order to raise levels of motivation and interest in science, an emphasis on students' real life experiences and discussion of societal or philosophical aspects of science is considered useful. In European countries, the most commonly recommended context-based issues are related to contemporary societal issues. Environmental concerns and the application of scientific achievements to everyday life are recommended for discussion in science lessons in almost all European countries. The more abstract issues relating to scientific method, the nature of science or the production of scientific knowledge tend to be reserved for the teaching of science as separate subjects, which correspond to the later school years in most European countries.

The activities recommended for primary level science frequently encompass collaborative, hands-on experimental and project work and occasionally more abstract pursuits such as debates on issues concerning science and society but these are more usually mentioned with respect to higher school levels. Overall, however, European countries' steering documents seem to allow for various types of active, participatory inquiry approaches from primary level onwards.

There are no specific policies to support low achievers in science in any European country. By and large, support for students in science is covered by countries' general support framework for pupils experiencing difficulties in any subject. Countries report very few science-specific initiatives at school level. The most common types of support are differentiated teaching, one-to-one tuition, peer-assisted learning, tutoring and ability grouping. Small learning support groups are usually offered outside normal teaching hours. In the majority of countries, in-class ability grouping is not applied in science subjects at either primary or lower secondary level. In the countries where ability grouping exists, steering documents recommend the same subject content for all ability levels but this should be taught to different levels of difficulty.

As with compulsory education, sciences at upper secondary level (ISCED 3), might be taught as separate subjects or, alternatively, be grouped as an integrated area of the curriculum. The vast majority of European countries adopt a separate subject approach. However, in six countries, integrated science teaching exists alongside the separate subject approach. In some countries, schools are free to decide for themselves how to teach science.

In the majority of countries science subjects are compulsory for every student at ISCED 3. Nevertheless, in a large number of countries, science teaching is organised according to streams and educational pathways chosen by students. In consequence, not all students are taught science at the same level of difficulty and/or throughout all grades of ISCED 3. In a few countries, science subjects are available and students may choose them as an optional subject.

There are no specific guidelines for authors/publishers of science textbooks or teaching materials, however, they usually comply with the requirements/recommendations in steering documents. Teaching materials are often produced as part of science promotion activities involving partnerships and/or science centres.

The organisation of extra-curricular activities is the responsibility of schools in most countries. In the few countries where education authorities provide recommendations on extra-curricular activities, it is usually with a view to supplementing the curriculum and thereby helping to raise pupil achievement. Science clubs where students can develop small research projects are examples of good practice in several countries.

There have been general curriculum reforms at different levels of education in more than half of European countries during the last six years. These reforms have, of course, also affected the science curriculum. In many countries, the main impetus for these reforms was a desire to conform to the European key competences approach.

CHAPTER 4: STUDENT ASSESSMENT IN SCIENCE

Introduction

Student assessment takes many different forms and serves a number of different functions. Whatever form it takes it is always closely connected with the curriculum and with the processes of teaching and learning. This chapter, which is divided into three main sections, describes the main features of the assessment process for science in European countries.

The first section presents a brief overview of the research issues surrounding student assessment and, in particular, assessment in science. The second section provides a comparative analysis of the main features of student assessment in science at different levels of education. It examines the assessment (formative and/or summative) of students' knowledge and skills by teachers in the classroom and presents an overview of assessment guidelines for primary and secondary science teachers. The recommended methods and/or approaches for assessing various science-related skills are then described. Finally, the support provided to help teachers plan and organise the assessment process is examined.

The third section describes the issues related to national standardised testing in science at primary, lower and upper secondary levels of education. It describes the arrangements for standardised tests in science in terms of frequency and timing and examines the purposes of the tests as well as their scope and content (specific subjects included). Finally, the chapter concludes with data from the TIMSS 2007 international survey on assessment practices for science subjects in schools in Europe.

4.1. Student assessment in science: a review of the academic literature

'Assessment' is a term used to refer to judgements of students' work. More precisely, it is defined as a process 'characterised as a cycle involving elicitation of evidence, which, when interpreted appropriately, may lead to action, which in turn, can yield further evidence and so on' (Wiliam & Black 1996, p. 537).

According to the purposes it serves, assessment is usually referred to as being 'formative' or 'summative'. Summative assessment is the more traditional form of assessment. It refers to 'the type of assessment used at the end of a term, course, or program for purposes of grading, certification, and evaluation of progress' (Bloom et al. 1971, p. 117).

The concept of formative assessment is more recent. It was first used by Scriven (1967) in relation to the improvement of the curriculum and teaching methods. It emphasises the role played by classroom assessment in improving the learning-teaching process and, eventually, students' learning outcomes. Systematically undertaken, formative assessment is 'useful in the process of curriculum construction, teaching, and learning for the purpose of improving any of these three processes' (Bloom et al. 1971, p. 117).

With the increasing number of standardised national and international assessments in science, as well as in other subjects, a new body of research has recently been developed on assessment for accountability purposes. These assessments take place in a broad context where changes in practice and in policy are driven by holding people accountable for achieving national educational aims or the desired reforms (National Research Council, 1999).

4.1.1. Summative assessment: towards alternative assessments to test a wider range of skills

Over the last few years, research on student assessment in science subjects for summative purposes has been mainly concerned with developing assessments for a wide range of science-related skills. In parallel, it has also focused on the development of different assessment tasks and formats such as performance assessment, concept maps, portfolios, etc. The main issues underpinning these recent developments relate to the quality of summative assessment, especially its validity and reliability (Bell 2007, p. 981).

Assessing process skills in science such as observing, measuring, experimenting, inquiring, is indeed a particular challenging task. Not only due to the technical difficulties in assessing such skills, but also because of the way science education is sometimes seen as only being concerned with the development of scientific knowledge and concepts (Harlen 1999, p. 130). It is therefore crucially important to be clear about what exactly teachers must teach and, consequently, what they need to assess (Gott & Duggan, 2002). Recent research specifically addresses how to test a wide range of science-related skills.

Some evidence suggests that performing investigations is largely a holistic task. Breaking it down into separate skills in order to assess it more easily might therefore completely miss the essence of the work, which requires integrated skills interacting with one another (Matthews and McKenna, 2005). Using computer simulations might be one way to overcome this pitfall, as they allow teachers to test complete investigations. Gott and Duggan (2002), however, consider that it is still debatable whether an electronic device can really measure all the abilities needed to perform investigations. Nevertheless, these authors agree that it is useful to consider the use of computers as an additional assessment tool.

Practical work is not assessed in isolation, but in specific contexts and in relation to particular topics. These contextual and content-related elements influence student performance, although the extent to which they do so is still a matter of debate. One way of reducing such biases is to use different tasks for different topics. This option, however, leads to other difficulties such as the length of the test, which should remain reasonable. At all events, assessing practical work definitely raises the issue of test reliability as student results may depend on the topic addressed by the tests (Harlen, 1999; Gott and Duggan, 2002). This is of particular importance in cases where assessment is conducted for summative purposes: when test results are used to determine students' further study or career options, care should be taken that the results are not dependent on the context in which the practical work is assessed (Harlen, 1999).

Using written tasks to assess practical investigations can help overcome some difficulties as more items can be tested in a reasonable period of time. These tasks, however, raise the issue of validity (Harlen, 1999). Several studies show differences in student performance in the area of practical investigations, depending on whether a practical assessment mode or a written assessment mode is used. It is suggested that written tasks measure something different to practical assessment (Gott & Duggan 2002, p. 198).

Research on alternative forms of assessment such as performance assessment, portfolios, concept maps, interviews, etc. has been carried out with a view to find new ways of assessing wider ranges of science skills and knowledge and increasing assessment validity (Bell, 2007).

According to Ruiz-Primo and Shavelson (1996a), science **performance assessment** is 'a combination of (a) a task that poses a meaningful problem and whose solution requires the use of concrete materials that react to the actions taken by the student;(b) a format for the student's response; and (c) a scoring system that involves judging not only the right answer, but also the reasonableness of the procedure used to carry out the task' (1996a; p. 1046).

However, the authors call for going beyond the rhetoric about performance assessment to develop a 'performance assessment knowledge base and technology'.

They define **concept mapping** as an assessment tool which comprises:

(a) 'a task that elicits evidence bearing on a student's knowledge structure in a domain;

(b) a format for the student's response; and

(c) a scoring system by which the student's concept map can be evaluated accurately and consistently' (Ruiz-Primo and Shavelson 1996b, p. 569).

For Bell (2007) though, the use of scoring systems, raises concerns about validity and reliability.

Collins (1992, p. 453) defines **portfolios** as 'a container of collected evidence with a purpose. Evidence is documentation that can be used by one person or groups of persons to infer another person's knowledge, skill, and/or disposition'. In this context too, the scoring methods require careful scrutiny (Bell, 2007). In a review of Canadian research on the use of portfolios, Anderson and Bachor (1998) point to three reasons that might explain the decreasing use of portfolios as students move up grades: greater subject specialisation, an increasing number of students per teacher and a growing emphasis on getting marks to report student achievement to stakeholders outside the classroom, such as parents. However, portfolios as an assessment tool offer advantages such as increasing students' responsibility for their own learning and being more in phase with a learner-centred curriculum.

4.1.2. Formative assessment: the need to train teachers to use it effectively

Learner-teacher interactions are at the core of formative assessment (Bell, 2007). It is during teaching-learning activities that formative assessment is performed. As a consequence, this form of assessment is an integral part of teaching (Harlen and James, 1997). Some authors (Duschl and Gitomer, 1997; Ruiz-Primo and Furtak, 2006) use the term 'assessment conversation' to refer to these teacher-learner dialogues taking place every day in the normal course of teaching/learning activities.

Feedback or dialogue between teachers and learners are regarded as an essential element of formative assessment (Black and Wiliam, 1998a; Gipps, 1994; Ramaprasad, 1983). Giving feedback to pupils is not just about giving them information about the gap existing between what they have achieved and the reference level, it is also about using that information to alter the gap (Ramaprasad, 1983).

Black and Wiliam (1998a; 1998b) show that formative assessment improves learning. To be really effective, however, it should be designed and administered in such way that immediate feedback can be given to learners and teachers (Ayala, 2008). Furthermore, it is a complex, highly skilled task (Torrance & Pryor, 1998). Curriculum and assessment specialists cannot expect teachers to use formative assessment effectively in their classroom without proper training. For example, although able to bring out pupils' understanding of scientific concepts taught in a lesson, teachers do not necessarily use this information to take students further in their learning. Ayala (2008, p. 320) suggests that teachers define a 'learning trajectory' for each teaching unit when they develop formal formative assessment. This should help them see more clearly what they need to know about students' understanding of a particular topic before carrying on with their teaching. More generally, one of the important goals of professional development should be to help teachers reconceptualise the role of assessment in their teaching, 'linking formative assessments to overall goals' (Ayala 2008, p. 316).

4.1.3. The continuum to summative assessment

There is no need for teachers to develop two distinctive assessment systems, one for formative purposes and the other for summative purposes. Although it is acknowledged that tensions will always exist when the same assessment is used for both purposes, some suggest moving away from the formative and summative dichotomy (Wiliam and Black, 1996; Taras, 2005). According to Taras (2005, p. 476), 'a false separation has been created between summative and formative assessment. The separation has been self-destructive and self-defeating'.

Wiliam and Black (1996) call for more research to investigate common ground between formative and summative functions of assessment, which they consider rather as the two extremes of a same continuum. The same evidence collected could serve both purposes on condition that the elicitation evidence is separated from its interpretation within the assessment process. In other words, instead of aggregating formative assessment marks to produce summative assessment results, teachers should go back to the original evidence collected for formative assessment. Then, the collected data should be reinterpreted with a view to carrying out summative assessment.

4.1.4. Assessment for accountability purposes

In many countries, large-scale standardised assessments (see Section 4.3), both at national and international levels, are used to monitor student attainment and feed education stakeholders with relevant information to improve education systems. Such tests may be divided into two main categories according to the purposes they serve. The first category comprises tests administered mainly for certification purposes, they summarise the attainment of pupils and students at the end of a particular stage of education and may have a significant impact on an individual's progression/transition within the education system or their access to the workplace. The results of the tests are used as the basis for the award of certificates to individual pupils/students, or for making important decisions regarding streaming, progression from one school year to the next, or final grading. The second category relates to standardised assessment where the main objective is to evaluate schools and/or the education system as a whole. More specifically it provides a measure for school accountability and enables stakeholders to compare performance across schools. The results of these tests may be used in conjunction with other parameters such as indicators of the quality of teaching and the performance of teachers. They also serve as pointers to the overall effectiveness of education policies and practices and provide evidence of whether or not improvements have occurred in a particular school or at system level ([161]).

In a relatively small number of countries, there may be high stakes associated with student and school achievement, such as the threat to shut down a school if performance is consistently poor. In many more countries, however, assessment leads some teachers and schools to behave as if there were equally high stakes as they wish to avoid being stigmatised for having low performance (OECD, 2010d). This trend does not only affect science education, but also other key curriculum areas such as mathematics or reading literacy. Britton and Schneider (2007) give an overview of the main issues involved in such assessments.

Firstly, curriculum subjects that are externally tested usually benefit from particular attention from schools and teachers, which proves to be very positive. However, the focus tends to be on the test content rather than on curriculum standards or objectives. For example, what is not tested might not get teachers' full attention or might not be taught at all.

([161]) National Testing of Pupils in Europe: Objectives, Organisation and Use of Results. Eurydice 2009.

Secondly, large scale standardised assessments rely very much on multiple-choice questions and short-answer-type items to elicit evidence of students' knowledge and skills. These assessment modes certainly help to save time, covering more scientific domains and making scoring easier and less costly. However, they usually fail to assess the wide range of skills students need to be truly successful in science.

Finally, if standardised large scale assessments aim to provide teachers and students with relevant feedback in order to raise student attainment, there should be some congruence between the curriculum and the assessment content. Some studies (Britton and Schneider, 2007) show, for example, that the skills and knowledge tested tend to be at a lower level than curriculum requirements.

4.2. Official guidance on assessment in science subjects

As highlighted in the recent research on the issues linked to the process of assessing science skills (see Section 4.1), assessment performed by teachers during teaching and learning activities is a particularly challenging task. This section therefore explores whether any guidelines or other types of support are provided for teachers in European countries.

4.2.1. Guidelines for teachers

In the majority of European countries, pupil/student assessment in the classroom is regulated by official guidelines which usually set out the basic principles of assessment, including general aims and sometimes a range of recommended approaches and/or methods. Other aspects of assessment, such as possible grading for students, criteria for their progression through school, etc., may also be included. Although, in a large number of these countries, schools and/or teachers have substantial autonomy in determining the basis and choosing the criteria on which their students will be assessed, this freedom is often limited and/or exercised within a specific educational framework which entails compliance with the general conditions included in official guidelines ([162]).

Assessment guidelines may take the form of a general framework for the whole assessment process, irrespective of the subject concerned, or they may be specific to each subject (or subject area) within the curriculum. In both cases, they are established by central level authorities and are intended to reflect and support the objectives and/or learning outcomes associated with the curriculum.

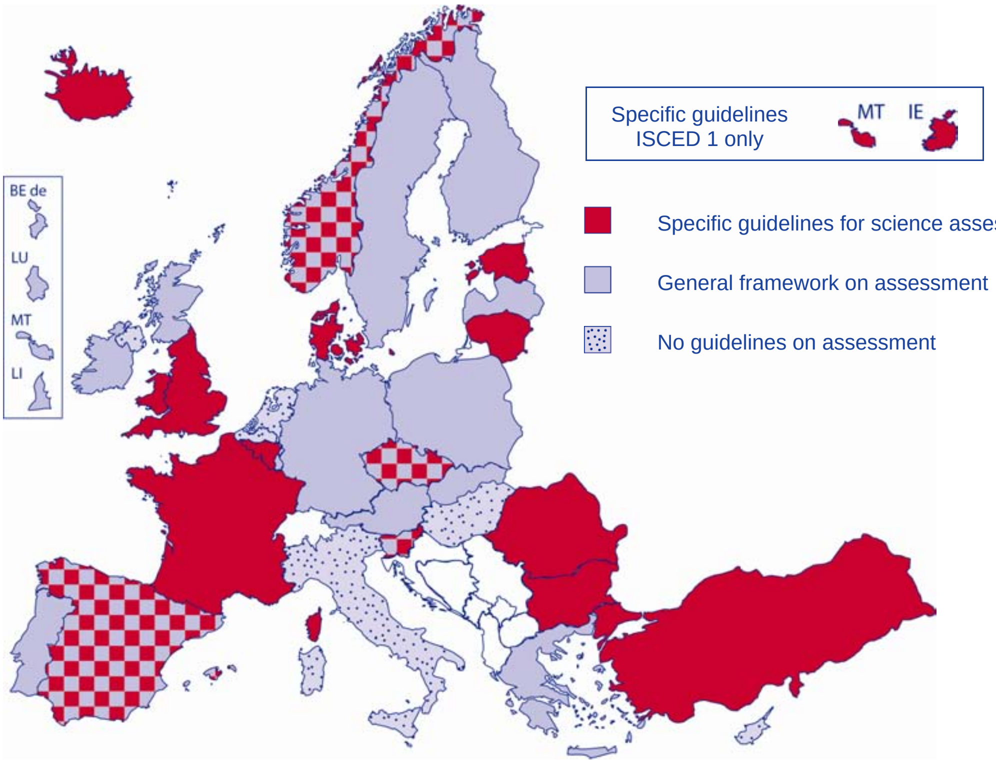
In half of the European countries examined, there are specific guidelines for the assessment of students' knowledge and skills in science for both primary and lower secondary education. Ireland and Malta are the only exceptions; they have specific guidelines only for primary level.

Other countries have only a general assessment framework which usually focuses on the aims of assessment, elements to be included, and the conditions and procedures that teachers and schools must take into account when developing their own assessment procedures.

Some countries or regions have either very few or no centrally set guidelines on student assessment. In Belgium (Flemish Community) and the Netherlands, for example, where school curricula only provide teaching and learning objectives, teachers monitor progress through classroom assessment based on students' individual development plans. In Hungary, only a general recommendation on assessment is set down in the Public Education Act; specific assessment procedures are regulated through schools' local curricula.

([162]) For more information, see: *Levels of Autonomy and Responsibilities of Teachers in Europe*, Eurydice 2009.

Figure 4.1: Guidelines on assessment in science (ISCED 1 and 2), 2010/11



Source: Eurydice.

In the Czech Republic, Estonia (since 2011), Spain, Slovenia and Norway, specific guidelines on assessment in science exist alongside general requirements for student assessment.

In the **Czech Republic**, the 'Manual for the development of schools' educational programmes for basic education' ([163]) sets down the rules to be followed by teachers and schools when developing the assessment criteria and methods for use within their own programmes of study. In addition, publications issued by the Institute for Information on Education ([164]) following international survey results include also different approaches and methods for student assessment in science at ISCED 1 and 2.

In **Estonia**, the National Curriculum for Basic Schools (ISCED 1 and 2) includes general guidelines on assessment as well assessment criteria for each subject of the curriculum, including science subjects. Guidelines for individual subjects are also available in virtual classrooms for teachers ([165]).

In **Spain**, the 2006 *Ley Orgánica de Educación* (LOE) and the Royal Decrees on the National Core Curriculum for primary and lower secondary education ([166]) include some very general guidelines on assessment. Similarly, the assessment criteria for each curriculum subject, including science subjects, are stipulated in the Royal Decrees. However, the Autonomous Communities also issue guidelines for teachers on assessment methods and techniques, as well as criteria which correspond with their own curricula.

([163]) 'Manuál pro tvorbu školních vzdělávacích programů v základním vzdělávání'. http://www.vuppraha.cz/wp-content/uploads/2010/01/manual_kSVP_ZV.pdf
([164]) www.csicr.cz
([165]) http://www.oppekava.ee
([166]) http://www.boe.es/boe/dias/2006/12/08/pdfs/A43053-43102.pdf
http://www.boe.es/boe/dias/2007/01/05/pdfs/A00677-00773.pdf

In **Slovenia**, the key guidelines are included in the curricula and other relevant documents. Guidelines for individual subjects are issued by the National Education Institute and are also available in virtual classrooms where all relevant documents for teachers are published ([167]).

The official recommendations on assessment (whether or not they are specific to science) are usually included in national curricula, manuals for teachers and/or special legislation. However, some countries have developed an overall national approach or assessment strategy.

In the **United Kingdom (England)**, a structured national approach to pupil assessment, called Assessing Pupils' Progress (APP) ([168]), was developed by the Qualifications and Curriculum Development Agency (QCDA). There is specific APP guidance for science. It is a voluntary approach to pupil tracking and it is for the school to decide if they want to use it or not. There are no plans to make APP statutory.

In the **United Kingdom (Scotland)**, the Strategic Framework for Assessment was made available in 2009 as part of the Government's strategy on how to create an effective assessment system for the Curriculum for Excellence ([169]).

In some countries, there are also other 'alternative' sources of official guidelines on assessment. For example, in Latvia, assessment guidelines are included in the model curricula developed by the Ministry of Education and Science for each subject (including science) and conform to general and specific educational standards.

4.2.2. Recommended assessment methods

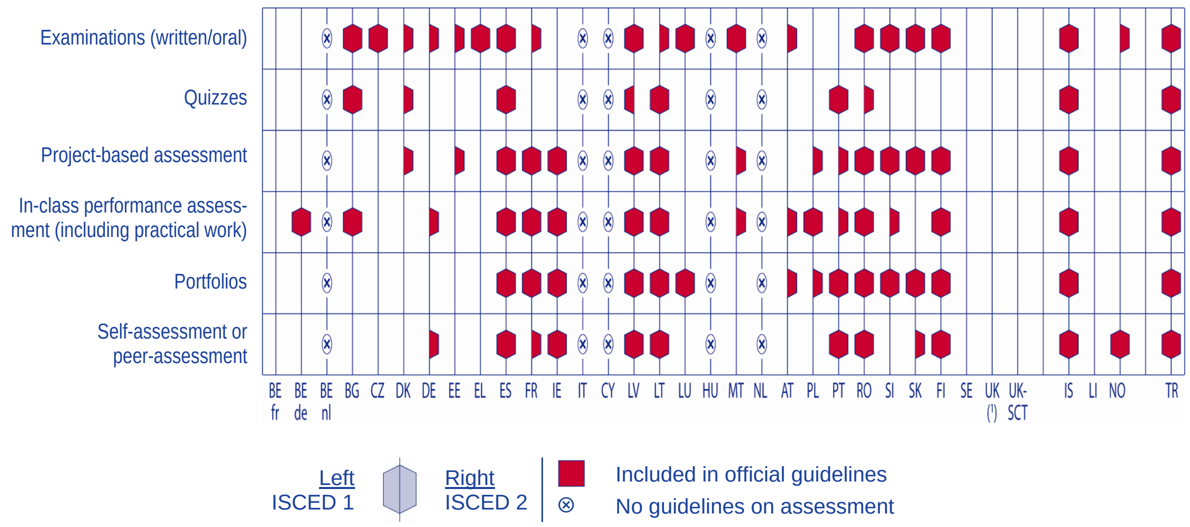
A variety of assessment methods and/or approaches are available for teachers to assess students' learning achievements in science in the classroom. The choice of method or approach will depend on the purpose of the assessment (formative and/or summative) as well as the type of skills to be assessed. The different methods listed here have been chosen as examples of either more traditional approaches or alternative methods which can be used to assess a wider range of skills. Other techniques may, of course, also be found in schools in Europe.

In the majority of European countries where either general or specific assessment guidelines are available to teachers, the use of at least one of the methods discussed below is explicitly recommended (Figure 4.2). The same assessment methods are mentioned in both types of guidelines. Furthermore, in some countries the specific guidelines for science do not recommend the use of any particular assessment methods.

In several countries, guidelines include references to all, or almost all of the methods to be used when assessing students, in particular at ISCED level 2. In France, for example, the recent implementation of the approach based on a set of common knowledge and core skills *(socle commun)*, has lead to a change in teachers' traditional assessment practices (mainly written tests) towards complex and diverse assessment techniques. In contrast, in Belgium (French Community), Sweden, the United Kingdom and Liechtenstein, the official guidelines do not recommend any particular methods of assessment, although teachers and schools may, of course, use any of the above methods in practice. In addition, other assessment methods and/or approaches (such as discussion, observation, interpretation of students' actions in different contexts, etc.) might be included within official documents. For example, in the United Kingdom, the assessment arrangements used in schools must take into account the full range and scope of the programmes of study as well as evidence of attainment in a variety of contexts including discussion and observation.

([167]) http://skupnost.sio.si
([168]) http://curriculum.qcda.gov.uk/key-stages-3-and-4/assessment/Assessing-pupils-progress/index.aspx
([169]) http://www.ltscotland.org.uk

Figure 4.2: Recommended assessment methods, according to official guidelines (ISCED 1 and 2), 2010/11



Source: Eurydice.

Explanatory note

Examinations (written/oral): Formal tests conducted under the responsibility of the teacher/school, involving answering written and/or oral questions for formative and/or summative purposes.

Quizzes: A more entertaining form of examination consisting of a questionnaire testing general or specific knowledge of pupils. The answers to the quiz are simple and contain one or a few words.

In-class performance assessment: Form of a testing that requires pupils and students to perform a task rather than select an answer from a ready-made list. For example, a student may be asked to solve problems or conduct research on an assigned topic during the process of teaching and learning. Teachers then judge the quality of their work based on an agreed set of criteria.

Project-based assessment: Involves carry out experiments or other investigative work that may be undertaken on a whole class basis or by pupils working individually or in small groups. Through this method, teachers can assess a wide range of knowledge and skills such as the understanding of concepts/theories, the ability to make scientific observations and the ability to collaborate.

Portfolios: Usually consist of collections of pupils' and students' work which demonstrate their skills. They may also be seen as a platform for self-expression.

Self-assessment (or peer assessment): Pupils and students participate in monitoring and regulating their own or each other's learning.

Country specific note

Spain: the cells ticked correspond to the different methods and evaluation techniques included in the curricula of some Autonomous Communities and the territory of the Ministry of Education (autonomous cities Ceuta and Melilla).

When looking at particular methods and approaches, written/oral examinations, assessing students' in-class performance and project-based work are recommended most often within official guidelines. Nevertheless, these are not always recommended for assessing pupils/students at both primary and lower secondary levels of education. In Denmark, Germany, Estonia, France, Lithuania, Austria and Norway, written/oral examinations are recommended only for lower secondary education. Ireland and Poland are the only countries where guidelines do not recommend written/oral examinations. However, in Poland, examinations can be held under certain conditions (i.e. for students who cannot be graded due to their high rate of absence or for those who do not acquire sufficient knowledge and skills to receive a positive final mark).

In-class performance and project-based work assessment are generally indicated for both primary and lower secondary levels. However, in a few countries, these methods are restricted to students at lower secondary level. It is interesting to add that in Poland, starting from 2011/12, project-based assessment will be a condition for completing lower secondary school. Students will have to present a group project, the mark for which will be added to the school-leaving certificate.

Fifteen European countries recommend that teachers use portfolios in primary and/or lower secondary education. In France, for example, the individual skills record *(livret personnel de compétences)* has two functions: to collect evidence to show that the common core skills have been mastered and to allow a student's progression to be followed throughout compulsory education. Nine countries make reference to quizzes.

In thirteen countries, official assessment guidelines recommend self-assessment (or peer assessment) during compulsory education.

Official guidelines do not include any recommendations for particular assessment methods to be applied in physics, chemistry or biology. However, some countries allow for different techniques to be used when assessing integrated and separate science subjects.

4.2.3. Support for teacher assessment in the classroom

Student assessment is a complex highly skilled task for which teachers need preparation during their initial education as well as part of their continuing professional development (see Chapter 5).

Most European countries or regions (except Belgium (Flemish Community), Italy, Hungary, Sweden, Iceland and Liechtenstein), provide a range of support to help teachers assess students in the classroom. In the majority of cases, the support provided relates to all subjects within the curriculum at primary and lower secondary levels and is not specific to science.

Websites and internet portals containing a range of teaching and assessment materials are the most common form of support provided for teachers.

> In the **Czech Republic**, a portal ([170]) that focuses on both the evaluation of education in general and assessment of performance in specific subjects has been developed within the project *Metodika II* (under the responsibility of the Education Research Institute and the National Institute of Technical and Vocational Education and co-financed by the European Social Fund and State Budget). The portal is structured according to curriculum areas, including science.
>
> **Latvia** provides specific help to teachers to carry out science assessment and this is directed at lower secondary education. These measures are included in the online project 'Science and Mathematics' ([171]).
>
> In **Poland**, the programme 'Formative Assessment' *(Ocenianie kształtujące)* carried out by the Centre for Citizenship Education *(Centrum Edukacji Obywatelskiej)* ([172]) constitutes the principal source of guidelines for teachers on how to assess pupils and students in order to support them in the learning process.
>
> In **Romania**, an online database of around 15 000 items for each subject in the 'mathematics and science' curriculum area is being developed for grades 9 to 11. Teachers will be able to use this database for assessment tests in class.
>
> In the **United Kingdom (Scotland)**, the National Assessment Resource (NAR) ([173]) is a new online education tool (available since 2010) to support teachers in developing their professional skills and their ability to make sound judgements about progress and achievement in assessment. NAR provides examples of a wide range of assessment approaches and evidence from across curriculum areas and stages.

Another way of supporting teachers with their assessment tasks is through the provision of special manuals. Publishers of textbooks and learning materials usually offer a teachers' handbook which includes supporting materials for assessment. In Estonia, a manual is published by the National examination and Qualification Centre.

([170]) www.rvp.cz
([171]) dzm.lv
([172]) http://www.ceo.org.pl/
([173]) http://www.ltscotland.org.uk/learningteachingandassessment/assessment/supportmaterials/nar/index.asp

In the Netherlands, support material is available for schools to help them design their own examinations. CITO, the central testing organisation ([174]), provides examples of examination questions to schools but a charge is made for this service.

A combination of the above support measures is available for teachers in most countries.

4.3. Standardised examinations/tests in science subjects

Although classroom assessment in science has a number of important advantages, its results are not readily comparable. In order to obtain standardised data on student performance, national tests have been developed by a large number of European countries.

For the purpose of this study, standard examinations/tests have been defined as an assessment instrument carried out under the authority of a national/centralised body which has standardised procedures for test content, administration, marking, and interpretation of results ([175]).

4.3.1. Arrangements for standardised assessment in science

In the majority of European countries and/or regions, pupils' and students' scientific knowledge and skills are assessed within standardised examinations/tests at least once during compulsory education (ISCED 1 and 2) and/or upper secondary education (ISCED 3).

Significant variations are apparent from one country to the next, both in the frequency with which individual students take national tests in science subjects and precisely when, in terms of school grade or age, such tests are conducted. These differences may reflect national policy agendas or priorities in education, while others may be partly attributable to the varied organisational structures of European education systems. As regards the latter factor, it should be borne in mind that some countries provide full-time compulsory education within a single structure, while others clearly distinguish between primary and lower secondary education.

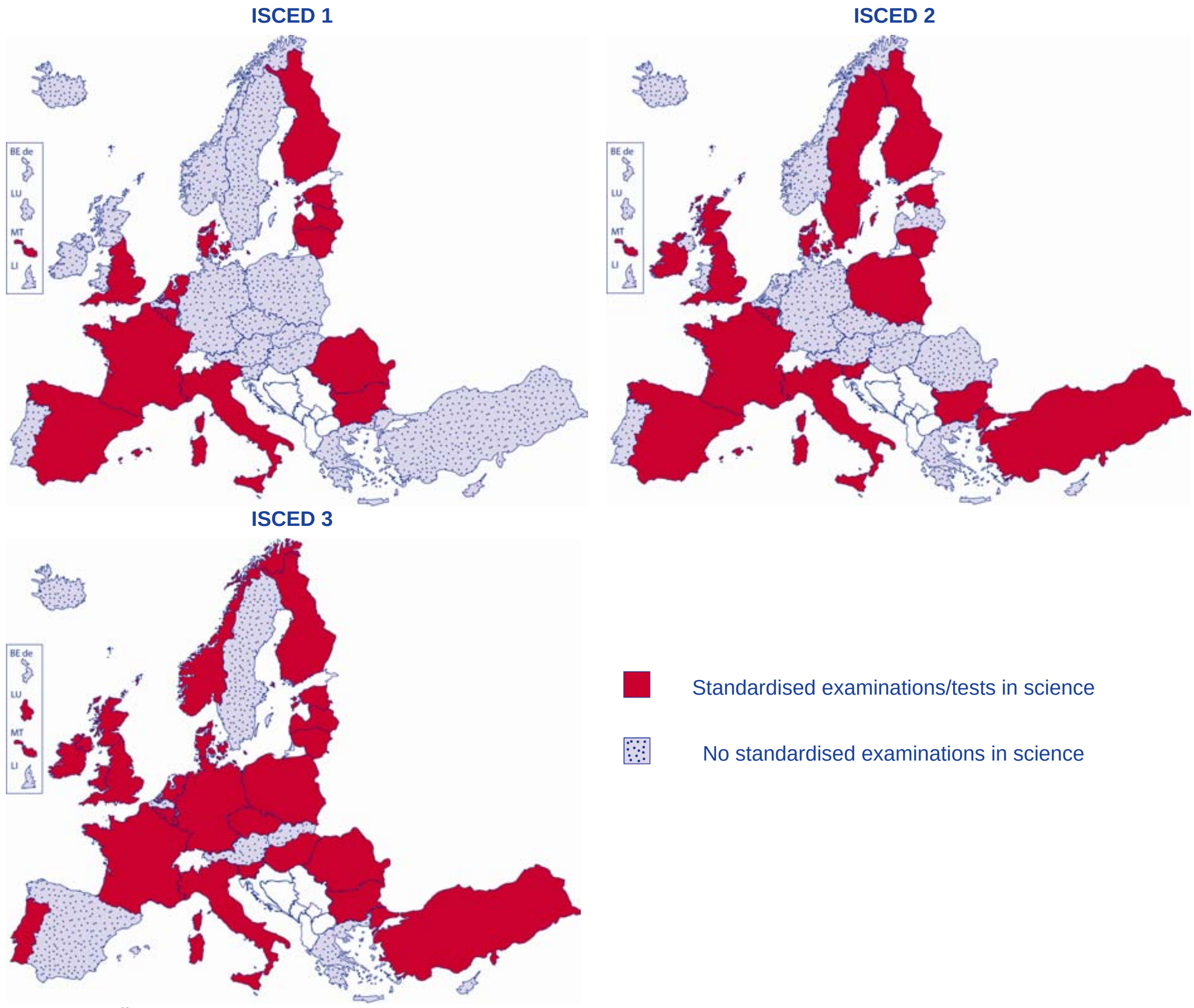
In nine European countries or regions, namely Belgium (French Community), Bulgaria, Denmark, France, Italy, Lithuania, Malta, Finland, and the United Kingdom (England), science tests are or may be held within the standardised assessment procedure in each school level (ISCED 1, 2 and 3). In contrast, in, the Czech Republic, Germany, Luxembourg, Hungary, Portugal, Sweden, the United Kingdom (Northern Ireland and Wales) and Norway, such assessment is conducted only at ISCED 3, except in Sweden, where standardised tests in science subjects are organised only at ISCED 2. In all other educational systems which have standardised tests, assessment is conducted in two of the three school levels.

In the majority of countries or regions, standardised tests in science are usually taken only once within a level of education, usually at the end of an educational stage. However, in some countries such as Belgium (French Community), Malta, United Kingdom (Scotland)), tests are conducted several times during general secondary education. In Malta, students must take standardised tests in science subjects annually throughout secondary education. Elsewhere, the subjects included in the standardised assessments rotate. In Estonia, for example, at the end of primary education, mother tongue and mathematics are tested every year but a third subject varies – science was last tested in 2010. In France, subjects are rotated on a five-year cycle at the end of primary and lower secondary education *(évaluation – bilan fin de l'école primaire et collège)*. Biology, chemistry and physics were last tested in 2007/08.

([174]) http://www.cito.com/en/about_cito.aspx
([175]) See National testing of Pupils in Europe, Eurydice 2009.

Where standardised examinations are conducted in order to assess student performance for the award of school certificates, they are generally taken at the end of an educational stage. In contrast, when the examinations are intended to monitor and evaluate schools and/or the educational system as a whole, these may also be organised at other key points during primary and secondary education. For example, in Belgium (French Community), in addition to the external assessment conducted for certification purposes at the end of primary education, there are also external evaluation examinations in the 2nd and the 5th year of primary education. Pupils' knowledge and skills are tested in mother tongue, mathematics and scientific 'initiation' *(éveil).* In Spain, there are General Diagnostic Evaluations of the education system, which include tests to evaluate pupils' science-related skills at the end of the 2nd cycle (grade 4) of primary education as well as at the end of the 2nd year (grade 8) of lower secondary education (ESO). At present, there is a plan to extend these tests to the 6th and 10th grades as well. In addition to these sample-based national tests, each Autonomous Community carries out an annual diagnostic evaluation of all students in their territory in the same grades.

Figure 4.3: Standardised examinations/tests in science (ISCED 1, 2 and 3), 2010/11



Source: Eurydice.

Explanatory note

Only standardised examinations or tests (or part of them) which cover integrated science subjects and/or the separate subjects of chemistry/biology/physics are considered here. Other forms of standardised assessment not including science are not included ([176]).

([176]) For more information on national testing across Europe, see *National Testing of Pupils in Europe: Objectives, Organisation and Use of Results*, Eurydice 2009.

Country specific notes

Czech Republic: Nationwide testing should be launched in 2013 for ISCED 1 and 2.
Austria: For biology, chemistry and physics test items are currently developed and pilot testing is under way.
Poland: At ISCED level 2, science and mathematics are now a common part of the external exam, but from 2012 onwards science will be separated from mathematics and will be a distinct part of the exam.
Slovenia: National tests are only partly standardised.
United Kingdom (ENG): Following the recommendation of the Expert Group on Assessment, standardised testing at key stage 2 has been discontinued. In 2009/10, national standards in science were monitored using sample schools.

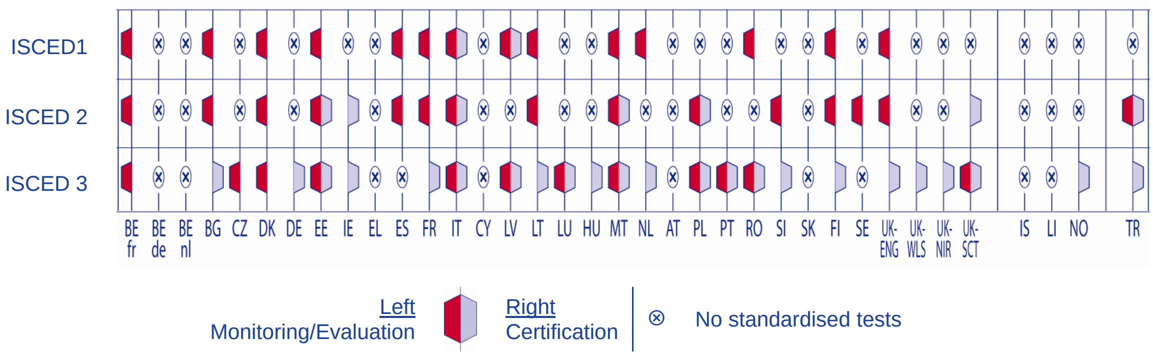
In general, standardised national assessment takes the form of a 'traditional' written and/or oral examination. In certain countries (e.g. Denmark and the Netherlands,), a system of computer-based testing has been developed. In France, the assessment of students' practical science skills is part of the standardised examination at the end of the scientific branch of general upper secondary education. The assessment lasts one hour and comprises a series of nationally standardised practical exercises on biological or geological problem-solving.

4.3.2. Purpose of standardised tests in science

The main purpose of the majority of the tests in science subjects conducted at upper secondary level is the award of certificates to students (see Figure 4.4). In around half of the countries concerned, the aim is to provide students with a final certificate which usually gives access to higher education. In contrast, where such tests are conducted during compulsory education (ISCED 1 and 2), in the majority of countries the evaluation and monitoring of individual schools and/or of the educational system as a whole are identified as the main purposes of testing.

Where standardised assessment takes place for certification purposes during compulsory schooling, it is usually in lower secondary (ISCED 2) rather than in primary education (ISCED 1).

Figure 4.4: Purpose of standardised tests in science (ISCED 1, 2 and 3), 2010/11



Country specific notes

United Kingdom: The tests conducted at ISCED 1 and 2 are mainly for summative purposes (i.e. not for certification or evaluation).
Turkey: At ISCED 2, the standardised tests for certification purposes are conducted only for access to free state boarding schools.

In secondary education (ISCED 2 and 3), standardised tests are often intended to serve both certification and evaluation purposes. However, in Belgium (French Community) and Turkey (except ISCED 1), two different standardised examinations with distinct purposes are used to measure student achievement. In primary education, the results of standardised tests serve both purposes only in Italy and Latvia.

4.3.3. Subjects covered and status

The precise content of standardised examinations/tests varies from country to country, and is determined by educational policy priorities, the level of education and the curriculum taught (see Chapter 3). As might be expected, where science is taught as an integrated subject (which is often the case at ISCED level 1 and/or 2, see Chapter 3), students' knowledge and skills are tested across the whole curriculum area. Where science is taught as separate subjects (chemistry/biology/physics) (often at ISCED 2 and/or 3), students take the corresponding separate examinations. However, in the Netherlands where schools can decide for themselves how to organise their science teaching, the standardised tests always take the form of separate subject tests. In the United Kingdom, there may be integrated or separate tests at ISCED 3. Science as an integrated subject and/or separate subjects is generally tested within a standardised assessment procedure at the same time as other subjects. At primary level, these subjects usually include mother tongue and mathematics. However, in secondary education, foreign languages, geography, health education and/or other subjects are also often examined. A large number of countries use a combination of compulsory and optional subjects, depending on the educational level and/or the type of school.

In **Bulgaria**, the 'man and nature' subject area is one of the subjects tested at the end of primary and lower secondary education and is compulsory for all pupils. State school-leaving examinations held at the end of upper secondary education include physics and astronomy, chemistry and environmental protection, and biology and health education but these are optional subjects.

In **Denmark**, depending on the type of education and stream chosen, students take both oral and written tests in biology, chemistry, physics at different levels of difficulty (A, B, C) at the end of general upper secondary education.

In **Estonia**, external testing at the end of primary education (mother tongue, mathematics and one other subject which is determined annually) is compulsory. Science was tested in 2002, 2003 and 2010. At the end of ISCED 2 (year 9) state examinations include tests in three subjects, of which the Estonian language and mathematics are compulsory. The third examination can be chosen from foreign languages, physics, chemistry, biology, history, geography and social studies. Examinations at the end of general upper secondary education include tests in five subjects, among which only the Estonian language is compulsory. The other examinations are chosen from mathematics, foreign languages, physics, chemistry, biology, history, geography and social studies.

In **Poland**, at the end of lower secondary education, exams consist of three parts (humanities, mathematics/science and language). The mathematics/science part covers maths, biology, chemistry, physics and geography. The external final upper secondary examinations include both compulsory and optional parts. The optional part involves examinations in one to six subjects (including biology, chemistry and physics), chosen by students and taken at basic or advanced level.

In **Romania**, sample tests at the end of primary education include mother tongue Romanian or mother tongue for the recognized national minorities (if the student belongs to a minority), maths and natural sciences. All of these are compulsory. The end of upper secondary education examination *(Baccalaureate)* includes an optional test in physics, biology or chemistry, depending on the profile and specialisation of the school, but excluding humanities and vocational schools.

In **Slovenia**, national assessment at the end of the single structure education (ISCED 2) includes tests in Slovenian (or Hungarian/Italian in ethnically mixed areas), mathematics, and a third subject determined annually by the Minister. Science subjects in the examinations at the end of upper secondary education are optional and can be chosen by students from the pool of natural sciences, including biology, chemistry and physics.

As illustrated by the examples above, depending on the country and the educational level concerned, integrated and/or separate science subject(s) may form part of the standardised testing process either as compulsory subjects (usually in primary and lower secondary education) or as optional subjects (usually at upper secondary level) (see Figure 4.5).

Figure 4.5: Status of science subjects within standardised examinations/tests at the end of upper secondary education (ISCED 3), 2010/11

BE fr	BE de	BE nl	BG	CZ	DK	DE	EE	IE	EL	ES	FR	IT	CY	LV	LT	LU	HU
◆	⊗	⊗	◆	◆	●	◆	◆	◆	⊗	⊗	⊗	◆	◆	◆	◆	●	◆
MT	**NL**	**AT**	**PL**	**PT**	**RO**	**SI**	**SK**	**FI**	**SE**	**UK-ENG**	**UK-WLS**	**UK-NIR**	**UK-SCT**	**IS**	**LI**	**NO**	**TR**
○	◆	⊗	◆	○	○	◆	⊗	◆	⊗	◆	◆	◆	◆	⊗	⊗	●	◆

⊗ No standardised tests ● Compulsory ○ Compulsory option ◆ Optional

Explanatory note

Compulsory subject: Science subjects are included in the examinations and are compulsory for all students.

Compulsory option: Science subjects are included in a pool of optional subjects but students are obliged to choose at least one subject from the pool.

Optional subject: Science subjects are included in a pool of optional subjects and students are free to choose them or not.

Country specific note

Austria: Ongoing pilot project on national testing.

Science subjects are compulsory for all students as part of the standardised testing process at the end of upper secondary education in only three European countries (Denmark, Luxembourg and Norway). In Malta, Portugal and Romania, students are obliged to take an examination in one optional science subject. In all other countries, students may choose biology, chemistry and/or physics as optional subjects from a wider pool of different subjects.

4.3.4. Current debate on standardised assessment in European countries

In some countries, there is an ongoing debate among policy-makers and other professionals in education about standardised assessment. For example, in Belgium (French Community), current debate focuses on the necessity for a greater harmonisation of subject content between the different school sectors (public, private grant-aided) as well as a clearer description of knowledge levels as a basis for external certification.

In Austria, the ongoing reform which aims to improve science education focuses on the development of standards and test items. Currently, new subject standards are being piloted. Priority has been given to the development of standards in German, mathematics and English but standards for science subjects (physics, chemistry, biology) are also being developed ([177]).

([177]) See: http://www.bifie.at/bildungsstandards

4.4. Assessment in science classes: TIMSS 2007 results

After considering the regulations and recommendations regarding science assessment in European countries, it is worthwhile looking at actual practices in schools using data from international surveys. TIMSS 2007 included several questions regarding the forms of science assessment used by teachers of students at the eighth grade (for more information on TIMSS, see Chapter 1). The survey explored how much emphasis science teachers gave to classroom tests, their own professional judgement or the results of national or regional achievements tests when monitoring students' progress in science. Data showed that the science teachers of eighth grade students put most emphasis on classroom tests (for example, teacher-designed or textbook tests). Teachers used classroom tests to some extent for nearly all students. In participating EU countries ([178]), on average, teachers reported putting major emphasis on classroom tests for 64 % of students and some emphasis for another 32 %. Teachers also reported using their professional judgment to some extent for most students. On average in participating EU countries, teachers reported putting major emphasis on their own judgement for 54 % of students and some emphasis for another 41 %. Yet, only moderate emphasis was put on national or regional achievement tests, with some emphasis for 37 % of students and little or no emphasis on this type of test for 34 % of students. Even fewer students had teachers who placed at least some emphasis on national or regional tests in the Czech Republic, Sweden, the United Kingdom (Scotland) and Norway (Martin, Mullis and Foy 2008, p. 334). In these countries either there are no national tests or the tests are based on a sample of students and therefore not all teachers have the opportunity to use the results of this method of assessment.

TIMSS 2007 also asked how often science teachers of eighth grade students gave science tests or examinations. The results showed that approximately half (49 %) of eighth-grade students were given science tests about once a month, on average in participating EU countries. About one-fifth (22 %) were given a science test or examination every two weeks (or more frequently). However, this varied considerably between countries (see Martin, Mullis and Foy 2008, p.335). In the Czech Republic, most students (82 %) were given a test at least every two weeks. In Hungary and Romania teachers also often reported giving science tests or examinations every two weeks or more (37 % and 45 % students respectively). There were also several countries where the majority of students were given science tests or examinations no more than a few times a year, including Malta (69 %), Slovenia (96 %), and Sweden (66 %).

This evidence shows the importance of classroom assessment in the countries surveyed and the prominent role teachers play in carrying this out. It therefore also indicates a potential need for guidelines and support for teachers in the area of assessment.

([178]) Here and elsewhere, the Eurydice calculated EU average refers only to the EU-27 countries which participated in the survey. It is a weighted average where the contribution of a country is proportional to its size.

Summary

Official guidelines on assessment take two main forms in European countries. Either they provide a general framework for the assessment process, irrespective of the subject concerned, or they are specific to science. In all cases, the main aim of these official documents is to reflect and support the objectives and/or learning outcomes associated with the curriculum. In half of the Eurydice network countries or regions, there are specific assessment guidelines for science. In some countries, few or no centrally set regulations/guidelines on student assessment exist. Instead, assessment procedures in these countries are regulated at local and/or school level or through classroom assessment managed by teachers according to students' individual development plans.

In general, assessment guidelines provide recommendations on the methods to be used by teachers when assessing student progress. Traditional written/oral examinations and students' in-class performance as well as project-based work are the assessment methods recommended most often. Significant differences exist between countries regarding the assessment methods recommended at particular levels of education. It is also interesting to note that the same methods appear in both general assessment guidelines and the guidelines specifically relating to science. There do not appear to be any forms of assessment recommended only for use in science subjects.

Almost all European countries provide various types of support for teachers in assessing students in the classroom. However, these types of support usually apply to assessment in general and relate to all subjects within the curriculum; they are not specific to science. The most widespread forms of support include the provision of teaching materials and information on assessment methods through official websites and internet portals, as well as teachers' manuals prepared by textbook publishers.

In the majority of the European countries and/or regions examined, pupils' and students' scientific knowledge and skills are assessed through standardised procedures at least once during their compulsory education (ISCED 1 and 2) and/or upper secondary education (ISCED 3). However, significant differences are apparent from one country to the next, both in the frequency with which individual students take national tests in science subjects and precisely when, in terms of school grade or age, such tests are conducted. In the majority of countries or regions, science subjects are tested at least once in two or three of the educational levels.

In almost all of the countries that conduct standardised tests in science in primary education, the purpose of the tests is to evaluate schools and/or the educational system as a whole. In lower secondary education, the situation is quite similar to primary education, but there are more countries which organise national testing in science with a view to awarding certificates to students. In upper secondary education, the awarding of certificates is the sole purpose of the majority of tests in science subjects.

Science as an integrated and/or separate curriculum subject is generally tested within the standardised assessment procedure at the same time as other subjects, usually alongside tests in the mother tongue and mathematics. While in primary and lower secondary education (ISCED 1 and 2) the science subjects tested within standardised assessment procedures are compulsory for all students, in upper secondary education (ISCED 3) science subjects are often optional.

CHAPTER 5: IMPROVING SCIENCE TEACHER EDUCATION

Introduction

Research into ways of improving the initial education and continuing professional development of science teachers is closely related to both common and unique strands. The field is complex since science teachers teach at different educational levels, are often educated in different science subjects, and belong to various cultures, both educationally and socially. Section 1 presents a review of the research literature across these dimensions and looks at the knowledge, skills and competences needed for teaching science, specific issues within science teacher education, and strategies for educating and developing science teachers. Section 2 provides an overview of national initiatives to improve the initial education and continuing professional development of science teachers which fall outside the framework of those already described in Chapter 2. Finally, Section 3 presents some results of a pilot field survey of teacher education institutions conducted by EACEA/Eurydice on current practices in the initial education of science and mathematics teachers.

5.1. Initial teacher education and continuing professional development for science teachers: A review of recent research results

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This review focuses on research published from 2006-2011 in major science education journals and relevant surveys and handbooks.

5.1.1. Necessary skills and competences for science teaching

To become a science teacher, as differentiated from teachers in other subjects, and to maintain professional skills, some science-specific competences are necessary. Science is characterised by modelling, i.e. the construction of copies of reality, often in an abstract or mathematical form, that accentuates specific features of reality. Other distinctive features of science are a specific epistemology or a way of acquiring knowledge often referred to as the 'Nature Of Science' (NOS), and its use of practical work (especially laboratory exercises) as well as other attributes. These skills and competences and the ability to teach these aspects of science must be a part of a science teacher's 'tool box'. In addition, general teacher competences such as learning through argumentation and teaching and using inquiry-based methods have their special relevance to science teaching. This is apparent when one considers the 'Professional Content Knowledge' (PCK) relevant to teaching science as conceptualized by Shulman (1986). This first section reviews research into these science-specific aspects of science teaching.

Modelling

Modelling is at the core of doing science and it is therefore important to design teacher education intervention focused on models and modelling. A recent Italian study showed that the knowledge about models and modelling of prospective teachers after the four- or five-year degree diploma is still rather poor and confused (Danusso, Testa & Vicentini, 2010). Specially designed courses with an emphasis on giving learning experiences in and materials for modelling have helped prospective teachers in engaging students in modelling practice (Kenyon, Davis & Hug, 2011). Valanides and Angeli (2008) have provided prospective primary school teachers with a module on computer modelling with great success. The programme effectively supported prospective teachers' first modelling experiences and enabled them to quickly build and test their models as well as reflect on their viability.

Nature of science

Akerson et al. (2009) show how scientific modelling can give a deeper understanding of the nature of science (NOS) and scientific inquiry processes. In a professional development programme focusing on scientific modelling, teachers improved their views of NOS and inquiry as they expanded their definitions of science from a knowledge-based orientation to a process-based one. Furthermore, an informed understanding of the NOS can be enhanced by the use of meta-cognitive strategies (Abd-El-Khalick and Akerson, 2009) and it seems that pre-service teachers who receive explicit instruction in the nature of science as a stand-alone topic are more able to apply their understanding of the nature of science appropriately to novel situations and issues than teachers learning within the context of a case such as for instance, climate change (Bell, Matkins & Gansneder, 2010).

Given the wide breadth of nature of science (NOS) concepts, short exposures during teacher education may not provide sufficient understanding to influence the science teaching behaviour of new teachers. Several studies have sought to increase experience with NOS and have proved successful in preparing prospective teachers for future inclusion of NOS issues in their teaching (Seung, Bryan and Butler, 2009; Lotter, Singer and Godley, 2009). Abd-El-Khalick and Akerson (2009) experienced similar success with the development of NOS understandings with prospective primary teachers using the meta-cognitive strategies of concept mapping, NOS ideas of peers and case studies.

Professional content knowledge

Little new research has been performed regarding the (controversial) relationship between science teachers' subject-matter knowledge and their teaching practice. Earlier research literature indicates that science teachers with a weak content background tend to avoid certain topics, or stick closely to their textbooks and to just asking lower-level questions (Van Driel and Abell, 2010). The relation is addressed in the concept of Professional Content Knowledge (PCK), as defined by Shulman (1986) as '…the ways of representing and formulating the subject that makes it comprehensible for others', i.e. the ability of knowing the content and being able to teach it in a way that makes it possible for students to learn.

A large number of recent studies deal with building teachers' PCK. Hume and Berry (2011) explore how student teachers can develop this through engaging in constructing their own content representation for new topics, and by investigating the development of PCK for prospective physics teachers. Sperandeo-Mineo et al. (2006) emphasise that this is a bi-directional process involving deepening knowledge of subject matter and increasing awareness of pedagogical issues. This process can be facilitated by the use of portfolios (Park & Oliver, 2008) and mentors taking the role of critical friends (Appleton, 2008). Nilsson (2008) and Loughran, Mulhall & Berry (2008) explore how different elements of PCK can be enhanced in science teacher education and they stress the importance of making PCK a concrete construct, for instance through discussing the issues surrounding an element of subject content (e.g. aspects students find difficult to learn) as well as specific ways of teaching that content (e.g. ways of engaging students with the content, vignettes of particular teaching and learning episodes, etc.).

Practical work

Relatively few studies have recently dealt with practical work in science teacher education. Nivalainen et al. (2010) reveal how prospective and in-service physics teachers see the challenges in laboratory work such as the limitations of facilities, an insufficient knowledge of physics, problems in understanding instructional approaches, and the general organization of practical work. Towndrow et al. (2010) examine the issues in the assessment of practical work in Hong Kong and Singapore. They found that some teachers focused on the technicalities of assessing practical work skills while others worked towards assessments that had the best interests of the students as their goal.

Inquiry teaching

Much research on practical work in science teacher practice has been subsumed by research into teachers' learning and use of inquiry processes. Inquiry is a huge area of research, and yet it is still without any consensus about what constitutes inquiry (Barrow, 2006). All learning is dependent on learners' pre-conditions and reflection, and prospective science teachers' capacity for teaching inquiry is dependent on their own inquiry experiences and their capacity to reflect on the challenges involved in implementing inquiry into their classrooms (Melville et al., 2008). In addition, teacher education programmes need to develop teachers' ability to critique, adapt, and design materials to make them more inquiry oriented (Duncan, Pilitsis & Piegaro, 2010). The importance of practicum experiences as a key determinant of prospective science teachers' emerging inquiry-based science views and practices is highlighted by Fazio et al. (2010). Widespread resistance to teach science through inquiry can be mitigated via an experiential learning strategy, labelled 'using yourself as a learning laboratory' (Spector, Burkett & Leard, 2007); i.e. through conducting systematic inquiry into one's own learning by recording, analyzing, and synthesizing data about one's own responses to all course events and communicating them to other student teachers. Scholarly descriptions of inquiry-based teacher questioning and video-based discourse analysis might develop an increased awareness of the social aspects of teacher questioning, resulting in an increase in teachers' referential questions (Oliveira, 2010). Whole models for using inquiry have been developed, such as the Inquiry-Application Instructional Model, but these models do not necessarily teach prospective science teachers all aspects of inquiry (Gunckel, 2011). It is tempting to conclude that it is not easy to prepare science teachers to foster learning through inquiry even for teacher education programmes designed to do so (Lustick, 2009).

Argumentation

Since argumentation and discourse are central to the work of scientists, their role in science teacher education is relevant since teachers need to emulate and facilitate both in their classrooms. In addition, both contribute to a pedagogically relevant socio-cultural framework for learning and can precipitate the active constructivism which can help students take ownership over their learning. Sadler (2006) describes a prospective teacher education course where the participants construct and evaluate arguments about scientific controversies, hereby realising the necessity of giving argumentation an instructional focus.

5.1.2. Strategies for initial teacher education and continuing professional development

The issue of cognitive conflicts

What teachers know about science content and pedagogical content knowledge both before they begin to teach and as they mature as teachers affects every programme of teachers' professional development (TPD) since they are the 'starting points' for participants. When teacher knowledge from either science studies or teaching experiences varies from research based perspectives, cognitive conflict for the teacher interacts with TPD. Attention to the issue of just what teachers think and know is important in planning and executing TPD. Vanessa Kind (2009) explored the effects of teacher's subject matter knowledge on their self-confidence by looking at their teaching within their science content area expertise and outside of it. Contrary to expectations, teachers were more competent outside their specialties than within them. When teaching less known content they more often relied on advice from experienced teachers and searched for useful ideas whereas in their strong science area they had a hard time choosing the most appropriate teaching content and strategies from the many in their repertoire.

Finding ways to reveal and understand the intuitive scientific ideas of teachers is useful in dealing with the issue of cognitive conflict which arises in science teacher education. One study of prospective teachers assessed the dependence upon a given context for a teacher's understanding of science content and the certainty that teachers have about any aspect of their science knowledge to understand cognitive positions and thereby more effectively address them in teacher education (Criado and García-Carmona, 2010). Another example of identification of primary teacher pre-conceptions found misconceptions similar to those of their pupils as well as a relationship between their personal understanding and the manner in which they explained scientific phenomena (Papageorgioua, Stamovlasis and Johnson, 2010). The correlation is a useful way to assess the efficacy of TPD in that, as this study found, when teachers' misconceptions are addressed their explanations in the classroom reveal their newly adjusted conceptions.

In turn, the issue of pupil pre-conceptions is also relevant to successful teaching. Susan Gomez-Zwiep (2008) set out to find out what primary teachers know about pupil science misconceptions and how they alter them. She found that while most teachers were well aware of their students' pre-conceptions they did not realize the importance they had to the success of their teaching. Realizing that mere awareness of the importance of pupil conceptions is not enough for teachers to change their teaching behaviour, Rose Pringle (2006) sought to teach prospective teachers how to identify pupil conceptions and to diagnostically use pedagogical strategies to influence them.

Self-efficacy

The use of the personal belief of self-efficacy (i.e.an individual's beliefs about their own abilities) both as an indicator of teacher confidence and as a measure of programme success has grown in recent years. This is particularly the case with prospective primary teacher education where researchers have used self-efficacy to trace confidence development during methods courses (Gunning and Mensah, 2011) and found effects of science content coursework and increases in self-efficacy (Hechter, 2011; Bleicher, 2007). One group of researchers found a positive correlation between initial teaching environments and self-efficacy scores taken three times during the first year of teaching (Andersen et al., 2007). Used to reveal the impact of professional development programmes, increases in self-efficacy have been positively correlated with increased uses of inquiry-based instruction (Lakshmanan, Heath, Perlmutter and Elder, 2011). While increases in self-efficacy during teacher education and professional development have commonly been found, the outcome expectations of teachers, which indicate how likely they think their efforts are to make a difference, have often not shown an increase (Lakshmanan, Heath, Perlmutter and Elder, 2011; Hechter 2011). Bandura (1997) links self-efficacy beliefs about how capable a teacher predicts they will be at performing a given task to the chances of their teaching actually making a difference to pupils. Whether results showing no changes in outcome expectations can be attributed to either realistic perceptions of school classrooms or inadequate experience with highly self-efficacious teaching would be worth further investigation. One study (Settlage, Southerland, Smith and Ceglie, 2009) casts some doubt on the utility of self-efficacy to assess programme outcomes due to findings of only small changes over a final year of teacher preparation.

Heightened interest has also produced new instrumentation for measuring self-efficacy as well as techniques for enhancing it during initial teacher education and professional development programmes. In an effort to more narrowly focus the most commonly used instrument for assessment, the Science Teacher Efficacy Beliefs Instrument (STEBI-B) (Enochs and Riggs, 1990), Smolleck, Zembal-Saul and Yoder (2006) developed and validated a test to measure self-efficacy for teaching science using inquiry methods. Others have sought to discover which methods have been most influential in self-efficacy changes (Brand and Wilkins, 2007; Bautista, 2011; Palmer, 2006; Yoon et al., 2006).

Research-based Teacher Professional Development

Andrew Lumpe (2007) notably began a synthesis of the research in teacher professional development (TPD) from the first half of the past decade with a call to stop conducting one-time workshop-based teacher development programmes. Their popularity is based on their efficiency not on their proven value. He reviewed and noted that recently expanded views of TPD including attention to school contexts, teacher beliefs, faculty support, classroom applications and leadership all had had some positive impacts on student learning, but that research beyond the science education community also offers useful ideas. He specifically suggests considering: effective feedback, cooperation, collegiality, practice-oriented staff development and cultures of shared beliefs and relationships (Marzano, 2003; Marzano, Waters & McNulty, 2005). He posits that all of these factors can best be used through the development of professional learning communities at the school level where the focus is on groups of teachers cooperatively applying innovative teaching methods in their classrooms, getting feedback from one another and from teacher educators, reflecting and evaluating their lessons and then adjusting their practice to accommodate these inputs (Lumpe, 2007). Formal workshops using this model can provide the basis and organizational impetus for initiating professional learning communities. Carla Johnson (2010) also provides support for a movement from short duration workshops which few teachers from one school may attend towards longer term school-based reform which can include the entire school community and consequently may be more likely to effect change. Such school-level effort utilises the effective feedback, cooperation, collegiality, practice-oriented staff development and cultures of shared beliefs and relationships which Marzano (2003) and Marzano, Waters & McNulty (2005) advocate.

Collegiality

Singer, Lotter, Feller and Gates (2011) tested Marzano's (2003) suggestion of practice-oriented staff development and cultures of shared beliefs and relationships through a programme aimed at ensuring that teachers brought inquiry-based teaching methods back from professional development into their classrooms by providing a situated learning environment to support the transfers. They had significantly positive results in enhancing the use of inquiry strategies and found that the institutional environment was an important factor. In an earlier study, Dresner and Worley (2006) identified the collegiality which Lumpe (2007) highlights, as the supporting mechanism which allows teachers to modify their methods. They considered collegiality among teachers as well as with scientists as helpful in sustaining modifications in teaching. Another expression of collegiality, mentoring and coaching, was explored by Zubrowski (2007) through the development and refinement of more effective 'tools' used by teacher partners for feedback and planning. Watson et al. (2007) confirmed the importance of collegiality in a programme to retrain teachers from other subjects over a six month period to teach physics. The adjustment for these teachers was difficult in many ways, yet those who were supported by experienced staff made the transition while others whose qualifications to teach science were never accepted by experienced teachers did not. Collegiality with research scientists has been found to have a positive effect on teaching science when they lead experiences with problem solving, although the potential continued benefits of researcher/teacher collegiality were not explored (Morrison & Estes, 2007). In a large scale study in the United States of the characteristics of research-based TPD where local school districts were partnered with science-related higher education institutions, Cormas and Barufaldi (2011) found that teachers developed more communication skills and knowledge of real world applications.

Lesson study and co-teaching

Researchers continue to investigate applications of lesson study in which teachers view and share insights into one another's lessons and make changes in iterative cycles. Roth et al. (2011) used video-based lesson analysis for a professional development programme whose aim was to help teachers analyse teaching and learning by closely examining practice through video. The results established connections between better student learning with teacher content knowledge, pedagogical content knowledge about student thinking and some teaching practices. In another innovative use of lesson study, teams of prospective primary school teachers designed and taught common lessons in three different classrooms with collective analysis and revision between each of the three applications of the lesson. Results showed notable improvements in both teaching and learning (Marble, 2007). A similar concept, co-teaching for prospective science teachers, was successfully explored as a model for collaborative learning by Scantlebury, Gallo-Fox and Wassell (2008). More recently, Milne et al. (2011) examined the benefits of co-teaching in university teacher education courses for prospective elementary and secondary students. Various roles and mutual reflection revealed expanded opportunities for the preparation of teachers.

Duration and focus of TPD

In concurrence with Lumpe's (2007) thesis that short-term TPD is less efficacious than longer term efforts, a number of studies have consciously employed longer term teacher development as an essential aspect of a programme. Johnson and Marx (2009) used such a sustained programme along with collaboration to influence urban science education. Not only did the participating teachers improve their effectiveness but they also began to positively change their school climate and classroom learning variables. Duration and attention to teacher needs were also paramount in a year-long study which had teachers guide the emphases of their programme and which found that such attention to teacher needs was an effective strategy (Lotter, Harwood & Bonner, 2006). Similarly, addressing the individual needs of prospective teachers through a process of 'tuning' teaching to students resulted in higher learning outcomes (Vogt & Rogalla, 2009). In an evaluation of a Cognitive-Affective Conceptual Change model, Ebert and Crippen (2010) made long-term professional development an essential component of their efforts to help teachers apply inquiry based teaching.

Tools for TPD

Several recent research studies have focused on tools to enhance TPD. Hudson and Ginns (2007) developed a construct-oriented instrument to track teachers during professional development. Through multiple samplings of teachers' self-perceptions, they found that the instrument was helpful in assessing progress towards course outcomes. Another way to achieve TPD formative assessment used teachers' journal reflections about both 'what' they learned and 'how' they learned it (Monet & Etkina, 2008). They discovered that teachers found it difficult to reflect on their learning, but those who knew how they reasoned from evidence had the highest learning as measured by various surveys and tests while those who could not explain about learning a concept had the smallest gains.

Evidence-based continuing professional development was achieved through the use of portfolio-construction as a means of generating professional dialogue and hence teacher learning (Harrison, Hofstein, Eylon and Simon, 2008). The portfolios also provided a means to tailor the TPD to individual needs and thereby increase the programme effects. Various overall models for TPD have been tested.

One example is that of Russell Tytler (2007) who introduced 'School Innovation in Science' as a model for working at the school level with science teams and teachers and providing a large amount of support for change.

Mentoring

The mentoring of new science teachers has recently been re-examined by Bradbury and Koballa (2007) who found that mentors gave more general rather than science specific pedagogical knowledge, offering, for example, little information about inquiry, the nature of science and scientific literacy. They suggest that teacher educators could influence the mentoring agendas towards better alignment with teacher education. Schneider (2008) suggests taking mentoring further back to prospective candidates so that experienced teachers begin guiding students during their education studies. She suggests that this would also provide an opportunity for educating the mentors to help them align with the teacher education programme. John Kenny (2010) tested the effectiveness of a similar partnership between prospective primary teachers and a classroom teacher where the students taught science lessons in the teacher's class and were supported in their reflections about the experiences. Findings indicated the approach built confidence among the prospective teachers and had benefits for the practicing teachers. Julie Luft (2009) explored the relative merits of four teacher induction programmes. She found that when prospective secondary teachers were engaged in science specific induction programmes, their use of science relevant methods such as investigations, were enhanced. Interestingly, the proximity of colleagues during the various programmes was found to be important to the well-being of the teachers. A cross-cultural team of researchers from Australia and the United States proposed a mentoring model for primary teachers' professional development (Koch and Appleton, 2007). This model was based on a socially constructed image of a science education mentor and when tested revealed successful components of the model, including help with understanding science content and the value of working with teacher predispositions.

Current societal problems and issues

Akcay and Yager (2010) investigated the use of current societal events and issues as curriculum organisers for initial teacher education. Students participated in selecting topics, establishing various perspectives on controversial issues and collaborations in problem solving. Results from a number of points of view suggest that this approach resulted in grounded instruction that situated science in the student's life experiences. Visser et al. (2010) described how a variety of content perspectives were the focus of a programme to promote multi-disciplinarity in science education. Innovatively, they put together parts of physics, chemistry, biology, mathematics and physical geography into a new multi-disciplinary subject for teacher professional development and identified five characteristics essential for such TPD: teachers should acquire new knowledge as part of the TPD; get to cooperate with peers; participate in a well-developed network with other teachers; be well prepared and organised for TPD lessons and be immersed in modules which are interesting both to them and to the students they teach.

Action research

Action research, in which teachers inquire into their teaching practice in order to improve it, is being used in various settings and with different elements as a continuing strategy for teacher professional development. However, current action research related to professional development is also addressing the problem of a perceived lack of rigor and scientific basis for its own value, resulting in reduced acceptance (Capobianco and Feldman, 2010). The recent goal then has been to increase the quality of action research and more fully tap into its potential to inform teacher practice. Karen Goodnough (2010) uses collaborative action research in the form of teacher inquiry groups to support classroom practice through knowledge generated by teachers. Another study using collaborative action research at the secondary level aimed at teaching role modification through collective negotiation (Subramaniam, 2010). The author found that those facilitating action research need to explain their theoretical perspective before working with teachers on research projects and to fully accept the teachers as fellow researchers.

Kimberly Lebak and Ron Tinsley (2010) applied a model which follows adult and transformative learning theory to action research with science teachers using video to facilitate weekly peer collaborative reflection sessions to identify goals for improvement. Results included altered pedagogical approaches from teacher centred to inquiry-based teaching.

5.2. Programmes and projects for improving science teachers' skills

As the analysis of science promotion strategies shows in Chapter 2, strengthening teacher competences is considered to be of particular importance in European countries. Where national strategic frameworks for the promotion of science education exist, they normally include the improvement of science teacher education as one of their objectives. France, Austria and the United Kingdom (Scotland), in particular, focus their attention on this issue.

Science promotion activities such as school partnerships often provide strong support for teacher professional development. The direct contact with applied research and additional resources provided by private companies or research institutions may be particularly beneficial. Good examples of this are the strong training component in the French programme *La main à la pâte* ([179]) as well as the Spanish *El CSIC – Consejo Superior de Investigaciones Científicas – en la Escuela* (The High Council for Scientific Research in Schools) ([180]).

Similarly, science centres and like institutions also contribute to teachers' informal learning and may give valuable advice to teachers. In several countries they provide targeted and formal CPD activities, such as in Ireland, Spain, France, Lithuania, Poland, Slovenia, Finland, Sweden, the United Kingdom and Norway. Further information on these kinds of activities can be found in Section 2.2.

The main focus of this section is, however, on initiatives for improving science teachers' knowledge and skills which fall outside the main body of promotional activities.

Nearly all countries report that specific activities for science teachers form part of the official continuing development programmes for serving teachers.

> For example, in **Sweden**, the programme for continuing professional development for teachers is the largest part of the 'Boost for Teachers' government initiative for raising the status of teachers. It covers the period 2007-2011. 30 000 teachers are able to take part in this initiative. The focus is on strengthening the competence of teachers in both the theory of their subject and educational methodology ([181]).

There are however only few national initiatives which focus on the initial education of prospective science teachers.

> In **Denmark**, within the new initial teacher education programme (2006), science *(naturfag)* became one of three core subjects worth 72 ECTS (along with mathematics and Danish). Students must choose one of these three subjects as their first specialisation. The intention was to underline the importance of these three subjects in the Danish primary and lower secondary school system. In 2010, a number of standard trials have been introduced in initial teacher education

([179]) See: http://lamap.inrp.fr/?Page_Id=1117
([180]) See: http://www.csic.es/web/guest/el-csic-en-la-escuela
([181]) See: http://www.skolverket.se/fortbildning_och_bidrag/lararfortbildning/in-english-1.110805

to make science more attractive as a specialisation for students. These standard trials involve introducing science (either directed towards primary school teaching or lower secondary school teaching) as minor subjects (36 ECTS). These minor subjects are chosen as the students' second or third specialisation. The introduction of science as a minor subject should encourage a broader range of students to take science as a specialisation, even if their main subject is Danish or mathematics. Preliminary results show an increasing interest in science as a specialisation. The trials will run until 2012. At that point, a decision will be made whether to extend the trial period, to stop the trials, or to fully implement the new system.

In Estonia, Greece, Cyprus and Latvia, training initiatives for prospective and serving teachers are linked to on-going curricular reforms (see Chapter 3).

In **Estonia**, linked to the curricular reform and its implementation in 2011, there are on-going discussions regarding science teachers' initial education. Greater focus is being put on training in education research for all concerned (teacher educators, teachers, members of professional organisations, etc.) including for science teachers ([182]).

In **Latvia,** as part of the current curriculum reforms, a teacher professional development programme is being developed for all science subjects by the National Education centre. The programme is module-based. The modules include general guidelines on contemporary science at school; multiple methods of teaching and learning; scientific inquiry in the laboratory; and use of ICT. The length of the programme is 54 hours for basic school teachers; 36 hours for secondary school teachers with experience; and 72 hours for upper secondary teachers. These training courses are being phased in until 2012. They are directed at all science subject teachers responsible for implementing the new curriculum. This programme is organised and financed as a part of the curriculum reform (see Chapter 3).

Hungary, Portugal and Slovenia have particular projects running to improve the teaching of practical science skills.

In **Hungary**, the main activities of the National Talent Programme ([183]) include supporting the continuing professional development of science teachers and talent development in the field of science education. Short training courses are offered to teachers and psychologists as well as to staff members of the talent network in schools, NGOs, etc. It is based on a network of a range of organisations such as schools and NGOs. The funding sources are from the European Union, national co-financing and the National Talent Fund financed from the central budget, the Labour Market Fund and private sector sources.

In **Portugal**, the national programme 'Experimental Science Work in Primary School' was conceived to develop primary school teachers' knowledge about different types of practical work and its role in science education. The aim is to implement these activities in the classroom with a teacher trainer coaching. School teachers learn about the educational relevance of different types of practical work, and how to deal with inquiry in primary school practices. Experimental work should be explored in classrooms according to a general problem-solving approach in order to develop pupils' critical thinking, argumentation skills, reasoning and basic science knowledge. The Programme has been funded by the Ministry of Education and European funds since the 2006/07 school year and will continue until 2010/11. Attendance is not compulsory.

The evaluation reports, carried out by the National Monitoring Commission and by an external team of experts, had referred to the following as strengths of the programme: professional, personal and social development of school teachers; pupils' learning improvement; quality of the training environment; good planning and organisation, high quality teaching resources/guides; close correlation with national curriculum issues.

In **Slovenia**, the project 'Development of Science Competences' ([184]) has been running since 2008 with the aim of developing and testing expert guidelines to raise the level of science literacy in schools. The objective is to develop

([182]) See: www.eduko.archimedes.ee/en

([183]) http://www.tehetsegprogram.hu/node/54

([184]) See: http://kompetence.uni-mb.si/oprojektu.html teaching strategies and approaches especially in those fields of natural sciences which might have a significant impact on society in the future. As part of the project, strategies, methods and techniques have been developed that will ensure a successful adaptation of scientific findings to school purposes and, at the same time, make natural sciences more popular among students. The partners in this project are the University of Maribor and the University of Ljubljana together with a large number of basic and upper secondary schools and kindergartens. Planned outcomes are: new teaching guidelines for natural sciences; didactical materials/models developed for specific scientific disciplines; testing materials/models in schools; teacher training workshops.

Upper secondary school teachers, basic school teachers and kindergarten teachers continuously test newly developed teaching materials and write evaluation reports. The project will finish at the end of 2011.

The issues of recruitment and the specialisation of science teachers are tackled through programmes in Denmark and the United Kingdom and within the Norwegian science promotion strategy.

In 2006, the **Danish** government set aside a total of DKK 230 million for the continuing education of teachers in public schools. The funds were predominantly intended to provide teachers with a specialisation in science or mathematics, although other subjects were included in the initiative. The initiative ran for the period of 2006 to 2009. During the period, more than 800 teachers acquired a specialisation in a science subject. A further 430 finished courses to become science guidance counsellors. At ISCED level 3, teachers in first year of employment must undertake a four-day course in the didactics of science. The course is a prerequisite for teachers who want permanent employment and is funded by the employing school.

Initiatives in the **United Kingdom (England)** focus primarily on attracting more candidates into science teaching: The Transition to Teaching Programme is aimed at those who want to change career to teach mathematics, science or information and communication technology (ICT) in state secondary schools in England. To be eligible for the programme, candidates must have a degree in science, technology, engineering, maths or a related subject and be recommended by an employer ([185]). Enhancement courses ([186]) are also available for graduates who are interested in teaching physics, maths or chemistry but who need to develop their subject knowledge to teach secondary pupils. These usually comprise the equivalent of two weeks' study which may be taken in one go or spread over a longer period of time possibly through evening drop-in sessions or weekend courses. They are aimed at those who have already been offered a place on a postgraduate initial teacher training course subject to completion of a subject knowledge enhancement course.

5.3. Initial education for mathematics/science teachers: generalist and specialist programmes – SITEP results

5.3.1. Introduction and methodology

Teacher education is recognised as an important factor for ensuring high teaching standards and positive educational outcomes (see Menter et al., 2010). Nevertheless, the present lack of comparable information on the content of initial teacher education programmes due to the high level of institutional autonomy makes European-wide comparison in this area complex. For this reason, the Eurydice unit at the EACEA has developed a new European-level Survey on Initial Teacher Education Programmes in Mathematics and Science (SITEP).

The objective of the survey was to gain information on the content of teacher education programmes that goes beyond the recommendations given by the authorities responsible for higher education in each country. The survey also aimed to show how specific competences and skills, which are

([185]) http://www.tda.gov.uk/Recruit/adviceandevents/transition_to_teaching.aspx

([186]) http://www.tda.gov.uk/get-into-teaching/subject-information-enhancement/age-groups/teaching-secondary/boost-subject-knowledge.aspx considered crucial for future mathematics and science teachers, are taught within existing initial teacher education programmes and how they are integrated in the overall workload.

The survey was targeted at 815 higher education institutions across Europe that provide 2 225 initial teacher education programmes for primary and/or lower secondary general education teachers. In each country, the programmes were analysed in accordance with the national qualification framework and the specific criteria that apply to the level and minimum length of initial teacher education. Alternative pathways to become a teacher (short professional courses for side entrants from other professions) were excluded from the framework as they follow different regulations and are only available in some countries.

The development of the SITEP theoretical framework started at the beginning of 2010 and a comprehensive list of institutions providing initial teacher education was prepared. In September 2010, a consultation was organised to validate and test the draft questionnaire with the Eurydice national units, researchers and policymakers. Consequently, the final version of the questionnaire was developed and 22 linguistic versions were prepared taking into consideration country specific terms and interpretations. The data collection was carried out between March and June 2011.

The survey used an online data collection tool. Responses were received from 205 institutions offering 286 programmes. As the response rates and/or the number of responses by country were usually low, the following sections present only pooled results from the education systems with the highest response rates, namely Belgium (Flemish Community), the Czech Republic, Denmark, Germany, Spain, Latvia, Luxembourg, Hungary, Malta, Austria and the United Kingdom (a total of 203 teacher education programmes). The exact response rates by country can be found in Table 3 in the Annex.

Due to low response rates, the data are not fully representative and therefore should be considered as an indication only. Reporting by country or even presenting standard errors was not meaningful.

5.3.2. General description of education programmes for generalist teachers and specialist mathematics/science teachers

SITEP addressed two distinct types of teacher initial education, namely programmes for generalist teachers and programmes for specialist teachers. A generalist teacher is defined as a teacher who is qualified to teach all, or almost all, subjects or subject areas in the curriculum. A specialist teacher is a teacher qualified to teach one or two different subjects. SITEP was directed at only specialist teacher education programmes for mathematics or natural sciences.

The descriptive analysis of the SITEP results seems to reflect the common pattern of what was already known about initial education programmes for generalist and specialist teachers (see Figure 5.1). As expected, the generalist teacher programmes usually award a Bachelor's degree, while specialist mathematics/science teacher education programmes were organised at Master's or equivalent level. Correspondingly, the mean duration of the generalist teacher education programmes was longer than that of the specialist teacher education programmes. However, it is important to note that access to Master's degree programmes is usually conditional on graduation from a Bachelor's degree or equivalent programme. This leads to an overall length of study for specialist teachers to 4-6 years ([187]). The generalist teacher education programmes usually produced graduates qualified to teach at primary or pre-primary levels of education, while most specialist mathematics/science teacher education programmes were preparing graduates to teach at lower and upper secondary levels.

([187]) For more information on the minimum length of initial teacher education for general lower secondary level, see EACEA/Eurydice, Eurostat (2009), p. 155.

Predictably, the proportion of female graduates was higher in generalist teacher education programmes than in specialist programmes for mathematics/science teachers.

Teacher education programmes for both generalist and specialist teachers are normally delivered either by a single unit/department or by a combination of units/departments in a faculty or institution. The latter model is more common with respect to specialist teacher education.

Figure 5.1: General information on the initial education programmes for mathematics and science teachers, 2010/11

	Generalist		Specialist	
	COUNT	PER CENT	COUNT	PER CENT
Number of programmes surveyed	43	-	160	-
Awarded qualification – Bachelor's degree or equivalent	38	88.4	43	26.9
Awarded qualification – Master's degree or equivalent	3	7.0	75	46.9
Mean duration of the programme (years)	3.7	-	2.6	-
Qualifies for teaching at pre-primary level	17	39.5	6	3.8
Qualifies for teaching at primary level	33	76.7	30	18.8
Qualifies for teaching at lower secondary level	6	14.0	138	86.3
Qualifies for teaching at upper secondary level	3	7.0	106	66.3
Average proportion of female students	-	60.3	-	55.7

Source: Eurydice, SITEP survey.

Explanatory note

As institutions can provide teacher qualifications for more than one level of education, the percentages may therefore not add up to 100 %.

As the response rates were low, the data are not representative and therefore should be considered as an indication only.

Despite low response rates, the general characteristics of teacher education programmes that answered the SITEP survey correspond to the usual features or distinctions between generalist and specialist teachers. Therefore, some further analysis of the pooled results was performed.

5.3.3. Knowledge and competences in initial teacher education programmes for generalist and specialist mathematics/science teachers

The main focus of SITEP was the analysis of the specific competences or content areas covered during the initial education of teachers of mathematics/science. Additional information was gathered on how the competences were addressed in the programmes. The response categories offered made a distinction between 'general references'; competences/content included as 'part of a specific course' and competences/content 'included in assessment'. In order to facilitate direct comparisons, the three types of responses were assigned a different weight. It was assumed that the least attention to a competence/content area was given when only a general reference was made in the programme (one point). Medium weight (two points) was attributed when the competence/content was included in a specific course, and the highest weight was given when the competence was included in assessment (three points). If more than one answer option was chosen, the highest value was assigned. Figure 5.2 lists the responses as percentages by category and as total using weighting.

The survey aimed to gather information about certain competences and skills that, according to the scientific literature (see Section 5.1), are crucial for future mathematics or science teachers (see the list in Figure 5.2). Most of the competences and content areas analysed were grouped into several broader categories. Only one competence, namely 'knowing and being able to teach the official mathematics/ science curriculum' stood alone. The official mathematics/science curriculum is a formal document that describes the objectives and content of mathematics/science courses, as well as the teaching, learning, and assessment materials available. Knowledge of the curriculum therefore could be seen as an overarching competence and is analysed separately. However, other competences were grouped into three broader categories.

The largest category included six competences or content areas related to innovative teaching and assessment approaches. It contained the application of inquiry- or problem-based learning, collaborative learning, portfolio assessment and the use of ICT (previously discussed in Chapters 3 and 4). Two competences in this category may require additional explanation. Personalised teaching and learning means taking a highly structured and responsive approach to each child's or young person's learning, so that all students are able to progress, achieve and participate. It means strengthening the link between learning and teaching by engaging pupils – and their parents – as partners in learning. In addition, the category includes one competence that is related to an understanding of the production of scientific knowledge. The competence 'explaining the social/cultural aspects of mathematics/science' refers to a way of thinking that conceives knowledge production as a social practice that is dependent on the political, social, historical and cultural realities of the time. It includes examining and being able to explain the values implicit in scientific practices and knowledge; looking at the social conditions as well as the consequences of scientific knowledge and its changes; and studying the structure and process of scientific activity.

Another distinct category included five competences summarised under a heading 'dealing with diversity'. It included two types of competences: those related to being able to teach pupils with different abilities and interests, and those that promote sensitivity to gender issues. As discussed earlier (see Chapter 3), this type of competence is important in addressing the issues of low achievement, challenging gifted students and motivating both girls and boys.

Lastly, three competences were put together into the 'collaboration with peers and research' category. It includes important aspects of teachers' work, such as conducting and applying research, as well as collaborating with colleagues on pedagogy and innovative teaching approaches.

As answers in each of the categories were interlinked and had consistent patterns ([188]), it was possible to compute the scale totals. Figure 5.2 lists the scale averages per item in order to account for different numbers of questions in each category.

Generalist teacher education programmes and mathematics/science teacher education programmes were rather similar in the ways they addressed mathematics/science competences and content areas. On average, all competences/content areas were given medium importance, analogous to the category 'part of specific course' (see Figure 5.2).

([188]) The Cronbach alpha coefficients indicated sufficient internal consistency of the scales. 'Creating a rich spectrum of teaching situations and assessment' had Cronbach alpha=0.68, 'dealing with diversity' had Cronbach alpha=0.75 and 'collaboration with peers and research' had Cronbach alpha=0.67. Cronbach's alpha is the most widely used index of the reliability or the internal consistency of a scale, which is based on the average of all inter-item correlations in a survey instrument (for explanation, see Cronbach (1951), Streiner (2003)).

Figure 5.2: Addressing knowledge and competences in teacher education programmes for generalist and specialist mathematics and science teachers, percentages and total weightings, 2010/11

	General reference %	Part of a specific course %	Included in assessment %	Not included %	Total
Generalist teachers					
Knowing and being able to teach the official mathematics/science curriculum	46.5	83.7	76.7	0.0	**2.7**
Creating a rich spectrum of teaching situations					**2.1**
Applying inquiry-based or problem-based learning	51.2	72.1	65.1	2.3	2.4
Applying collaborative or project-based learning	48.8	62.8	62.8	4.7	2.3
Using ICT for teaching mathematics/science phenomena through simulations	34.9	76.7	55.8	7.0	2.3
Explaining the social/cultural aspects of mathematics/science	44.2	69.8	46.5	2.3	2.2
Applying personalised learning techniques	51.2	44.2	32.6	11.6	1.8
Applying portfolio-based pupil assessment	37.2	41.9	25.6	32.6	1.4
Dealing with diversity					**1.6**
Teaching a diverse range of pupils with different abilities and motivation to study mathematics/science	44.2	58.1	39.5	11.6	2.0
Using diagnostic tools for early detection of pupils' learning difficulties in mathematics/science	39.5	58.1	37.2	23.3	1.8
Analysing pupils' beliefs and attitudes towards mathematics/science	46.5	58.1	23.3	14.0	1.7
Avoiding gender stereotypes when interacting with pupils	55.8	34.9	23.3	20.9	1.4
Teaching mathematics/science taking into account the different interests of boys and girls	32.6	37.2	25.6	32.6	1.3
Collaboration with peers and research					**1.9**
Applying research findings to daily teaching practice	62.8	62.8	34.9	7.0	2.0
Collaborating with colleagues on pedagogy and innovative teaching approaches	53.5	53.5	34.9	18.6	1.8
Conducting pedagogical research	37.2	58.1	37.2	20.9	1.8
All competences					**1.9**
Specialist teachers					
Knowing and being able to teach the official mathematics/science curriculum	21.9	83.1	61.3	2.5	**2.5**
Creating a rich spectrum of teaching situations					**2.1**
Applying collaborative or project-based learning	24.4	76.3	49.4	1.9	2.4
Applying inquiry-based or problem-based learning	25.0	78.8	46.3	4.4	2.3
Using ICT for teaching mathematics/science phenomena through simulations	21.3	76.9	44.4	6.9	2.2
Explaining the social/cultural aspects of mathematics/science	31.3	70.6	29.4	6.9	2.0
Applying personalised learning techniques	35.0	63.8	36.9	8.8	2.0
Applying portfolio-based pupil assessment	30.6	47.5	22.5	24.4	1.5
Dealing with diversity					**1.8**
Teaching a diverse range of pupils with different abilities and motivation to study mathematics/science	26.9	73.1	46.9	4.4	2.3
Using diagnostic tools for early detection of pupils' learning difficulties in mathematics/science	27.5	61.9	31.3	15.0	1.8
Avoiding gender stereotypes when interacting with pupils	42.5	52.5	20.6	10.0	1.7
Teaching mathematics/science taking into account the different interests of boys and girls	36.9	50.0	25.0	18.1	1.6
Analysing pupils' beliefs and attitudes towards mathematics/science	35.0	48.8	18.1	15.0	1.6
Collaboration with peers and research					**2.0**
Applying research findings in daily teaching practice	36.3	65.0	40.6	4.4	2.1
Collaborating with colleagues on pedagogy and innovative teaching approaches	33.1	66.9	33.8	5.0	2.0
Conducting pedagogical research	28.8	56.3	39.4	18.1	1.9
All competences					**2.0**

Source: Eurydice, SITEP survey.

Explanatory note

The columns 'General reference', 'Part of specific course', 'Included in assessment', 'Not included' show the percentage of total programmes which include these elements. As the respondents could choose more than one option, the sum of the percentages may exceed 100 %. The column 'Total' shows the average highest score for a competence/content area, where General reference = 1; Part of specific course = 2; 'Included in assessment' = 3; 'Not included' = 0. Scale total shows average per scale item.

As the response rates were low, the data are not representative and therefore should be considered as an indication only.

Knowing and being able to teach the official mathematics/science curriculum

The overarching competence 'knowing and being able to teach the official mathematics/science curriculum' was the most important competence emphasised in both generalist and specialist teacher education programmes. Knowledge of the curriculum was assessed in 76.6 % of the examined generalist teacher education programmes and 61.3 % of the mathematics/science teacher programmes. Moreover, all generalist teacher education programmes addressed the knowledge of mathematics/science curriculum at least as a general reference.

Creating a rich spectrum of teaching situations

The scale 'creating a rich spectrum of teaching situations' was often addressed in the programmes provided by the institutions that answered the SITEP survey. This type of competence was mostly 'part of a specific course' (scale average for both generalist and specialist teachers was 2.1 points).

Collaborative learning, or making pupils work together in small groups on one or more phases of a task, is an important motivational aspect in learning (see Chapter 3). According to the research, project work with no known answer or no previously learned solution should become an essential educational activity in science and mathematics involving experiments or construction of models (see Chapter 3). The responses to SITEP showed that these innovative forms of learning were often addressed when training prospective teachers. 'Applying collaborative or project-based learning' was included in the assessment in 62.8 % of generalist teacher programmes and in 49.4 % of mathematics/science teacher education programmes. It was 'part of a specific course' in 62.8 % of generalist teacher programmes and in 76.3 % of specialist teacher education programmes.

Inquiry-based and problem-based learning is currently widely advocated for science and mathematics teaching as a way to increase motivation and achievement. These forms of pupil-centred and self-directed learning were usually addressed as 'part of a specific course'. 'Applying inquiry-based or problem-based learning' was 'part of a specific course' in 72.1 % of generalist programmes and 78.8 % of specialist teacher programmes.

Using ICT for teaching mathematics/science phenomena through simulations was also widely addressed in generalist and specialist teacher education. Simulation is understood here as a computer program that attempts to simulate an abstract model of a particular system. Use of ICT for teaching through simulations was included in 'part of a specific course' in more than 70 % of generalist and specialist teacher education programmes.

One competence, namely 'applying portfolio-based pupil assessment', stood out from the category 'creating a rich spectrum of teaching situations' with lower values than other items. Portfolio assessment was not addressed at all in about a third of the generalist teacher education programmes and in about a quarter of mathematics/science teacher education programmes. However, the prospective teachers were themselves often assessed using portfolio evaluation (see the discussion below, Figure 5.5), which might prepare them to use this type of assessment in their teaching. These results might indicate that innovative forms of assessment are practiced, but not explicitly discussed during teacher education.

Collaboration with peers and research

The other two competence categories were given somewhat less attention in the teacher education programmes that answered the SITEP survey. The category 'collaboration with peers and research' had an average importance in programmes for specialist and generalist teachers. 'Collaborating with colleagues on pedagogy and innovative teaching approaches' and 'conducting pedagogical research' were not addressed in about a fifth of generalist teacher programmes. Collaboration with colleagues was included as part of a specific course in two-thirds of mathematics/science teacher programmes while conducting pedagogical research was not addressed in a fifth of all programmes.

Dealing with diversity

Meeting the needs of a diverse range of students and the different interests of boys and girls are important for motivating students to learn (see more Chapter 3). However, 'dealing with diversity' was the least addressed competence in both the generalist and specialist teacher education programmes according to the survey responses received. In particular, competences relating to dealing with diversity and gender were less frequently addressed in generalist teacher education programmes than in specialist. Such findings might be a reflection of current national policies on gender in education, as gender-sensitive teaching is promoted in about only one-third of European countries (EACEA/Eurydice 2010, pp. 57-59).

5.3.4. Patterns in addressing competences/content in teacher education programmes

After examining the overall importance attributed to specific competences in the teacher education institutions which responded to the survey, we considered whether there were any significant patterns in the way programmes addressed these competences. This section therefore analyses whether any programmes systematically gave priority to some categories of competences over others, or whether there were groups of teacher training programmes addressing the competences in particular ways.

For these purposes, the teacher education programmes examined were classified according to the scale averages (mean) for the various categories of competences: 'creating a rich spectrum of teaching situations', 'dealing with diversity' and 'collaboration with peers and research'; and the specific competence 'knowing and being able to teach the official mathematics/science curriculum'. The responses revealed four distinct groups, or clusters, where the programmes in the same cluster addressed the competences in a similar way (see Figure 5.3) ([189]).

Two of the four groups of teacher education programmes were extreme opposites. At the top end of the scale, one cluster had the highest values in all the competences analysed and virtually all programmes in this cluster assessed prospective teachers in their knowledge of the curriculum. The other competences analysed were also usually assessed in this cluster and relatively few competences fell into the lower value response groups. Approximately one fifth of the programmes that answered the survey belonged to this cluster.

([189]) A disjoint cluster analysis was performed on the basis of the analysed competences/content scales. 4-cluster solution explained 63 % of the total variance. 5-cluster model explained only 3.8 % additional variance, while 3-cluster solution decreased the explained variance by 13 %.

Figure 5.3: Means of the competences/content scales and distribution of teacher education programmes, by clusters, 2010/11

	Clusters			
	High values	High/medium except diversity	Medium	Low values
Knowing and being able to teach the official mathematics/ science curriculum	3.0	2.8	2.4	2.0
Creating a rich spectrum of teaching situations	2.7	2.3	1.7	1.4
Dealing with diversity	2.6	1.4	2.0	1.0
Collaboration with peers and research	2.7	2.0	1.8	1.3
All teacher education programmes	22.7 %	33.0 %	26.1 %	18.2 %
Generalist teacher education programmes	25.6 %	34.9 %	14.0 %	25.6 %
Specialist teacher education programmes	21.9 %	32.5 %	29.4 %	16.3 %

Source: Eurydice, SITEP survey.

Explanatory note

As the response rates were low, the data are not representative and therefore should be considered as an indication only.

The cluster at the other end of the scale had the lowest values in all competences analysed. On average, knowledge of the curriculum in programmes belonging to this cluster was included as 'part of a specific course'. Some of the programmes in this cluster included knowledge of the curriculum in their assessment of prospective teachers, but a few did not mention this competence at all or only made a general reference to it. This group included teacher education programmes that either did not refer at all to some of the analysed competences, or made only a general reference to most of them. More than half of the programmes in this cluster did not include any of the competences in question in their assessment process. In addition, dealing with diversity issues was usually either not mentioned, or mentioned only as a general reference in these programmes. Only 18.2 % of the programmes that answered the SITEP belonged to this cluster with low values in all dimensions.

Obviously, the other two clusters were somewhere in-between these two extremes. The second cluster had the second highest values in all competence areas except diversity issues and was labelled 'high/medium except diversity'. It included about one third of the programmes analysed. The third cluster, which included 26.1 % of the programmes analysed, had the second highest values on 'dealing with diversity' scale, and the third highest on all the other scales. It was labelled 'medium'.

Interestingly, there were only minor differences between generalist and specialist teacher education programmes. There were very similar proportions of generalist and specialist teacher programmes in the cluster with high values in all dimensions as well as in the cluster with high/medium values in all dimensions except diversity. In the third cluster (with higher values for diversity issues) there were proportionally more specialist teacher programmes than generalist teacher programmes; while in the fourth cluster (with the lowest values on all competences) there were more generalist teacher programmes.

These results suggest that there seems to be a tendency to treat the majority of competences in a similar way throughout a given programme. For example, if one category is included in the assessment process, it is likely that the rest will be also. If a major competence category is just mentioned as a general reference, the others are not likely to receive greater attention. There are, however, a few exceptions. Knowledge of the curriculum stands out from this tendency, as reference to the curriculum is made in virtually all programmes and the majority of them also include this in the assessment of prospective teachers. In addition, about a third of the teacher education programmes analysed place quite high emphasis on all dimensions except diversity issues. In general, dealing with different levels of achievement and sensitivity to gender issues seems to be inadequately addressed in many teacher education programmes.

The SITEP survey also included a few specific questions on some other important aspects of teacher education programmes. Partnerships with external stakeholders and assessment in teacher education programmes are briefly discussed in the next sections.

5.3.5. Partnerships between teacher education providers and external stakeholders

The providers of generalist and specialist teacher education programmes which responded to the survey gave very similar answers regarding collaboration with external stakeholders (see Figure 5.4). The main partners of teacher education institutions were primary and secondary schools. There was cooperation between the majority of both generalist and specialist teacher education programmes and schools in the area of programme implementation. Naturally, teacher education programmes cooperate with schools in organising in-school placements. Moreover, schools were also the main partners in the development of programme content and research.

Figure 5.4: Teacher education institutions' involvement in partnerships/collaborations, for generalist and specialist teachers (mathematics/science), 2010/11

	Programme content		Programme implementation		Research	
	Generalist	Specialist	Generalist	Specialist	Generalist	Specialist
Primary or secondary schools	53.5	46.3	76.7	85.0	23.3	22.5
National or local government organisations	44.2	40.6	46.5	50.0	9.3	11.3
Companies	2.3	2.5	9.3	6.9	7.0	5.6
Civil society organisations	7.0	10.0	18.6	20.0	14.0	13.8

Source: Eurydice, SITEP survey.

Explanatory note

As the response rates were low, the data are not representative and therefore should be considered as an indication only.

The responses of approximately half of the teacher education programmes indicated that collaboration existed with national or local government organisations in the area of programme implementation. Slightly fewer programmes had set up collaborative activities or projects with government organisations regarding programme content. Very few had established partnerships with civil society organisations and companies. As many countries reported numerous initiatives involving private companies and schools (see Chapter 2), it was rather unexpected that so few teacher education programmes had collaborated with the private sector.

Interestingly, teacher education institutions collaborated less with external stakeholders over research matters than in any other area. Only 20 % of teacher education programmes reported that they used partnerships with schools for carrying out research. Therefore, there seems to be further opportunities for collaborating with external stakeholders on research and development into innovative teaching approaches for educating future teachers.

5.3.6. Assessment of generalist and specialist teachers

Assessment is an important part of the teaching and learning process which can take different forms and serve different functions (see Chapter 4). Therefore, the question on assessment in teacher education programmes addressed both content knowledge and teaching skills (see Figure 5.5). The most common way of assessing content knowledge in both generalist and specialist teacher education programmes was through written and oral tests; while observation of teaching practice was most usually used to assess teaching skills.

Portfolio evaluation was the least common form of assessment used with respect to content knowledge, but was used in 58.1 % generalist and 66.9 % of specialist teacher education programmes to assess teaching skills. This is quite an encouraging result, as portfolio evaluation is a non-traditional (or innovative) form of assessment, which according to Collins (1992, p. 453) is 'a container of collected evidence with a purpose' that helps to increase students' responsibility for their own learning.

Figure 5.5: Assessment of generalist and specialist teachers in mathematics and science teacher education programmes, 2010/11

	Content knowledge		Teaching skills	
	Generalist	Specialist	Generalist	Specialist
Written and oral tests	95.3	86.9	69.8	55.0
Portfolio evaluation	39.5	44.4	58.1	66.9
Observation of teaching practice	48.8	47.5	83.7	91.9
Writing research papers	51.2	56.9	44.2	49.4
Thesis	44.2	61.9	25.6	51.9
Other	62.8	46.3	51.2	46.9

Source: Eurydice, SITEP survey.

Explanatory note

More than one answer category was allowed; the percentages may not therefore add up to 100.

As the response rates were low, the data are not representative and therefore should be considered as an indication only.

However, there were some differences between generalist and specialist teacher education programmes. Even though writing research papers was often used in both types of programme, a thesis was a much more common form of assessment in specialist than in generalist teacher education programmes. For assessing content knowledge, the thesis was used in 44.2 % of the generalist teacher programmes and 61.9 % of the specialist mathematics/science teacher education programmes examined.

This section of the study has attempted to give some indication of how future teachers are trained today in number of European education countries. It must be borne in mind, however, that this analysis of the content and skills taught and forms of assessment used in both generalist and specialist teacher education programmes only provides a guide to the knowledge and skills expected of European teachers, their actual knowledge and practical ability to teach in the classroom cannot be directly inferred from the content of teacher education programmes.

Summary

Research into the knowledge and skills needed by science teachers as well as the issues associated with teachers' professional development has been extensive in the past six years.

Knowledge and understanding of the core scientific process of modelling formed a key area of study. This process was found to positively modify teachers' understanding of the Nature of Science (NOS), which is fundamental if they are going to be able to transmit its essential features to students. NOS was also found to be enhanced through meta-cognitive strategies.

Prospective teachers' professional content knowledge (PCK), was found to be improved through a combination of learning specific content and opportunities for discussing ways of teaching that content.

In a few studies, teaching practical skills in the school science laboratory were shown to be weak due to lack of skill in planning, delivery and laboratory management. How to assess student competences in laboratory situations was found to be in need of improvement.

In contrast, there were many studies about inquiry-based teaching and learning and whether and how to transform teaching to become more inquiry-oriented. The complexities of migrating teachers from the standard methods they themselves experienced as students or are now using to the new inquiry approach continue to be explored. Various programmes and strategies provided examples on which to build these skills.

For both initial teacher education and continuing professional development, a number of specific issues have emerged from recent research. The issue of dealing with the cognitive conflicts which teachers and students experience when their personal explanations of the scientific world does not match that which scientists espouse have been substantially explored. Progress has been made in learning how to expose and alter such preconceptions.

Several studies showed the necessity of matching teacher needs to development programme goals. Evidence confirms intuitive assumptions that when a teacher's school-based demands and personal needs are not directly addressed in CPD, change is difficult to achieve. CPD programmes of sufficient length with built in reinforcement of key messages are not common, even though these types of programmes produce more profound effects on teachers.

Personal belief or self-efficacy has received considerable attention as a way to both actively enhance teacher performance and assess teacher growth and development. Considerable attention has also been paid to reducing single-event workshops for CPD since they have been shown to rarely have much of an impact when compared to significantly longer programmes.

Other strategies supported by recent research for improving the effectiveness of CPD include promoting collegiality within schools where vehicles such as lesson study or co-teaching are used to allow professionals to constructively improve their teaching. In-school mentoring (which focuses on current problems and issues) and even action research have been shown to provide positive results.

Countries which have a strategic framework for the promotion of science education normally include the improvement of science teacher education as an objective. School partnerships, science centres and similar institutions all contribute to teachers' informal learning and may give valuable advice to teachers. Science centres in several countries provide specific CPD activities for teachers.

Almost all countries report that their educational authorities include specific CPD activities for science teachers in their official training programmes for in-service teachers, in some cases this is linked to recent curricular reforms. Not very frequent are, however, specific national initiatives for initial science teacher education.

Initial teacher education forms an essential part of learning to teach and lays the foundations for necessary teaching skills. As initial teacher education programmes have high levels of institutional autonomy, EACEA conducted a pilot survey of Initial Teacher Education Programmes in Mathematics and Science (SITEP).

Despite low response rates, the general characteristics of teacher education programmes examined in the SITEP survey correspond to the usual features or distinctions between generalist and specialist teachers. The indications of the aggregated results from 203 programmes confirm to a greater or lesser degree the patterns established from earlier research.

The most important competence addressed in teacher education is the knowledge and ability to teach the official mathematics/science curriculum. It is very often included in the assessment of prospective teachers. Creating a rich spectrum of teaching situations, or applying various teaching techniques, is usually a part of a specific course in both generalist and specialist teacher education programmes. Applying collaborative or project-based learning and inquiry- or problem-based learning is frequently addressed in both types of teacher education programmes.

Dealing with diversity, i.e. teaching a diverse range of students, taking into account different interests of boys and girls, and avoiding gender stereotypes when interacting with students, is less often addressed in generalist teacher education programmes than in programmes that prepare mathematics/science teachers. Generally, these competences are the least often addressed in both types of programme, although diversity issues are important in order to improve motivation and tackle low achievement.

Regarding partnerships between teacher education institutions and other stakeholders, the most common area of collaboration is in programme implementation, while research is the area with the least number of partnerships. Primary and secondary schools are the major partners of teacher education institutions. Many institutions also collaborate with national or local government organisations. There are very few partnerships with companies or civil society organisations. This is rather surprising considering the many cooperation projects and initiatives between schools and companies, especially in science education (see Chapter 2).

The traditional forms of assessment such as oral or written tests and observation of teaching practice are the most common methods used in the teacher education programmes that answered the survey. Although portfolio evaluation is the least common way of assessing content knowledge, it is used in more than half of programmes for assessing teaching skills. However, the application of portfolio-based pupil assessment is not often included in the teacher education programmes examined.

Interestingly, there are more similarities than differences in the competences covered by generalist and specialist training programmes. Broadly speaking, teaching programmes, whether they are generalist or specialist, usually treat competences in a similar way throughout the programme. If one competence is assessed, most of the others are also; if a competence is included as part of a specific course, most of the other competences are included likewise. Similarly, if a programme makes a general reference to core mathematics/science teaching skills, only general references to other content areas are also made.

CONCLUSIONS

This study has examined organisational features of science teaching across Europe and it has mapped the policies and strategies put in place to improve teaching and promote science learning in schools. In particular, it has looked at the support available to teachers to help them change students' attitudes to science and raise levels of interest in this key subject. The study also incorporates reviews of recent research literature on science education, the main findings from international surveys (PISA and TIMSS) as well as the results of a Eurydice pilot survey of initial teacher education programmes.

A. Countries support many separate initiatives but overall strategies to improve science education are rare

Only a few European countries have strategic frameworks for the promotion of science education. Where these do exist, their stated aims either relate to broad educational goals and to society as a whole, or they have a clear focus on schools. Areas usually considered important and in need of improvement at the level of school education are curricula, teaching approaches and teacher education. Although they may have a different focus, in most cases these strategies involve a multitude of stakeholders.

School science partnerships exist in many countries and may come under the umbrella of broader strategies or they may be stand-alone initiatives; in either case their organisation differs between European countries. Partners may vary and range from government agencies and higher education institutions to science associations and private companies. Although some partnerships focus on one specific topic, the vast majority embrace various aspects of science education. Nevertheless, very few partnerships seem to focus their attention on raising girls' interest in science. All the partnerships reported have one or more of the following aims in common:

- to promote scientific culture, knowledge and research by familiarising pupils and students with scientific procedures;
- to enable students to understand how science is used, particularly through contacts with applied science in companies;
- to strengthen science education by enhancing and supporting the implementation of the science curriculum; providing teachers with continuing professional development opportunities focused on practical work and inquiry-based learning; and supporting science activities for pupils and students;
- to increase recruitment to MST professions by encouraging talented pupils and inspiring more students to choose MST careers by making science more work-relevant.

Science centres and similar institutions also contribute to the promotion of science education in Europe. Two-thirds of countries report that such institutions exist at national level and provide students with activities that go beyond what schools typically offer. These science centres also often provide training schemes for teachers.

For most of the countries which have a science promotion strategy in place, science-oriented career guidance is an integral component. However, outside this group, specific career guidance measures to encourage future scientists are rare, although many countries do have programmes and projects which include a science-related guidance objective, however limited this may be. It must be noted that very few countries provide initiatives which focus on encouraging girls to choose scientific careers.

Similarly, few countries have implemented specific programmes and projects to support gifted and talented pupils and students. Usually, these students are offered extra science learning activities which are more suitable to their needs outside normal curriculum time.

There seems to be a wide range of activities for the promotion of science education in a large number of countries but the impact of these various activities is often difficult to measure. Evaluations undertaken as part of earlier science promotion strategies have revealed that providing a coordinated approach is important for success. However, it has also been shown that bottom-up approaches to science promotion can have very positive outcomes for students and teachers.

Other important criteria for success include:

- establishing performance agreements with participating institutions;
- creating measurable objectives and ensuring clear responsibilities for delivery;
- reporting on results and disseminating good practice;
- ensuring follow-up.

B. From an integrated approach to science at lower levels to separate subject teaching in the later stages of schooling

In all European countries, science education begins with one general integrated subject and is taught in this way almost everywhere throughout the entire period of primary education. In many countries the same approach is continued for one or two years into lower secondary education.

By the end of lower secondary education, science teaching has usually been split into the separate subjects of biology, chemistry and physics. Nevertheless, evidence from countries' steering documents shows that many countries continue to emphasise the links between the different subjects and teachers are generally encouraged to apply cross-curricular approaches whenever possible.

At general upper secondary level (ISCED 3), the large majority of European countries adopt a 'separate subject' approach and organise science teaching differently depending on streams and educational pathways chosen by students. Consequently, not all students are taught science at the same level of difficulty and/or throughout all grades of ISCED 3. Nevertheless, in the majority of countries science subjects are compulsory for every student for at least one year of ISCED 3.

C. Increased attention to context-based issues and hands-on activities in science curricula

In order to increase motivation and interest in science, it is essential that the curriculum emphasises connections with students' personal experiences. Links between science and issues in contemporary society and discussion of the philosophical aspects of science are both important. Most commonly recommended context-based issues when teaching science involve contemporary societal issues. In almost all European countries, environmental concerns and the application of scientific achievements to everyday life are recommended areas of study in science lessons. The more abstract issues relating to scientific method, the 'nature of science' or the production of scientific knowledge are mentioned more often in steering documents in connection with separate science subjects, which are taught in the later school years in most European countries.

The activities recommended for primary level science frequently encompass hands-on experimental work and project work in its collaborative form. In general, steering documents in European countries promote varied forms of active learning and participatory inquiry approaches from primary level onwards.

Over the last six years, there have been general curriculum reforms at different levels of education in more than half of the European countries examined. These reforms have also obviously affected science curricula; the main driver for reform in many countries has been a desire to embrace the European key competences approach.

In this context, countries have made efforts to integrate more context-based issues and hands-on activities into science curricula. The reforms in various countries where science skills were re-focused in line with key competences illustrate the desire of policy makers to raise the importance of science education.

D. No specific support measures for low achievers in science

No European country has implemented a specific policy to address the needs of low achievers in science subjects. Help for these learners is, however, usually provided as part of a general framework of support for pupils and students which applies to all subjects. The most common forms of support are differentiated teaching, one-to-one tuition, peer-assisted learning, tutoring and ability grouping. Small learning support groups usually take place outside regular teaching hours. In most countries, support for students is determined at school level; this delegation of responsibilities allows teachers to respond to particular situations and individual needs. Only a few countries have launched nationwide programmes for tackling low achievement generally in schools.

E. Traditional assessment methods still prevail

The main aim of assessment guidelines is to ensure that students' knowledge and skills are assessed in accordance with the objectives and/or learning outcomes defined in the curriculum. In half of the Eurydice countries or regions, there are specific assessment guidelines for science.

These guidelines generally contain recommendations on the techniques to be used by teachers when assessing student progress. Traditional written/oral examinations and assessment of students' performance in class as well as their project work are the most frequently recommended methods. It is also interesting to highlight that no distinction can be made between specific science assessment guidelines and those which apply to all curriculum subjects; the techniques recommended are similar in both. Overall, official guidance material to help teachers assess students' science-specific skills is sparse.

F. Standardised assessment in science at least once during compulsory education

In the majority of European countries and/or regions, pupils' and students' knowledge and skills in science are assessed within standardised procedures at least once during their compulsory education (ISCED 1 and 2) and/or upper secondary education (ISCED 3). However, significant variations are apparent from one country to the next, both in the frequency with which individual pupils take national tests in science subjects and precisely when, in terms of school grade or age, such tests are conducted. In the majority of countries or regions, science subjects are tested at least once in two or three of the educational levels concerned.

While in primary and lower secondary education (ISCED 1 and 2) the science subjects tested within standardised assessment procedures are compulsory for all pupils; in upper secondary education (ISCED 3) they are often optional. Science clearly does not, at present, have the same prominent status as mathematics and mother tongue teaching, although it seems that it is becoming part of national testing procedures in an increasing number of countries.

G. Teacher education: many national initiatives to help improve teachers' skills

As past evaluations of science promotion strategies have shown, strengthening teacher competences is a particularly important concern for policy makers.

Science education research has had a renewed focus on inquiry teaching methods during the last five years. This study has therefore explored the complexities of moving teaching from traditional methods to those which are inquiry-based and has considered the steps needed to deliver this fundamental change in approach.

Research into teachers' professional development has identified the difficulties in successfully changing classroom practices; it has affirmed what was already known about effective teaching methods and has also found new directions. For instance, teachers' professional development combined with in-school lesson evaluation and co-teaching has shown positive results for the schools and teachers using these methods.

More specific challenges have also received attention including how to resolve the problem of pre-conceptual knowledge in new teaching/learning situations for both students and teachers; facilitate student modelling of scientific processes; and apply appropriate teaching and assessment skills for laboratory activities.

Countries which have a strategic framework for the promotion of science education normally include the improvement of science teacher education as one of their objectives. School partnerships, science centres and similar institutions all contribute to teachers' informal learning and may give valuable advice. Science centres in several countries also provide specific formal CPD activities for teachers.

Almost all countries report that their educational authorities include specific CPD activities for science teachers in their official training programmes for teachers in service. Less frequent, however, are national initiatives specifically targeting initial science teacher education.

H. Initial teacher education: still curriculum focused

Despite low return rates, the institutions which responded to the SITEP survey confirmed that their teacher education programmes conformed to the expected pattern of similarities and differences between generalist and specialist programmes. Therefore, some basic analysis of pooled results from programmes in 12 education systems was presented.

The indications of the aggregated results from 203 programmes confirm to a greater or lesser degree the patterns known from research. The most important area of competence addressed in teacher education is the knowledge of and ability to teach the official mathematics/science curriculum; most prospective teachers are assessed in this area. Creating a rich spectrum of teaching situations, or applying various teaching techniques, are usually mentioned as elements of a specific course in both generalist and specialist teacher education programmes. Applying collaborative or project-based learning and inquiry- or problem-based learning methods are frequently addressed in both types of teacher education programmes.

However, dealing with diversity, i.e. teaching a diverse range of students, taking into account different interests of boys and girls, and avoiding gender stereotypes when interacting with students, is less often addressed in generalist teacher education programmes than in programmes that prepare mathematics/science teachers. Generally, these competences are the least often addressed in both types of programmes, although diversity issues have been shown to be important in improving motivation and tackling low achievement.

Partnerships between teacher education institutions and other stakeholders are important if teaching programmes are to meet the needs of schools and students. The most common area of collaboration is programme implementation, while research is the area least involved. Primary and secondary schools are the main partners of teacher education institutions. However, contrary to expectations, there are very few science partnerships with companies or civil society organisations.

Obviously, the results of this pilot survey only provide indications about teachers' preparedness to teach, as teachers' actual knowledge and their ability to teach cannot be directly inferred from the content of teacher education programmes. Nevertheless, the SITEP results provide some concrete evidence from the institutions themselves on how future teachers are trained today which adds to the evidence base of information gathered from national steering documents.

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GLOSSARY

Country codes

EU-27	European Union
BE	Belgium
BE fr	Belgium – French Community
BE de	Belgium – German-speaking Community
BE nl	Belgium – Flemish Community
BG	Bulgaria
CZ	Czech Republic
DK	Denmark
DE	Germany
EE	Estonia
IE	Ireland
EL	Greece
ES	Spain
FR	France
IT	Italy
CY	Cyprus
LV	Latvia
LT	Lithuania
LU	Luxembourg
HU	Hungary
MT	Malta

NL	The Netherlands
AT	Austria
PL	Poland
PT	Portugal
RO	Romania
SI	Slovenia
SK	Slovakia
FI	Finland
SE	Sweden
UK	The United Kingdom
UK-ENG	England
UK-WLS	Wales
UK-NIR	Northern Ireland
UK-SCT	Scotland
EFTA/EEA countries	The three countries of the European Free Trade Association which are members of the European Economic Area
IS	Iceland
LI	Liechtenstein
NO	Norway
Candidate country	
TR	Turkey

Statistical code

: Data not available

International Standard Classification of Education (ISCED 1997)

The international standard classification of education (ISCED) is an instrument suitable for compiling statistics on education internationally. It covers two cross-classification variables: levels and fields of education with the complementary dimensions of general/vocational/pre-vocational orientation and educational/labour market destination. The current version, ISCED 97 ([190]) distinguishes seven levels of education.

ISCED 97 LEVELS

Depending on the level and type of education concerned, there is a need to establish a hierarchical ranking system between main and subsidiary criteria (typical entrance qualification, minimum entrance requirement, minimum age, staff qualification, etc.).

ISCED 1: Primary education

This level begins between four and seven years of age, is compulsory in all countries and generally lasts from five to six years.

([190]) http://unescostat.unesco.org/en/pub/pub0.htm

ISCED 2: Lower secondary education

It continues the basic programmes of the primary level, although teaching is typically more subject-focused. Usually, the end of this level coincides with the end of compulsory education.

ISCED 3: Upper secondary education

This level generally begins at the end of compulsory education. The entrance age is typically 15 or 16 years. Entrance qualifications (end of compulsory education) and other minimum entry requirements are usually needed. Instruction is often more subject-oriented than at ISCED level 2. The typical duration of ISCED level 3 varies from two to five years.

Definitions

Certification purposes: the results of national standardised tests are used to award certificates, or to make important decisions regarding streaming, progression from one school year to the next, or the final grading of pupils. (Eurydice 2009, p. 23).

Computer simulation: a computer program that attempts to simulate an abstract model of a particular system. Simulations can be used to explore and gain new insights into new technology, and to estimate the performance of systems too complex for analytical solutions (Wikipedia, 2010a).

Collaborative learning: pupils are asked to work together in small groups on one or more phases of a task. Strong examples of collaborative activities ask pupils to take on different roles/expertise and create interdependent products (Langworthy et al. 2009, p. 30).

Contextual issues:

- **History of science:** history of human thought about the natural world from its beginnings in prehistoric times to the present. It may include the following topics (non-exhaustive list):

  Science as natural philosophy, Greek science, Aristotle and Archimedes, Hippocrates, science in Rome and Christianity, science in Islam, medieval European science, the rise of modern science (Leonardo da Vinci, renaissance), the scientific revolution (Copernicus, Tyho, Cepler, Galileo, Newton), the classic age of science, science and the industrial revolution, the romantic revolt (Kant, field theory), the founding of modern biology, and the 20th century revolution (Encyclopædia Britannica, 2010a).

- **Philosophy of science**: a branch of philosophy that attempts to explain the nature of scientific inquiry – observational procedures, patterns of argument, methods of representation and calculation, metaphysical presuppositions – and evaluate the grounds of their validity from the points of view of epistemology, formal logic, scientific method, and metaphysics. It may include the following topics (non-exhaustive list):

  Logical positivism and logical empiricism, logics of discovery and justification, eliminativism and falsification, underdetermination, explanation as deduction, the semantic conception of theories, the historic conception, unification and reduction, scientific change (T. Kuhn), scientific realism (Encyclopædia Britannica, 2010b).

- **Social/cultural embeddedness of science**: a way of thinking that conceives scientific knowledge production as a social practice that is dependent on the political, social, historical and cultural realities of the time. It includes examining/questioning the values implicit in scientific practices and knowledge; looking at the social conditions as well as the consequences of scientific knowledge and its changes; and studying the structure and process of scientific activity. It may include the following topics (non-exhaustive list):

  - Reasons for accepting or rejecting new scientific discoveries (e.g. the execution of scientists for religious reasons);
  - Access and barriers to the scientific profession (i.e. who could be a scientist – only men who were educated in certain ways);

    - How science is/was used for justifying the intellectual and physical inferiority of women (reproduction function, hysteria, brain differences);
    - Changing concepts of public health (hygiene, e.g. discovery of washing hands before the surgery; changing perception of smoking).
- **Science and ethics**: examining the ethical consequences brought by advances in science and technological innovations. It may include the following topics (non-exhaustive list):
    - Bioethics (boundaries of life: abortion, euthanasia; animal rights: testing on animals, its use in the cosmetic industry and for medical research; genetic engineering: cloning, GMOs, stem cells);
    - Military applications (dynamite, poisons, atomic bomb).
- **Science and the environment/sustainability**: the environmental implications of scientific activity. It may include the following topics (non-exhaustive list):

    The impact of man-made materials on quality of life and the environment; industry and pollution; garbage recycling; renewable energy; climate effects of science developments (global warming, the ozone layer, acid rain); food industry, additives in foodstuffs.
- **Science and everyday technology**: everyday technological applications of scientific phenomena; linking science and technology to its everyday practices. It may include the following topics (non-exhaustive list):

    How computers work; how mobile phones can send and receive messages; how cassette tapes, CDs and DVDs store and play sound and music; how to use and repair everyday electrical and mechanical equipment; the use of satellites for communication and other purposes; optical instruments and how they work (glasses, telescope, camera, microscope, etc.); detergents, soaps and how they work; medicinal use of plants; how X-rays, ultrasound, etc. are used in medicine (ROSE, 2010).
- **Science and the human body**: contextualising scientific phenomena through examples of the human body and its functioning. It may include the following topics (non-exhaustive list):

    Forces acting in muscles when using them in sports; heart, blood pressure and blood flow; how radiation from solariums and the sun might affect the skin; influence of electric shock/electricity on muscles and the body; how radioactivity affects the human body (ROSE, 2010); pharmaceutical products and their effects on the body/skin; health and nutrition.

Evaluation purposes: the results of national standardised tests are used to monitor and evaluate schools, or the education system as a whole. These aims may include the comparison of performance across schools, the provision of input into measures for school accountability, and performance evaluation of the entire system. The results of tests are used in conjunction with other parameters as indicators of the quality of teaching. They also serve as pointers to the overall effectiveness of education policies and practices, and to whether or not improvements have occurred at a particular school or at system level (Eurydice 2009, p.23).

Multilevel regression models: allows variance in outcome variables to be analysed at multiple hierarchical levels, whereas in simple linear and multiple linear regression all effects are modelled to occur at a single level. Student data are considered as nested within classes and within schools. Such models lie on assumption that the performance of students within the same class or school may be correlated. These correlations must be taken into account for correct interpretations. By means of these models, it is possible to differentiate between the impact of contextual variables depending on whether they relate to schools or the students within them. At their simplest, such models are used to subdivide the total variance in student performance into a between-school variance and a student variance within schools.

Policy: refers to a definite course of action adopted by a national/regional government in an effort to promote a particular practice suitable to achieving the desired results.

Portfolio (or e-portfolio, if electronic): serves as a demonstration of the students' skills as well as seen as a platform for self-expression. A portfolio is a type of learning record that provides actual evidence of achievement (Wikipedia, 2010c).

Programme: a group of projects with similar aims, initiated or funded typically by a national/regional government.

Project: a collaborative enterprise that is carefully planned to achieve a particular aim (Wikipedia, 2010d). Projects' scale as well as the extent of collaboration can vary widely.

Project work: a science project is an educational activity for students in science involving experiments or the construction of models. In the case of science projects, students construct the whole process from project design to evaluation on their own (individually or in a group). Science projects may be classified in four main types: experimental projects, engineering or technology projects, display projects and theoretical projects (Wikipedia, 2010b). Project-based learning activities engage pupils in open-ended, long term (1 week or more) questions or problems, usually one with no known answer or no previously learned solution (Langworthy et al. 2009, p. 30).

Project-based assessment: assessment method based on project-based learning activities.

Self-assessment (pupils): pupils are required to take responsibility for their own learning. They must plan and monitor their own tasks. They know the criteria that define 'success' for this task, and they must revise their work based on feedback from teachers or peers or based on self-reflection (Langworthy et al. 2009, p. 30).

Standard deviation: measures the dispersion or spread in a distribution with respect to the mean. In PISA surveys the score average of OECD countries is set at 500 points, while the standard deviation is 100. A 50 point difference in score thus indicates a difference in 0.5 of standard deviation.

Standard error: the standard deviation of the sampling distribution of a population parameter. It is a measure of the degree of uncertainty associated with the estimate of a population parameter inferred from a sample. Indeed, due to the randomness of the sampling procedure, one could have obtained a different sample from which more or less different results could have been inferred. Suppose that, on the basis of a given sample, the estimated population average was 10 and the standard error associated with this sample estimate was two units. One could then infer with 95 % confidence that the population average must lie between 10 plus and 10 minus two standard deviations, i.e. between 6 and 14.

Statistical significance: refers to 95 % confidence level. For example, a significant difference means that the difference is statistically significant from zero at 95 % confidence level.

Steering documents: official documents containing programmes of study/curricula which may include any or all of the following: learning content, learning objectives, attainment targets, and guidelines on pupil assessment or model syllabuses. Several types of documents with different degrees of flexibility in their application can exist at the same time and at the same education level in a country. However, they all establish the basic framework in which teachers are required (or advised, where mandatory requirements do not exist) to develop their own teaching to meet their pupils' needs.

Variance: a measure of dispersion, averaging the squared distance of its possible values from the expected value (mean). The unit of variance is the square of the unit of the original variable. The positive square root of the variance, called the **standard deviation**, has the same units as the original variable and can be easier to interpret for this reason.

TABLE OF FIGURES

Chapter 5: Improving Science Teacher Education

ANNEX

Table 1 (to Figure 3.2): Titles of integrated science curriculum area and separated science subjects in ISCED1 and 2, 2010/11

	Title of integrated science curriculum area	Titles of separate science subjects
BE fr	- 'Living beings' - 'Matter' - 'Energy' - 'Air, water, earth' - 'Men and environment' - 'History of life and sciences'	Only integrated
BE de	- 'Living beings have a metabolism' - 'Living beings reproduce themselves' - 'Living beings move' - 'Living beings react on their environment' - 'Energy in our life'	School autonomy (biology, chemistry, physics)
BE nl	Grades 1-6: 'World Orientation' Grades 7-8: 'Natural Sciences'	biology, chemistry, physics
BG	Grade 1: 'Homeland' Grade 2: 'Outside World' Grades 3-6: 'Man and Nature'	'Physics and Astronomy',' Biology and health education', 'Chemistry and environmental protection'
CZ	School autonomy. Defined educational area 'People and Their World', organisation depends on school.	School autonomy. Separate educational fields biology, chemistry, physics are defined in the 'Framework Educational Programme for Basic Education'.
DK	Grades: 'Nature/Technology'	Grades 7-9: biology, chemistry, physics, geography
DE	'Regional and social studies and basic sciences'	Grades 7-10: Biology, chemistry, physics. Astronomy (only in the *Länder* Mecklenburg-Western Pomerania and Thuringia)
EE	'Science'	Grade 7: Biology, geography, science (integrating chemistry and physics) Grades 8-9: Biology, chemistry, physics, geography
IE	Elements of biology, physics, chemistry and environmental science (known as content strands) under the headings, respectively, of 'Living things', 'Energy and forces', 'Materials' and 'Environmental awareness and care'	Biology, chemistry, physics
EL	Grades 1-4: 'Environmental studies' Grades 5-6: 'Exploring Natural World'	Grade 7: Biology Grade 8: Chemistry, physics Grade 9: Biology, chemistry, physics Grade 10: Chemistry, physics Grade 11: Biology, chemistry, physics
ES	Grades 1-6: 'Knowledge about Natural, Social and Cultural Environment' Grades 7-9: 'Natural Sciences'	Grade 9: 'Biology and geology', 'Physics and chemistry' Grade 10: optional 'Biology and geology', 'Physics and chemistry'
FR	Grades 1-2: 'World Discovery' Grades 3-7: 'Experimental Sciences and Technology'	Grade 6-9: 'Life and earth sciences', 'Physics and Chemistry'
IT	Grades 1-5: 'Natural and Experimental Sciences' Grades 6-8: 'Science and Technology'	
CY	'Science'	Grade 7: Biology, geography Grade 8: chemistry, physics, geography Grade 9: Biology, chemistry, physics
LV	'Science'	Grade 7: Biology, geography Grade 8-9: Biology, chemistry, physics, geography
LT	Grades 1-4: 'World Discovery' (natural sciences, social and moral education integrated course) Grades 5-6: 'Nature and Man' (natural sciences integrated course)	Grade 7: Biology, physics, Grade 8-10: Biology, chemistry, physics

	Title of integrated science curriculum area	Titles of separate science subjects
LU	'Man, nature, technology, the child and its environment, citizenship, space, time'	Only integrated
HU	School autonomy. 'Humans and Nature' is usually taught in Grades 1-6.	School autonomy. Most schools separate science teaching in Grade 7-8 into biology, chemistry, physics, geography
MT	Integrated Science	Physics compulsory, biology and chemistry optional
NL	School autonomy. ISCED 1: 'Nature and Technology' ISCED 2: 'Humans and the Environment'	School autonomy (biology, chemistry, physics, geography)
AT	'Regional and social studies and basic sciences'	Biology and environmental education, chemistry, physics, geography
PL	Grades 1-3: 'Nature Education' (content area, not a separate subject) Grades 4-6: 'Natural Sciences' (old curriculum)	Grades 7-8: Biology, chemistry, physics, geography Grade 9: Biology, chemistry, physics, geography, health education, ecological education
PT	Grades 1-4: 'Study of the environment' Grades 5-6: 'Sciences of the nature'	Grades 7-9: 'Natural sciences' (biology and geology) and 'Physical sciences' (chemistry and physics)
RO	Grades 1-2: 'Studying the Environment' Grades 3-4: 'Natural Sciences'	Grade 5: Biology Grade 6: Biology, physics Grades 7-10: Biology, chemistry, physics
SI	Grades 1-3: 'Environmental Education' Grades 4-5: 'Natural Sciences and Techniques' Grades 6-7: 'Natural Sciences'	Grades 8-9: Biology, chemistry, physics
SK	'Nature and society'	Grade 5: Biology Grades 6-9: Biology, chemistry, physics
FI	Environmental and Natural Studies	Biology, chemistry, physics, geography, health education
SE	School autonomy. 'Natural Sciences Orientation'	School autonomy (biology, chemistry, physics)
UK-ENG	School autonomy. 'Science'	School autonomy
UK-WLS	School autonomy. Foundation stage: 'Knowledge and understanding of the world' KS2-3: 'Science'	School autonomy
UK-NIR	School autonomy. Foundation stage: 'The World around us' KS1-2: 'The World around us' ('Science and Technology') KS3: 'Science and Technology'	School autonomy
UK-SCT	'Science'	Grade 7-11: 'Healthy and Safe Living', 'An Introduction to Materials', 'Energy and its uses', 'A Study of Environments'
IS	'Natural History and Environment Education'	Only integrated
LI	'Realities' (includes biology, chemistry and physics)	Grade 9: Biology and physics (compulsory for all students)
NO	'Natural Science'	Only integrated
TR	Grades 4-8: 'Science and Technology'	Only integrated

Table 2 (to Figure 3.8): Science subjects within the curriculum at ISCED level 3, 2010/11

	Grades following the national system	**Compulsory subjects for all students (at the same or different level of difficulty)**	**Compulsory subjects for a group of students**	**Optional**
BE fr	9 to 12	Biology, chemistry, physics		
BE de	9 to 12	Subjects are determined by the school boards		
BE nl	11, 12	Biology, chemistry, physics		
BG	9, 10	Biology and health education, chemistry and environmental protection, physics and astronomy		Biology and health education, chemistry and environmental protection, physics and astronomy
	11, 12		Biology and health education, chemistry and environmental protection, physics and astronomy (specialized training)	Biology and health education, chemistry and environmental protection, physics and astronomy
CZ	10, 11	Educational area: People and Nature Subjects: biology, chemistry, physics, geology and part of geography, either separate subjects or integrated science area (depends on the school)		
	12, 13			Biology, chemistry, physics, geology and part of geography: inclusion within the curriculum is determined by each school
DK	10	General (stx) educational path: - integrated science: scientific basis, including physical geography - separate subjects: biology, chemistry, nature geography (two of three subjects) General (hf) educational path: - integrated science: scientific basis, including geography but no physics Technical (htx) educational path: technical science, physics, chemistry, technology, biology	Integrated science: depends on educational paths Separate subjects: biotechnology and physics (biotechnology stream)	
	11	**stx**: physics (at the same level of difficulty), one of the subjects: chemistry, biology, nature geography, physics (at different levels of difficulty) **htx**: physics, chemistry	Biology, chemistry, biotechnology: depending on stream	Biology, chemistry, physics: depending on stream
	12		Biology, chemistry, physics, biotechnology: depending on stream	Biology, chemistry, physics: depending on stream
DE	11 or 11, 12	One or two out of: biology, chemistry, physics		
EE	10 to 12	Biology, chemistry, physics		

	Grades following the national system	Compulsory subjects for all students (at the same or different level of difficulty)	Compulsory subjects for a group of students	Optional
EL	10	Chemistry, physics		
	11	Biology, chemistry, physics	Natural sciences and mathematics stream: physics, chemistry Technical stream: physics	Biology or chemistry
	12	Biology, physics	Natural sciences and mathematics stream: physics, chemistry, biology Technical stream: physics, chemistry-biochemistry or informatics	
ES	11	Science for the contemporary world	Biology; Biology and geology; Earth and environmental sciences; Physics and chemistry; Chemistry; Physics (Science and Technology stream)	Decision of the school
	12			Decision of the school
FR	10	Biology and geology, chemistry, physics	Integrated science (scientific methods and practices) offered from September 2010 within the integrated optional course *enseignements d'exploration.*	Biology and geology, chemistry, physics: proposed by some schools
	11	Biology and geology, chemistry, physics	Monitored personal projects (scientific or not). From 2011, will be replaced by the integrated optional course *enseignements d'exploration.*	
	12		Until 2012: biology and geology or physics/chemistry. From 2012 will be replaced by the integrated optional *enseignements d'exploration*	
IE	10		Decision of the school	Physics, chemistry, biology, agricultural science, physics and chemistry
	11,12			Physics, chemistry, biology, agricultural science, physics and chemistry
IT	9 to13	Natural sciences/physics		
CY	10	Biology, chemistry, physics		
	11	Science (all students who do not choose separate subjects)	physics, chemistry (depending on student's selection)	Environmental science
	12		Physics, chemistry, biology (depending on student's selection)	
LV	10 to 12	Biology, chemistry, physics or science	Biology, chemistry, physics or science	

	Grades following the national system	**Compulsory subjects for all students (at the same or different level of difficulty)**	**Compulsory subjects for a group of students**	**Optional**
LT	11	Biology, chemistry, physics (one of the subjects is compulsory at basic or extended level of difficulty)		One or two of the remaining science subjects can be chosen.
	12	Subject chosen in grade 11. Students may change the level of difficulty or the subject.		Subject(s) chosen in the 11th grade. Students may change subject difficulty level or subject.
LU		(:)	(:)	(:)
HU	9	Physics, geography and environment		
	10	Biology, chemistry, physics, geography and environment		
	11	Biology, chemistry, physics		
	12	Biology, chemistry		
MT	12, 13	at least one subject out of: Biology, chemistry, environmental science, physics		
NL	11 to 13	General science	Biology, chemistry, physics	
AT	9 to 12	Biology and environmental education, chemistry, physics, geography		Deepening or enlarging the contents of the compulsory subjects biology, chemistry, physics, geography
PL	10 to 12	Educational paths: Ecological education, health education Subjects: biology, chemistry, physics, geography	biology, chemistry, physics, geography (as a chosen compulsory option, at advanced level)	
PT	10, 11		Biology and geology, physics and chemistry	
	12		One out of: Biology, geology, physics, chemistry	
RO	11 to 13	Biology, chemistry, physics science, (depending on the pathway)		
SI	10 to 12	Biology, chemistry, physics		
	13			Biology, chemistry, physics
SK	10	Integrated science teaching		
	11	Biology, chemistry, physics		
FI	7 to 12	Biology, chemistry, geography, physics		Biology, chemistry, geography, physics
SE	10 to 12	Natural science	Biology, chemistry, physics	Biology, chemistry, physics, environmental science

	Grades following the national system	**Compulsory subjects for all students (at the same or different level of difficulty)**	**Compulsory subjects for a group of students**	**Optional**
UK-ENG/ WLS/ NIR	10, 11	Science courses (biology, chemistry, physics), as defined within the study programmes of study for GCSE		
	12, 13			Biology, chemistry, physics
UK-SCT	12, 13			Biology, chemistry, physics and Human Biology
IS	11 to 14		Biology and/or chemistry, physics (depends on the programme of study)	Biology and/or chemistry, physics: depends on the programme of study
LI	10, 11	Biology, chemistry, physics	Physics and chemistry (one additional lesson)	
	12	Physics	Biology, chemistry	
NO	11	Natural science	Geography	
	12		Geography, one out of: biology, physics, geosciences, chemistry, technology, theory of research	Biology, physics, geosciences, chemistry, technology, theory of research
	13		One out of: biology, physics, geosciences, chemistry, technology, theory of research	Biology, physics, geosciences, chemistry, technology, theory of research
TR	9	Geography, biology, chemistry, physics and "knowledge of health"	Geography, biology, chemistry, physics	
	10	Geography	Geography, biology, chemistry, physics	Biology, chemistry, physics and 'knowledge of health'
	11, 12		Geography, biology, chemistry, physics	Geography, biology, chemistry, physics and 'knowledge of health'

Table 3: Response rates by country from the Survey on Initial Teacher Education Programmes in Mathematics and Science (SITEP)

	Available programmes	Institutions	Replies by programme	Replies by institution	Rate of response by programmes	Rate of response by institutions
Belgium (French Community)	39	16	2	2	5.13	12.50
Belgium (German-speaking Community)	:	:	NA	NA	NA	NA
Belgium (Flemish Community)	31	18	13	9	41.94	50.00
Bulgaria	33	8	2	2	6.06	25.00
Czech Republic	80	12	25	12	31.25	100.00
Denmark	14	7	6	6	42.86	85.71
Germany	469	144	41	32	8.74	22.22
Estonia	11	2	2	1	18.18	50.00
Ireland	23	20	2	2	8.70	10.00
Greece	33	9	4	4	12.12	44.44
Spain	110	51	26	16	23.64	31.37
France	91	33	4	4	4.40	12.12
Italy	24	24	4	3	16.67	12.50
Cyprus	5	4	0	0	0.00	0.00
Latvia	19	5	7	5	36.84	100.00
Lithuania	24	8	3	1	12.50	12.50
Luxembourg	2	1	2	1	100.00	100.00
Hungary	38	17	8	7	21.05	41.18
Malta	2	1	2	1	100.00	100.00
Netherlands	96	45	10	8	10.42	17.78
Austria	35	18	14	8	40.00	44.44
Poland	163	95	12	8	7.36	8.42
Portugal	93	42	8	8	8.60	19.05
Romania	80	27	5	4	6.25	14.81
Slovenia	29	3	1	1	3.45	33.33
Slovakia	24	11	3	2	12.50	18.18
Finland	14	8	2	2	14.29	25.00
Sweden	55	22	1	1	1.82	4.55
United Kingdom (England)	347	70	45	33	12.97	47.14
United Kingdom (Wales)	21	6	4	4	19.05	66.67
United Kingdom (Northern Ireland)	12	4	3	1	25.00	25.00
United Kingdom (Scotland)	35	8	7	6	20.00	75.00
Iceland	2	2	0	0	0.00	0.00
Liechtenstein	:	:	NA	NA	NA	NA
Norway	16	16	1	1	6.25	6.25
Turkey	155	58	13	10	8.39	17.24
TOTAL	**2 225**	**815**	**282**	**205**		

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