



Science Teaching in Schools in Europe

Policies and Research





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Eurydice
The information network on education in Europe

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PREFACE



Science gives pupils the means required to enhance their understanding of the world around them. It encourages curiosity and a critical outlook. It throws light on the relation between human beings and nature and reminds us that natural resources are finite.

Science is also part of today's world – we are surrounded by its products, from MP3 players through medical instruments to the computers hidden in our cars. And we rely increasingly on science. We all hear 'experts' advising on subjects of public concern, such as climate change or GMOs in our food. Their expertise comes from science. If we are to appreciate what they are telling us and how they reach their views, we all need a 'scientific culture' – we need to be able to judge what we are being told.

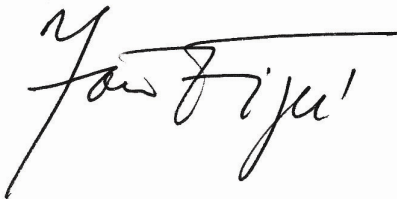
In addition, Europe needs young scientists capable of innovation in a competitive society rooted in knowledge. Boosting enrolment in scientific and technical fields of study is one of the objectives set by the Education Ministers in 2001 as part of their contribution to the Lisbon process.

So it is crucially important for Europe that its young people should acquire proficiency and knowledge in science subjects.

This Eurydice study on science teaching in schools in Europe is an integral part of the debate on developing science teaching in the EU. It offers a comparative analysis of current official regulations relating to science teaching in general in 30 European countries. It focuses in particular on teacher education programmes, the school curriculum and standardised pupil assessment. In addition, this material is very helpfully placed in context through an overview of the main findings from research into the teaching of science.

The study, which is the outcome of close collaboration between the Eurydice European Unit and the National Units, emphasises that the training of science teacher trainers merits particular attention on the part of policy-makers. Greater sensitivity to the different ways in which girls and boys approach science subjects might also result in more balanced gender participation in mathematical, scientific and technological fields of study.

I know that educational policy-makers are keenly aware of the importance of the teaching of science subjects. I hope that they will find that this report supports their efforts to provide quality education in the field of science for all European citizens.



Ján Figel'

Commissioner responsible for Education,
Training, Culture and Multilingualism

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INTRODUCTION

Purpose and focus of the study

The way in which science is taught in schools depends on many factors related mainly to the training received by teachers, and the content of both the school curriculum and standard tests or examinations. Directly or otherwise, these factors influence the content of – and approaches to – science teaching, as well as science activities in the classroom.

The aim of this study is twofold: firstly, to provide a comparative review of the regulations and official recommendations concerning science teaching and, secondly, to present an overview of the main findings of research into science teaching. The first part portrays the situation as regards current educational policies for science teaching in Europe. The overview of research literature aims to offer an appraisal of the expertise now available on the most effective approaches for getting young people to learn about science. The most important associations of these two complementary perspectives are emphasised in the conclusions. It is hoped that the study as a whole will help to inform decisions taken by policy-makers to improve the quality of science teaching.

The reference year for data in the comparative study is 2004/05, with reference made to reforms ongoing in 2005/06. The study covers 30 Eurydice Network member countries ⁽¹⁾.

The levels of education concerned are primary (ISCED 1) and lower secondary (ISCED 2). Only schools managed and funded by the public authorities are covered in the report. However, Belgium, Ireland and the Netherlands are exceptions to this. Grant-aided private schools in these three countries are considered because they are attended by the majority of pupils.

In order to limit the scale of information gathering and ensure its feasibility, the survey focuses on science as a single integrated subject, and on biology and physics where these are distinctly separate subjects in the curriculum. The curriculum for lower secondary education often includes separate sciences, whereas integrated science is more typical of the primary curriculum. As physics and biology are relatively distinct science subjects, choosing them for the present study has enabled the widest possible range of information to be gathered in terms of aims and methodological approaches. However, it does not of course imply that these subjects are regarded as being more important than others in any way, such as chemistry for example.

Methodology

The information set out in this comparative enquiry was gathered from Eurydice National Units by means of a questionnaire accompanied by a list of specific terms and definitions. These information gathering instruments may be obtained from the Eurydice website (www.eurydice.org).

Besides the contributions from National Units, the European Unit received support from two experts in science teaching methods when preparing this study. As well as helping to draft the data collection questionnaire, they also wrote part of the report, including the overview of research findings, and read its entire content from a critical perspective.

⁽¹⁾ Turkey, a member of the Eurydice Network, did not contribute to this study.

In order to ensure that the content of the study is reliable and of sound quality, the first (comparative) part was closely checked by the National Units in the Eurydice Network.

All persons who contributed to the report are listed in the 'Acknowledgements' section at the end of the publication.

Structure of the report

The first part of this report contains a comparative investigation of regulations and official recommendations on the subject of science teaching.

The first chapter examines the content of qualification standards, guidelines concerning initial teacher education programmes and criteria for the accreditation of higher education institutions and programmes. The aim is to identify the types of competence and expertise that prospective science teachers should develop during their initial training, whether they relate to actual teaching practice or are of direct relevance to the science subject taught.

The second chapter deals with the qualifications and professional experience of the teacher trainers who supervise those intending to become qualified science teachers during their initial professional training. It considers the trainers in initial teacher education institutions and also the teachers who, from within their school, supervise prospective teachers during their school placement.

The third chapter focuses on the approaches set out in the prescribed school science curriculum, and in particular the aims that should be achieved and activities that should be undertaken in the classroom. The enquiry is especially concerned with the following aspects: the presence of references to the context-related aspects of science teaching, such as the history of science and contemporary societal problems; experimental work; information and communications technology (ICT); and communication. An overview of ongoing debate and reforms relating to the school curriculum is also provided.

The fourth chapter considers standardised tests and examinations in the field of science. After first identifying countries that make use of such tests, the chapter examines the types of knowledge and skill that are assessed. It also deals with standardised assessment of a particular kind of activity, namely science projects. As in Chapter 3, it offers a short general overview of reforms and debate concerned with evaluation of the results of science teaching.

The overview of the main findings of research into science teaching constitutes the second part of the report. It considers a set of issues of major importance for the training of teachers, and more generally, for their teaching practice. It covers the most significant aspects of work carried out, to answer questions such as 'What forms of learning should be encouraged?', 'How should pupils be motivated?', 'What special contributions can be made by ICT?', 'How do teachers view science and science teaching?', 'What professional expertise do they have to mobilise for teaching purposes?', and 'How do they develop innovative approaches and procedures?'

A glossary is included at the end of the report.

CHAPTER 1

SCIENCE TEACHER EDUCATION PROGRAMMES

Introduction

The focus of this chapter is teacher education for all intending science teachers, whether generalists or specialists. The question underlying the data presented here is what regulations are defined at central level and whether these have much to say about what teachers should know and be able to do in order to teach science. Obviously, a good science teacher should know and be able to do all those things that are associated with teaching the subject: they should acquire a sound knowledge of scientific concepts and theories, and receive training to teach experimental work, in laboratories or elsewhere. Beyond this, however, lie the broader areas of educational psychology and knowledge of teaching methods, as well as very practical teaching knowledge and skills associated with working in the classroom.

Teachers training for ISCED 1 may often expect to teach all, or almost all, subjects on the curriculum. They do not necessarily have specialised science knowledge. Teacher education for generalist teachers would therefore normally be much broader-based in terms of subject knowledge, in contrast to ISCED 2, where most teachers are science specialists. An overview of how science is taught at both levels of education in Europe is given in Figure 3.1. A second difference between ISCED 1 and 2 is that science is usually taught as a single subject at primary level and as separate subjects in lower secondary education. Teacher education provisions at ISCED 1 would therefore presumably reflect a less specialised approach to the teaching of science.

These two facets of science teaching – science knowledge and teaching knowledge and skills – form the thread underlying this chapter. The first section looks at what dimensions contribute to preparing trainee science teachers to be teachers. This is inevitably very broad, because in most respects good teaching cuts across school subjects. This focus on practical science teaching skills is generally seen to be important in enhancing both the attractiveness and effectiveness of science in schools. In Germany, for example, part of the far-reaching reforms in education currently underway concerns a redefinition of the aims of science teacher education in order to give more importance to educational psychology and teaching knowledge and skills. Previously, the emphasis in teacher education was more on subject knowledge *per se*.

Some teaching skills are more specific to the science context, however. These kinds of skills are considered in the second section in this chapter. The third section addresses teacher education in scientific knowledge and skills, with additional information on teacher competence in scientific experimentation and investigation. The emphasis therefore moves away from teaching and learning skills to focus more on science competences for trainee teachers.

Finally, the last section looks at whether there are specific accreditation criteria with respect to initial teacher education programmes for teachers qualified to teach science. Where such criteria exist, it examines which aspects of initial education they cover.

It is important to bear in mind that only information available in official documents at central or top education level is presented here. This means that the information does not tell us about what is actually taught in teacher education institutions, but only what is found in regulations (or, in a very few cases, recommendations) issued at central level addressing the content of teacher education programmes, or

other forms of centrally defined qualification standards. The extent to which this provides a reasonably complete picture of teacher education depends on the way each education system is governed. Only four countries (the Czech Republic, Greece, Ireland and the Netherlands) do not currently have any such type of central or top-level data source (Figures 1.1 – 1.5). This does not, however, mean that the content of teacher education programmes is not influenced by other centrally determined references, such as the pupil attainment targets or specific accreditation criteria and, more generally, the content of pupil curricula in science (see Chapter 3).

These top-level programme guidelines or qualification standards may be designed either for the whole of teacher education or more specifically for science teachers.

It should be noted that this type of programme guideline/qualification standard from top-level education authorities, and the development of teacher standards in particular, has recently been an area of discussion and action for education authorities in several countries. The Education Professions Act was adopted by the Dutch Parliament in 2004 and makes provision for standards of competence. The content of these standards was developed by professional organisations (e.g. the Association for Professional Standards in Education) and the Act is to enter into force in 2006. In the Czech Republic, proposals for minimal professional standards in teacher education are presently under debate. Other countries which are also debating the introduction or revision of centrally defined teacher profiles are Estonia (the National Development Plan for Teacher Training was introduced in 2003) and France (the April 2005 law on the *Avenir de l'École* requires teacher education to meet specifications fixed by the ministers for higher and school education). In the United Kingdom (Wales), the Welsh Assembly Government is currently considering responses to its 2005 consultation on revised Qualified Teacher Status (QTS) Standards that trainee teachers must meet and on revised requirements for the provision of initial teacher training courses. The proposal largely parallels the changes which took effect in England in 2002, and will allow providers greater freedom in the design and delivery of training, within stated boundaries. Revised requirements are expected to be published in 2006.

1.1. General teaching knowledge and skills

Irrespective of the subject to be taught, teacher education develops proficiency across a broad base of general teaching knowledge and skills, including theories of child development, creating and managing learning situations, working with diverse pupil groups and collaborative approaches to teaching. These categories have been broken down into specific competencies, which are presented in Figures 1.2a and 1.2b.

These types of skills and knowledge receive fairly comprehensive coverage for intending science teachers in top-level programme guidelines/qualification standards both at ISCED 1 and at ISCED 2. Specifically, there is complete coverage at both levels of education in Belgium (French and Flemish Communities), Germany, the three Baltic States, Malta, Portugal, Finland, the United Kingdom (Scotland), Iceland and Norway.

Overall, there are slightly more references to general teaching knowledge and skills in top-level programme guidelines/qualification standards at ISCED 1 than at ISCED 2, most notably with respect to theories of child development.

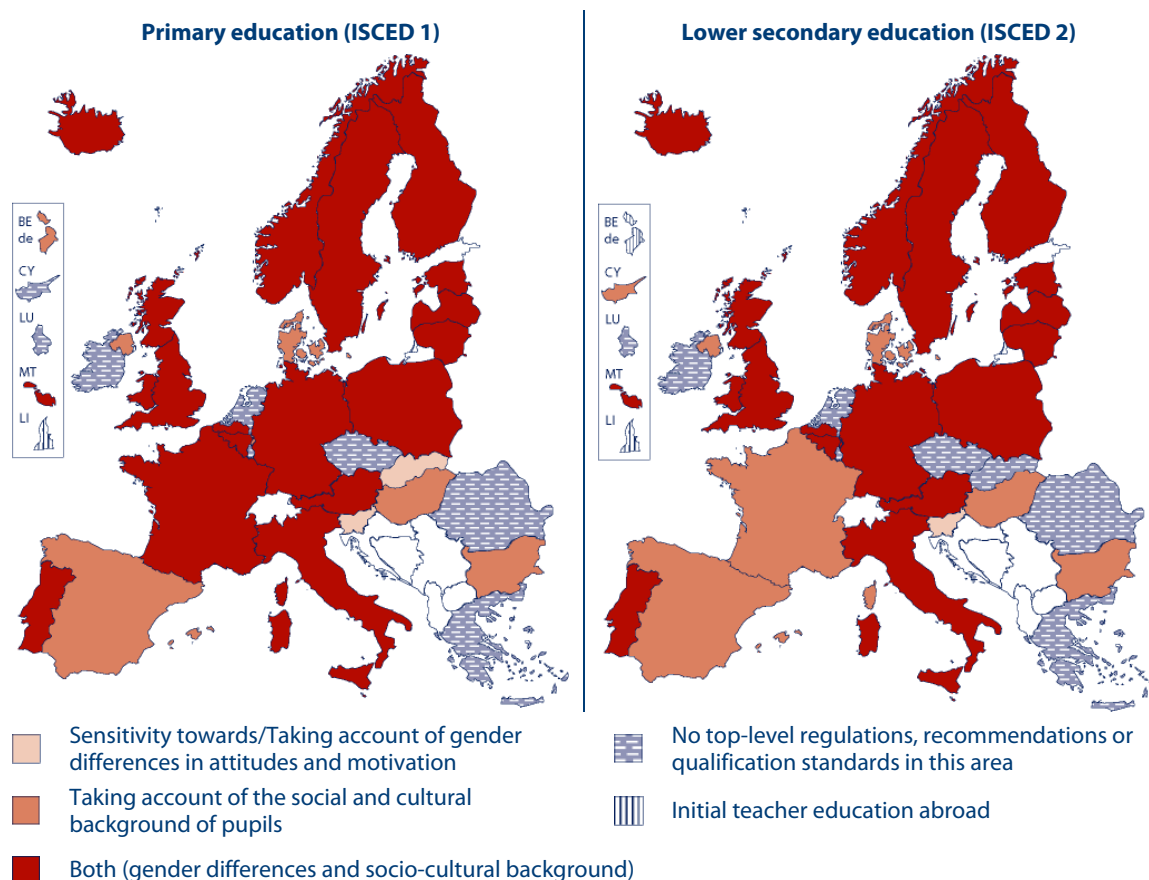
At ISCED 2, where science is usually taught as separate subjects, almost no differences at all are apparent between physics and biology as far as general teaching knowledge and skills are concerned. The only exceptions are in Belgium (Flemish Community), where only biology is reported as being the focus of top-

level programme guidelines/qualification standards, and especially in Cyprus, where most aspects are covered in physics guidelines only.

With respect to creating and managing learning situations, only Italy does not include reference to the choice of meaningful learning contexts.

Collaborative work, meaning both interdisciplinary work (that is, working across the school curriculum) and the skills associated with working in teams with other teachers, are comprehensively covered both at ISCED 1 and 2. This is especially true of teamwork at ISCED 2, where only Slovakia is an exception. At ISCED 1, teamwork is also not part of Cypriot and Swedish top-level guidelines. Interdisciplinary work does not feature in Italian or Luxembourg guidelines at all or in Cypriot guidelines at ISCED 2.

**Figure 1.1: Regulations in initial teacher education
with respect to gender and socio-cultural background (ISCED 1 and 2), 2004/05**



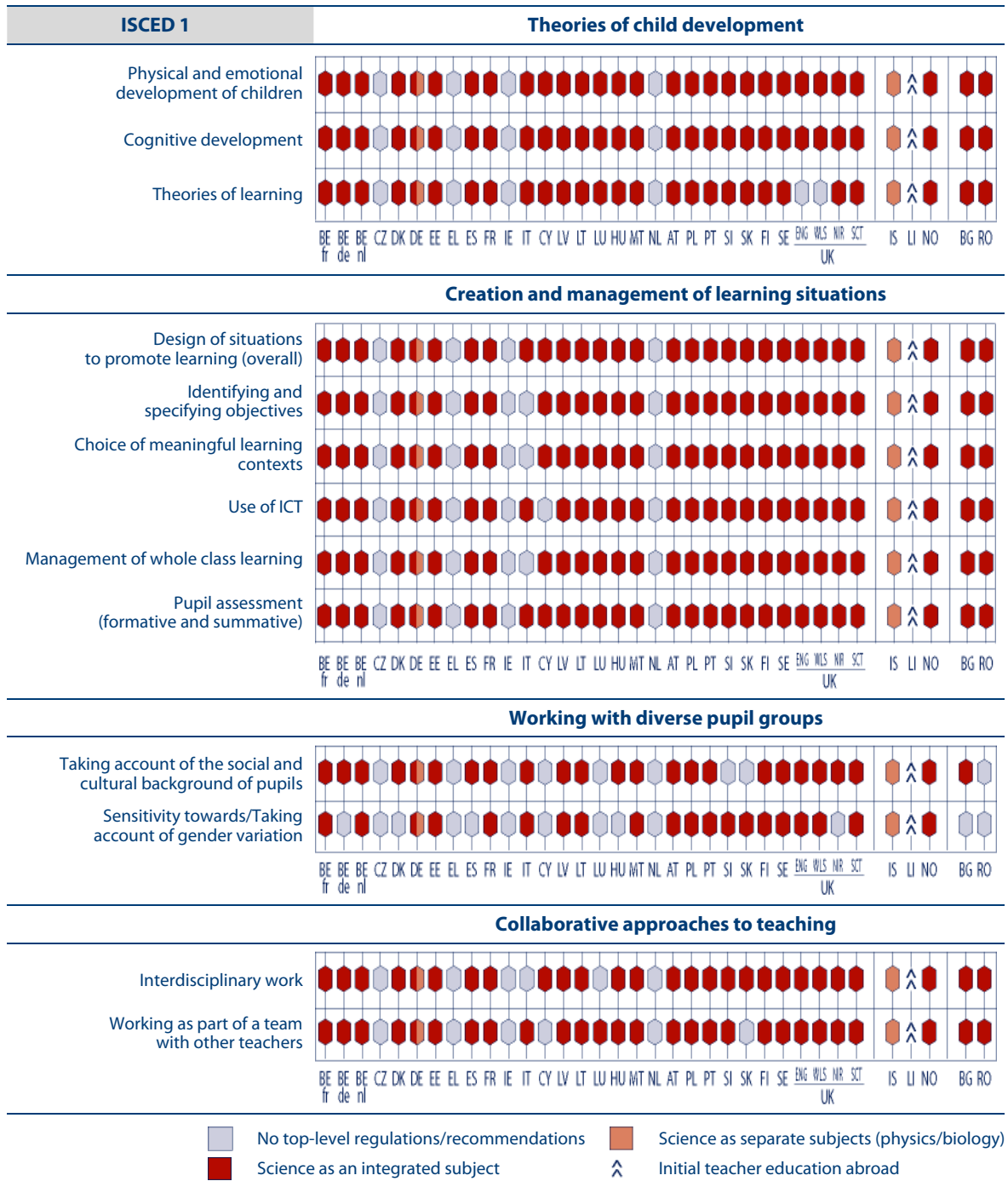
Source: Eurydice.

Additional notes

Cyprus: Top-level regulations at ISCED 2 concern physics teachers only (and not biology teachers).

Malta: There are no official regulations or recommendations. The situation shown refers to the faculty of education (University of Malta), which is the only institution to provide initial teacher education.

**Figure 1.2a: Regulations in initial teacher education
for general teaching knowledge and skills (ISCED 1), 2004/05**



Source: Eurydice.

Figure 1.2b: Regulations in initial teacher education for general teaching knowledge and skills (ISCED 2), 2004/05



Source: Eurydice.

Additional notes (Figures 1.2a and 1.2b)

Belgium (BE de): There is no teacher education for ISCED 2 (study in the French Community of Belgium or abroad).

Belgium (BE nl): Top-level regulations at ISCED 2 concern biology teachers only.

Czech Republic, Greece, Ireland and Netherlands: There are no top-level programme guidelines/qualification standards in this area for teacher education. Teacher education programmes may of course be influenced by centrally determined targets or other criteria not represented in this figure.

Germany: Data are partly based on regulations from each of the 16 *Länder*.

Cyprus: Top-level regulations at ISCED 2 concern physics teachers only (and not biology teachers) in the case of 'theories of learning', 'use of ICT', 'management of whole class learning', 'pupil assessment', 'taking account of the social and cultural background' and 'working as part of a team'.

Malta: There are no official regulations or recommendations. The situation shown refers to the faculty of education (University of Malta), which is the only institution to provide initial teacher education.

Austria: Data for ISCED 2 refer to teacher education at *Pädagogische Akademien* for *Hauptschule* teachers. There are neither regulations nor recommendations in qualitative terms specifically relating to teacher education at universities for *allgemein bildende höhere Schulen* teachers.

Slovenia and Slovakia: National regulations are the Criteria for the Assessment of Teacher Education Programmes and the Accreditation Commission respectively.

Norway: At ISCED 1, science is integrated with social sciences. From 2005/06, there are no compulsory science subjects at ISCED 1.

Explanatory note

- 'Regulations issued by top-level education authorities' are statutory requirements (law, decree, ordinance, etc.) which are of a prescriptive nature.
- 'Recommendations issued by the top-level education authorities' are official but non-statutory guidelines which are of an advisory nature.
- 'Qualification standards' are defined by the central or top-level education authority as being the set of core competencies, relevant knowledge and skills which a teacher must possess (a teacher profile) in order to obtain his or her initial teaching qualification.
- 'Meaningful learning contexts' means contexts likely to make sense to the pupils.
- 'Pupil assessment' means assessment designed to measure the acquisition of knowledge and skills through tests and examinations ('summative assessment') or assessment designed to enhance learning as an integral part of the everyday processes of teaching and learning ('formative assessment').

Besides top regulations in teacher education, it should be noted that other sources (not represented here) are influential in developing the content of teacher education programmes (such as, for example, pupil attainment targets).

Sensitivity towards gender variation in attitudes and motivation, and taking account of these differences in the classroom are aspects of considerable importance, as research shows that there are major differences between most boys and girls in what they would like to learn in their science lessons, in how they prefer to be taught and assessed, and in their attitudes towards science (see 'Science Education Research and the Training of Science Teachers'). However, these are the aspects that are least often cited in top-level programme guidelines/qualification standards as part of teacher education programmes: nine education systems at ISCED 1 and ten at ISCED 2 do not refer to this aspect at all.

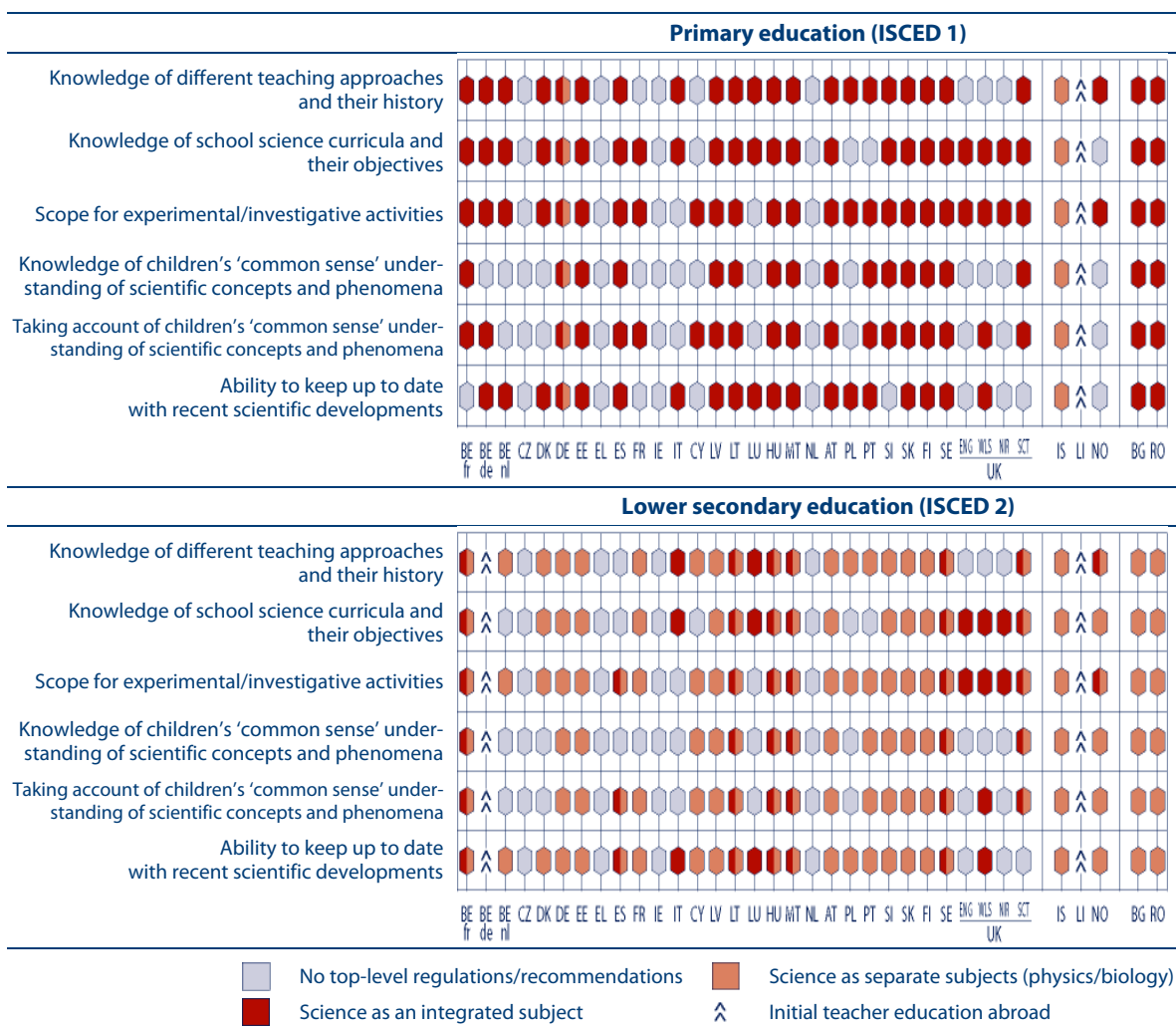
More countries take account of social and cultural differences with respect to pupils' backgrounds. Only five education systems at ISCED 1 and four education systems at ISCED 2 with top-level programme guidelines/qualification standards do not make provision for training in this aspect.

1.2. Teaching knowledge and skills for science

Compared to the general teaching skills shown above, references to specific skills for science teaching are somewhat less frequent in top-level programme guidelines/qualification standards (see Figure 1.3).

Very little difference is apparent between teacher education programmes for primary and secondary levels of education. This is therefore similar to the situation shown for general teaching knowledge and skills above.

**Figure 1.3: Regulations in initial teacher education
for subject-specific teaching knowledge and skills (ISCED 1 and 2), 2004/05**



Source: Eurydice.

Additional notes

Belgium (BE de): There is no teacher education for ISCED 2 (study in the French Community of Belgium or abroad).

Belgium (BE nl): Top-level regulations at ISCED 2 concern biology teachers only.

Czech Republic, Greece, Ireland and Netherlands: There are no top-level programme guidelines/qualification standards in this area for teacher education. Teacher education programmes may of course be influenced by centrally determined targets or other criteria not represented in this figure.

Germany: Data are partly based on regulations from each of the 16 *Länder*.

Italy: Top-level regulations concern teacher education as a whole and are not subject-specific.

Cyprus: Top-level regulations at ISCED 2 concern physics teachers only (and not biology teachers) in the case of 'Knowledge of' and 'Taking account of children's common sense understanding' and 'Ability to keep up to date with recent scientific developments'.

Additional notes (Figure 1.3 – continued)

Malta: There are no official regulations or recommendations. The situation shown refers to the faculty of education (University of Malta), which is the only institution to provide initial teacher education.

Austria: Data for ISCED 2 refer to teacher education at *Pädagogische Akademien* for *Hauptschule* teachers. There are neither regulations nor recommendations in qualitative terms specifically relating to teacher education at universities for *allgemein bildende höhere Schulen* teachers.

Poland: Top-level regulations at ISCED 2 concern physics teachers only (and not biology teachers) in the case of 'Scope for experimental/investigative activities'.

Slovenia and Slovakia: National regulations are the Criteria for the Assessment of Teacher Education Programmes and the Accreditation Commission respectively.

Norway: At ISCED 1, science is integrated with social sciences. From 2005/06, there are no compulsory science subjects at ISCED 1.

Explanatory note

- 'Regulations issued by top-level education authorities' are statutory requirements (law, decree, ordinance, etc.) which are of a prescriptive nature.
- 'Recommendations issued by the top-level education authorities' are official but non-statutory guidelines which are of an advisory nature.
- 'Qualification standards' are defined by the central or top-level education authority as being the set of core competencies, relevant knowledge and skills which a teacher must possess (a teacher profile) in order to obtain his or her initial teaching qualification.
- 'Common sense understanding of scientific concepts and phenomena' are forms of spontaneous/pre-scientific reasoning show important differences from scientific reasoning. These forms of reasoning have given rise to explanations of phenomena known as naïve conceptions or representations/common-sense understanding.
- 'Experimentation/investigation' refers to experiment-based work that introduces students/pupils to the various processes and activities that lead to the formulation of a problem and of a scientific hypothesis or model, the gathering of data, the conducting of appropriate experiments and the analysis and presentation of results.

Besides top regulations in teacher education, it should be noted that other sources (not represented here) are influential in developing the content of teacher education programmes (such as, for example, pupil attainment targets).

Experimental/investigative science activities feature very frequently in top-level programme guidelines/qualification standards at both levels of education. In Norway, it is the only aspect referred to in top-level guidelines (together with knowledge of different teaching approaches). Italy and Luxembourg refer to this type of activity only at ISCED 1.

A second area that is very well covered is knowledge of different teaching approaches (in science) and their history, together with knowledge of school science curricula and their objectives. Top-level programme guidelines ensure that intending science teachers are trained in this area in almost every education system.

Science teaching at school must be sensitive to children's 'common sense' understanding of scientific phenomena in order to be effective (that is, spontaneous or pre-scientific reasoning leading to naïve representations or conceptions of phenomena). This has been conclusively shown in a broad body of research, which underlines the myriad ways in which children see and interpret the world around them (see 'Science Education Research and the Training of Science Teachers'). Knowledge of what this implies and the ability to take account of such 'common sense' understanding in the science classroom and laboratory are, however, missing from top-level programme guidelines/qualification standards in 13 education systems at ISCED 1 and at 11 education systems at ISCED 2.

Finally, keeping up to date with scientific developments is important at both levels of education almost everywhere, although in Belgium (French Community), France, Cyprus, Slovenia and the United Kingdom (Scotland), only teachers at ISCED 2 are covered by this requirement.

1.3. Scientific knowledge and skills

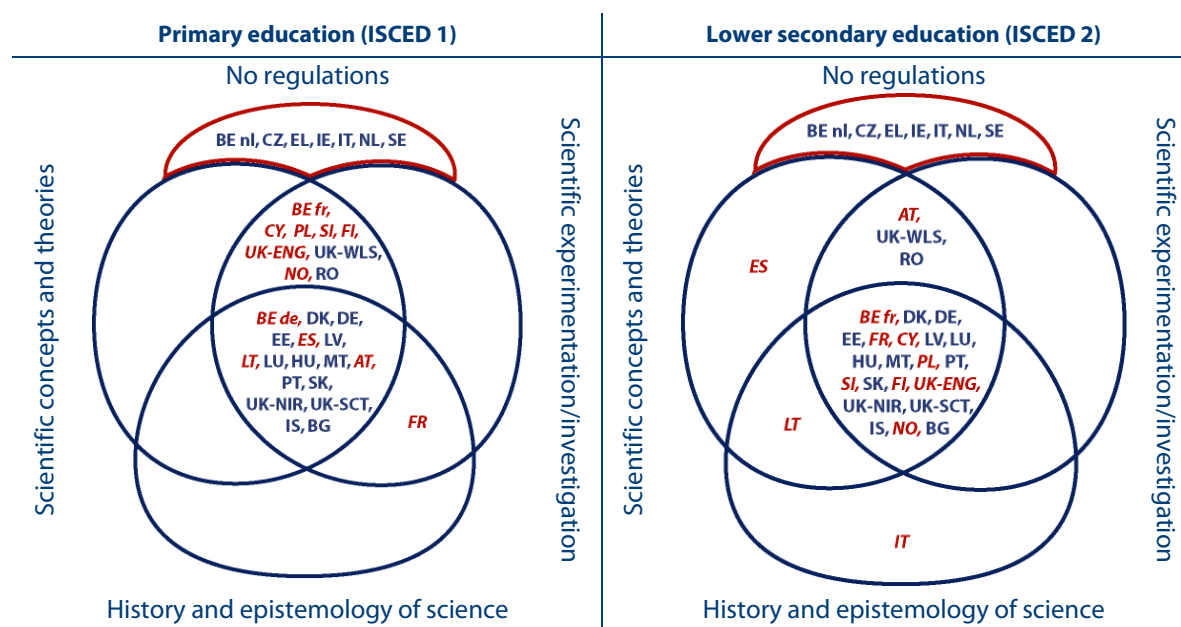
Teaching science is of course not only about having the requisite teaching skills, but is also about having a sound subject-based knowledge. In this third section, the focus is more on scientific knowledge as such rather than on teaching skills. Figure 1.4 gives a general overview of top-level programme guidelines/qualification standards on three main dimensions (scientific concepts and theories, history and epistemology of science, scientific experimentation/investigation), while Figure 1.5 provides some more detail with respect to the types of scientific experimental/investigative activities offered in teacher education.

Almost every education system with top-level guidelines includes reference to knowledge of scientific concepts and theories. The only exceptions are the Flemish Community of Belgium, France (ISCED 1), Italy and Sweden. These exceptions (not France), together with Spain and Lithuania (both at ISCED 2), also apply to guidelines on scientific experimental/investigative activities. Thus, the first two areas are very comprehensively covered in top-level teacher education guidelines in Europe.

This is only slightly less true of knowledge of history and epistemology of science, as almost half of education systems also refer to this aspect in their top-level programme guidelines/qualification standards (it is worth noting that this is the only area covered in Italian guidelines (at ISCED 2)). It is also noteworthy that in Cyprus and Poland, where there is differentiated provision for physics and biology at ISCED 2, the history and epistemology of science is covered in physics but not in biology teacher education.

In general, the situation is the same irrespective of whether teacher education is for ISCED 1 or 2, although in a few cases (the French Community of Belgium, Italy, Cyprus, Poland, Finland, the United Kingdom (England) and Norway (not integrated science), the history and epistemology of science is only covered at ISCED 2. In Spain and Austria, however, coverage at ISCED 1 is more comprehensive. In Spain, this is because these areas have already been covered in the general component of teacher education (in the consecutive model).

**Figure 1.4: Regulations in initial teacher education
for scientific knowledge and skills (ISCED 1 and 2), 2004/05**



Differences between ISCED 1 and 2

Source: Eurydice.

Additional notes

Belgium (BE de): There is no teacher education for ISCED 2 (study in the French Community of Belgium or abroad).

Czech Republic, Greece, Ireland and Netherlands: There are no top-level programme guidelines/qualification standards in this area for teacher education. Teacher education programmes may of course be influenced by centrally determined targets or other criteria not represented in this figure.

Germany: Data are partly based on regulations from each of the 16 *Länder*.

Lithuania: Knowledge of and competence in scientific experimentation/investigation at ISCED 1 applies only to non-university teacher education (ISCED 5B).

Malta: There are no official regulations or recommendations. The situation shown refers to the faculty of education (University of Malta), which is the only institution to provide initial teacher education.

Austria: Data for ISCED 2 refer to teacher education at *Pädagogische Akademien* for *Hauptschule* teachers. There are neither regulations nor recommendations in qualitative terms specifically relating to teacher education at universities for *allgemein bildende höhere Schulen* teachers.

Slovenia and Slovakia: National regulations are the Criteria for the Assessment of Teacher Education Programmes and the Accreditation Commission respectively.

Liechtenstein: Teacher education takes place abroad.

Norway: At ISCED 1, science is integrated with social sciences. From 2005/06, there are no compulsory science subjects at ISCED 1.

Explanatory note

- 'Regulations issued by top-level education authorities' are statutory requirements (law, decree, ordinance, etc.) which are of a prescriptive nature.
- 'Recommendations issued by the top-level education authorities' are official but non-statutory guidelines which are of an advisory nature.
- 'Qualification standards' are defined by the central or top-level education authority as being the set of core competencies, relevant knowledge and skills which a teacher must possess (a teacher profile) in order to obtain his or her initial teaching qualification.
- 'Scientific experimentation/investigation' refers to experiment-based work that introduces students/pupils to the various processes and activities that lead to the formulation of a problem and of a scientific hypothesis or model, the gathering of data, the conducting of appropriate experiments and the analysis and presentation of results.

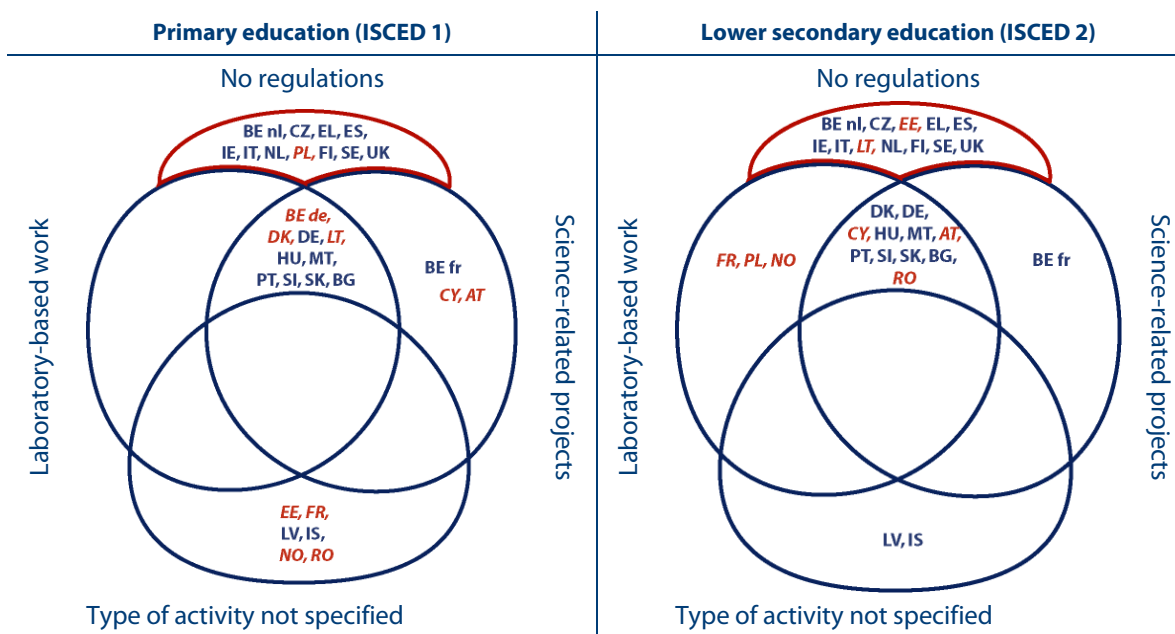
Besides top regulations in teacher education, it should be noted that other sources (not represented here) are influential in developing the content of teacher education programmes (such as, for example, pupil attainment targets).

The question of whether initial teacher education equips specialist and generalist teachers with skills in scientific experimentation and investigation was explored further to look at the types of scientific activity that trainees undertake (Figure 1.5).

Some form of project work is a widespread element of science teacher education: almost half of education systems with top-level programme guidelines/qualification standards refer to provision for teacher training (ISCED 1) including science-related projects. A second type of science-related activity sometimes included in training for primary school science teaching is laboratory work, although this is a little less common: ten education systems include this type of activity alongside project work. Six other education systems make reference to the requirement to engage in scientific experimentation and investigation, without specifying the types of activity required. This means that according to top-level programme guidelines/qualification standards, some trainees due to teach science at ISCED 1 may not be required to undertake practical training in scientific experimental or investigative skills because almost half of education systems do not make any reference to this type of training in top-level programme guidelines/qualification standards. This is probably a reflection of the fact that many teachers at ISCED 1 are generalists. They are trained to teach all, or almost all, the subjects on the school curriculum and do not necessarily have a specialisation in science.

At secondary level, many science teachers are specialists, which is evident in the top-level requirements on scientific experimental/investigative activities. Laboratory work is required in 15 education systems. In Cyprus and Poland, trainee physics teachers are required to do laboratory work, or alternatively a placement in a research laboratory. The latter is also an option in Romania and Bulgaria. Science-related projects are required in 13 education systems while a few countries do not specify the type of activity that is required.

**Figure 1.5: Regulations in initial teacher education
for scientific experimental/investigative skills (ISCED 1 and 2), 2004/05**



Differences between ISCED 1 and 2

Source: Eurydice.

Additional notes (Figure 1.5)

Belgium (BE de): There is no teacher education for ISCED 2 (study in the French Community of Belgium or abroad).

Czech Republic, Greece, Ireland and Netherlands: There are no top-level programme guidelines/qualification standards in this area for teacher education. Teacher education programmes may of course be influenced by centrally determined targets, standards or other criteria not represented in this figure.

Germany: Data are partly based on regulations from each of the 16 *Länder*.

Lithuania: Data refer to non-university teacher education (ISCED 5B) only.

Luxembourg: Data not available.

Malta: There are no official regulations or recommendations. The situation shown refers to the faculty of education (University of Malta), which is the only institution to provide initial teacher education.

Austria: Data for ISCED 2 refer to teacher education at *Pädagogische Akademien* for *Hauptschule* teachers. There are neither regulations nor recommendations in qualitative terms specifically relating to teacher education at universities for *allgemein bildende höhere Schulen* teachers.

Slovenia and Slovakia: National regulations are the Criteria for the Assessment of Teacher Education Programmes and the Accreditation Commission respectively.

United Kingdom (ENG/WLS/NIR): Initial teacher training providers must ensure that teachers have knowledge and understanding of the statutory pupil curriculum, including its experimental and investigative science requirements.

Liechtenstein: Teacher education takes place abroad.

Norway: At ISCED 1, science is integrated with social sciences. From 2005/06, there are no compulsory science subjects in schools at ISCED 1.

Explanatory note

- ‘Regulations issued by top-level education authorities’ are statutory requirements (law, decree, ordinance, etc.) which are of a prescriptive nature.
- ‘Recommendations issued by the top-level education authorities’ are official but non-statutory guidelines which are of an advisory nature.
- ‘Laboratory work’ is carried out in a laboratory or elsewhere as part of a science course. Such work may be routine (for example, involving simple observations or measurements) or have something of an investigative character.
- ‘Science project work’ involves experimental or other work in the laboratory or elsewhere and always has an investigative character.

Besides top regulations in teacher education, it should be noted that other sources (not represented here) are influential in developing the content of teacher education programmes (such as, for example, pupil attainment targets).

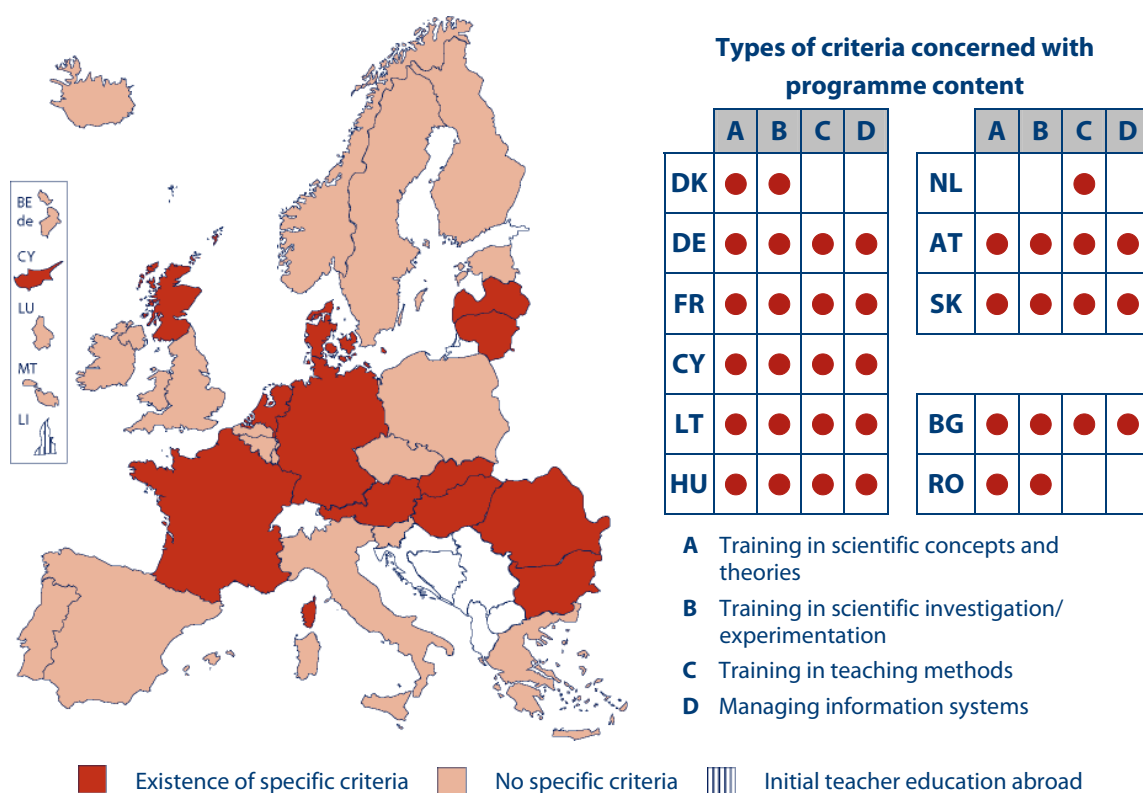
The information presented in these first three sections shows that regulations, recommendations or qualification standards defined by top-level education authorities have quite a lot to say about what should be included in science teacher education, not only in terms of general teaching skills but also in terms of skills and knowledge more specific to science as a discipline. This holds true for both levels of education (very slightly more so at ISCED 2 than at ISCED 1) and for the three science subjects – integrated science, physics and biology – covered by the data collection. Top-level programme guidelines/qualification standards are therefore characterised by a broad uniformity of treatment. This is perhaps not surprising, if it is accepted that these guidelines set a general framework for teacher education, which is subsequently filled out and given substance within the programmes developed by each teacher education institute.

1.4. Specific accreditation criteria

In many European countries, higher education institutions enjoy considerable or, in some instances, full management autonomy. Accreditation is one of the means adopted by the central or top-level education authorities for ensuring compliance with certain quality standards in the training offered in higher education. Accreditation is thus a process through which the legislative and professional authorities judge whether an institution or a programme meets predetermined quality standards authorising it to offer a particular course and award the corresponding qualification.

The aim of this section is not to deal with accreditation criteria in general, but to examine whether there are criteria specific to the initial training of teachers qualified to teach science at primary and lower secondary levels.

**Figure 1.6: Specific accreditation criteria
for programmes of initial teacher education for science teachers (ISCED 1 and 2), 2004/05**



Source: Eurydice.

Additional notes

Belgium (BE de): There is no teacher education for ISCED 2 (study in the French Community of Belgium or abroad).

Lithuania: The information relates solely to programmes offered by non-university higher education institutions. There are no specific accreditation criteria for university initial teacher education programmes.

Austria: Criteria A, B, C and D relate solely to training programmes in the *Pädagogische Akademien*.

Romania: The information relates solely to teacher education offered at ISCED level 5. For provision at ISCED 3 (*Liceu pedagogic*), the criteria refer to the content of programmes, which have to comply with national norms, and the quality of the training on offer. They are also concerned with pupil assessment.

Explanatory note

Accreditation: A process through which the legislative and professional authorities judge whether an institution or a programme meets predetermined quality standards authorising it to offer a particular form of (teacher) education and award the corresponding qualifications.

Thirteen education systems in Europe have accreditation criteria for programmes of initial teacher education (which include the final 'on-the-job' qualifying or induction phase in some countries) that are specific to programmes for intending science teachers. These criteria may relate to various aspects, including the content of programmes, staff support for students or, more specifically, to organisational matters.

In all countries except Latvia and the United Kingdom (Scotland), the criteria are concerned with the content of training programmes. In France, for example, the *Instituts Universitaires de Formation des Maîtres* (IUFMs, or university teacher education institutes) are expected to comply with a remit covering the three aspects of training (placements, teaching and personal work).

Accreditation criteria concerned with programme content relate to fundamental aspects of initial science teacher education, namely training in scientific concepts and theories, training in scientific experimentation/investigation, training in teaching methods and, to a lesser extent, in managing information systems.

CHAPTER 2

SCIENCE TEACHER TRAINERS

Introduction

The professional component of initial teacher education sets out to provide student teachers with theoretical and practical knowledge and expertise for their future profession. Besides courses in methodology and psychology given by teacher trainers, it also involves periods of classroom teaching. These are supervised by the teacher responsible for the class concerned and are periodically evaluated by staff from the training institution.

This chapter examines regulations or recommendations emanating from the central or top-level education authorities, concerning the qualifications and professional experience of those responsible for the professional component of initial teacher education for future science education.

The first section is concerned with the teacher trainers who work in institutions for initial teacher education and give theoretically oriented classes in professional training. The second section focuses on those in schools who are responsible for guiding or supervising prospective teachers in their practical training in placements during initial training and/or in a final 'on-the-job' qualifying or induction phase.

In almost all countries, prospective science teachers have to undertake a practical placement in a school during their initial training and/or final 'on-the-job' qualifying phase. In Greece, where institutions for initial teacher education are free to decide as they wish in this respect, such placements are not compulsory.

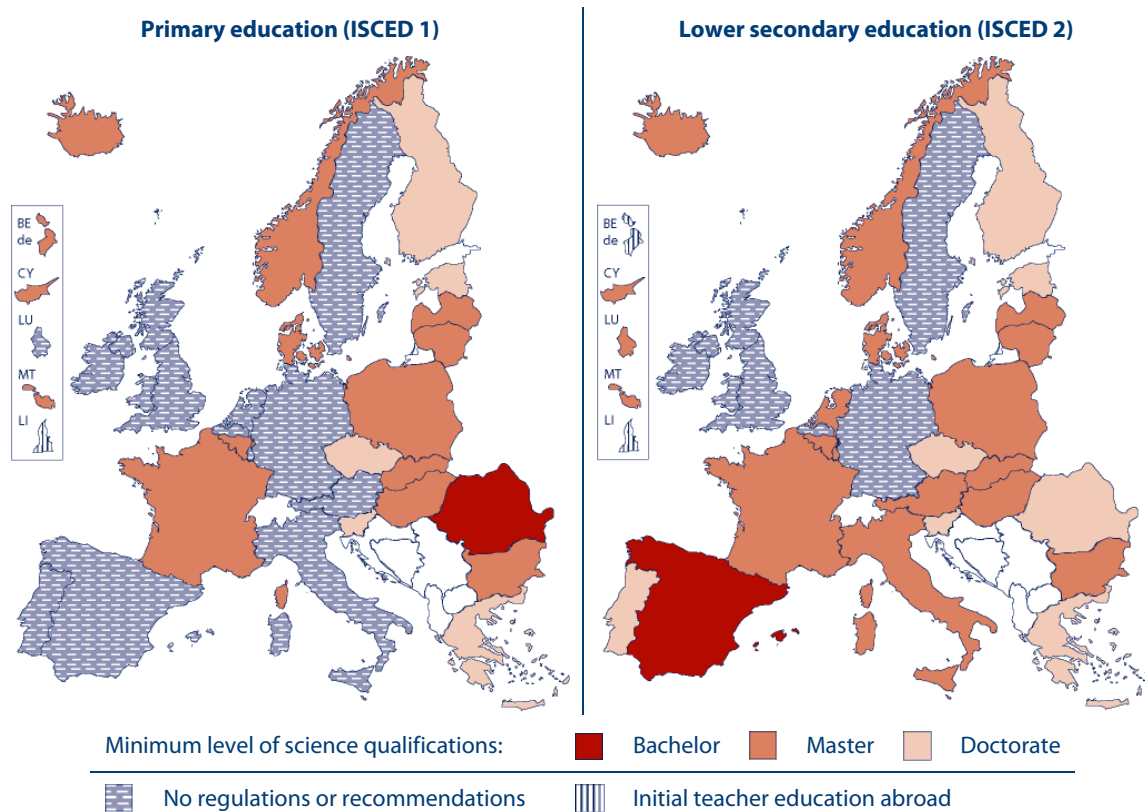
2.1. Trainers in institutions for initial teacher education

Qualification levels in science

In around 20 education systems, the level of the higher education qualification in science required of teacher trainers responsible for the professional component in the training of science teachers is specified in regulations or recommendations. A master's-level qualification is called for in most cases. However, a bachelor's type science qualification is required in Spain (ISCED 2) and Romania (ISCED 1), while teacher trainers in Estonia, Greece, Portugal, Romania (ISCED 2), the Czech Republic, Slovenia and Finland have to hold a doctorate in a science subject.

In Spain, Italy, Luxembourg, the Netherlands, Austria and Portugal, there are no regulations concerning the science qualifications of those who teach the professional component in the training of science teachers for primary education, whereas corresponding measures are applicable to teacher trainers for lower secondary education. Spain requires a bachelor's-level qualification, Italy, Luxembourg, the Netherlands and Austria a master's-level qualification, and Portugal a doctorate.

Figure 2.1: Minimum level of science qualifications required of teacher trainers responsible for the initial professional training of science teachers (ISCED 1 and 2), 2004/05



Source: Eurydice.

Additional notes

Belgium (BE de): Initial teacher education for secondary education is provided outside the German-speaking Community. Most teachers do their training in the French Community of Belgium.

Latvia: Persons with a bachelor's-level qualification and sufficient experience in the field of science or as science teachers are legally entitled to occupy posts as trainers responsible for the initial professional training of science teachers.

Malta: There are no official regulations or recommendations. The situation shown refers to the faculty of education (University of Malta), which is the only institution to provide initial teacher education. The university requires all teaching staff to obtain a doctorate if they do not already have one.

Portugal: In the Polytechnic institutes, there are no regulations or recommendations regarding the minimum level of science qualifications for teacher trainers (for ISCED level 1). In the universities, a doctorate is required.

Romania: In the case of ISCED 1, information relates solely to staff working in training institutions at upper secondary level (ISCED 3). In the case of ISCED 2, it relates to teaching staff in colleges for teacher education (ISCED 5B) as well as in higher education institutions at ISCED level 5A.

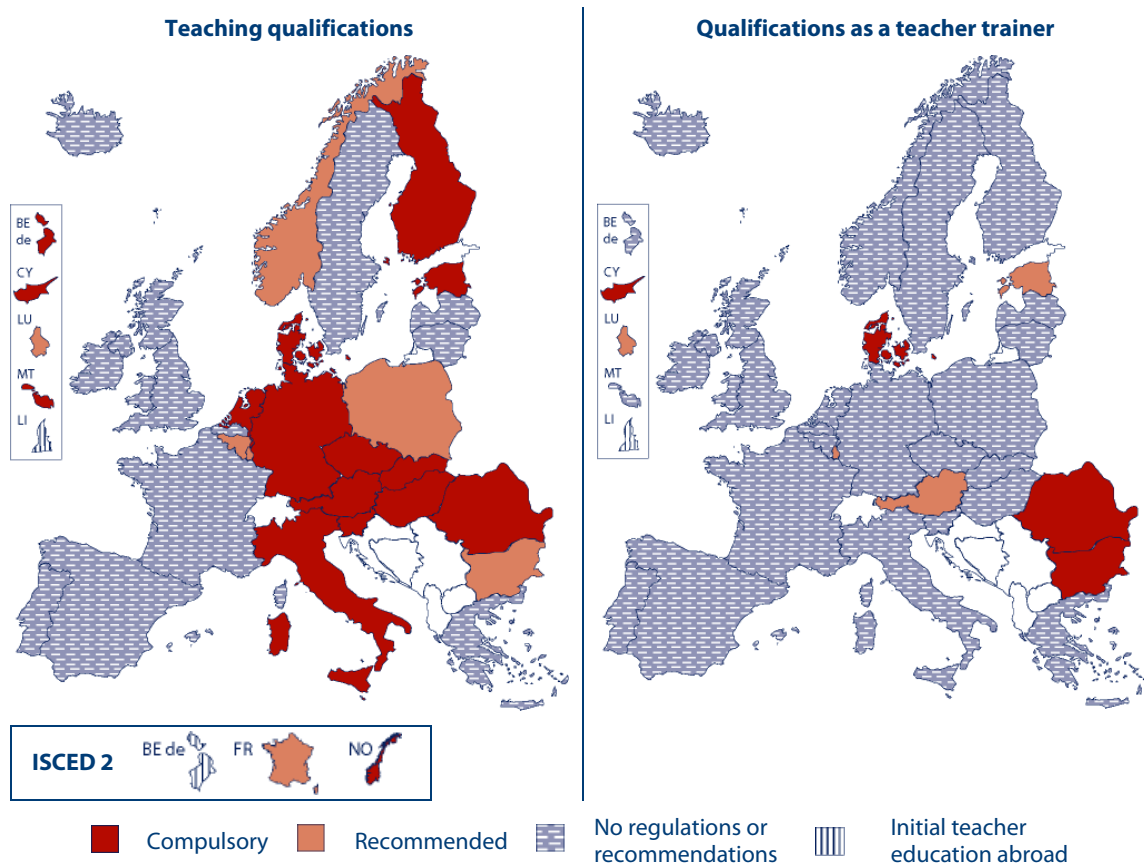
Explanatory note

Qualification: Diploma or certificate awarded by an institution for teacher education and/or the central or top-level education authorities, in official recognition of the skills and knowledge of its holder.

Teaching-type qualifications

Teaching qualifications are also the subject of either regulations or recommendations in the majority of countries. Those responsible for the professional component in the training of teachers qualified to teach science in primary education are required to possess such qualifications in 14 education systems. They are recommended in five others.

Figure 2.2: Teaching and teacher training qualifications required of those responsible for the initial professional training of science teachers (ISCED 1 and 2), 2004/05



Source: Eurydice.

Additional notes

Belgium (BE de): Initial teacher education for secondary education is provided outside the German-speaking Community. Most teachers do their training in the French Community of Belgium.

Latvia: Teacher trainers have to do in-service courses during which they develop their knowledge of psychology, teaching and education studies in general. These courses also provide them with an opportunity to develop their skills in a preferred area of scientific research.

Malta: There are no official regulations or recommendations. The situation shown refers to the faculty of education (University of Malta), which is the only institution to provide initial teacher education.

Austria: At ISCED 2, the situation shown relates to recommendations regarding the qualifications of those who train *Hauptschule* teachers. There are no recommendations concerning the teaching qualifications of teacher trainers in the professional component of initial teacher education for the *allgemein bildende höhere Schulen*.

Romania: In the case of ISCED 1, information relates solely to staff working in training institutions at upper secondary level (ISCED 3). In the case of ISCED 2, it relates to teaching staff in colleges for teacher education (ISCED 5B) as well as in higher education institutions at ISCED level 5A.

Explanatory note (Figure 2.2)

Teaching qualifications: A degree, diploma or certificate in education and teaching. It is awarded by an institution for teacher education and/or the central or top-level education authorities, in official recognition of the skills and knowledge of its holder.

Qualifications as a teacher trainer: A degree, diploma or certificate testifying that its holder has the knowledge and skills necessary to train teachers. It is awarded by an institution for teacher education and/or the central or top-level education authorities, in official recognition of the skills and knowledge of its holder.

In contrast to what is observed in the case of science and teaching qualifications, only a minority of countries possess regulations concerning the specific qualifications of a teacher trainer. The latter are compulsory in just two countries of central Europe (Bulgaria and Romania), as well as in Denmark and Cyprus in the case of those who train teachers for primary and lower secondary levels. Three other countries recommend that teacher trainers should possess such qualifications.

In Belgium (the German-speaking Community), a June 2005 decree enables teachers in primary education with at least ten years' experience to become teacher trainers themselves within a non-university higher education institution in the education studies sector, in which primary school teachers are trained. The decree thus enables those without a university qualification to obtain a post within a higher education institution. In the French Community, it is also possible under certain circumstances for teachers in primary and secondary education to teach in a non-university higher education institution. Since January 2005 in the Czech Republic, teacher trainers have to hold a doctorate in education studies.

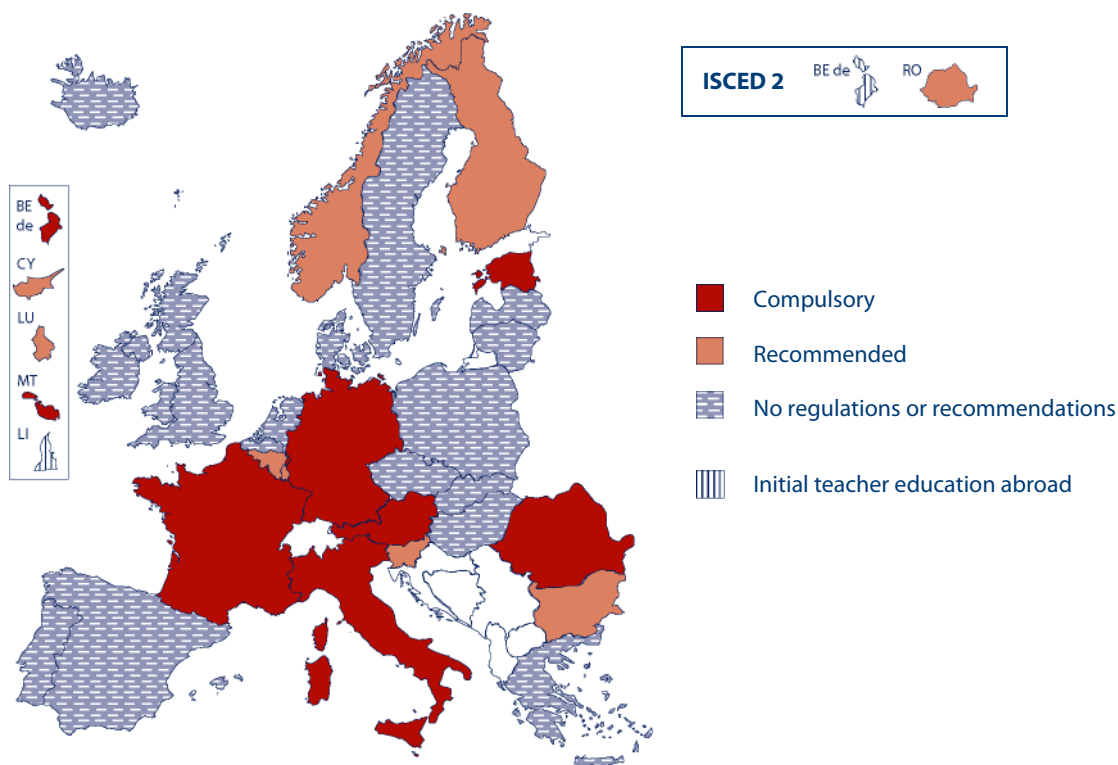
In the Czech Republic, Estonia and Lithuania, regulations also apply to training programmes. Thus, in these countries, the regulations specify the percentage of class time (Czech Republic and Estonia) or the number of subjects (Lithuania) that should be taught by teachers with a doctorate or who are engaged in research.

In countries where higher education institutions enjoy considerable independence and where there are relatively few regulations concerning the specific qualifications of teacher trainers, the central or top-level education authorities may issue other types of recommendation to ensure the quality of their provision. For example, in Sweden, a law refers to the need for experienced and highly qualified teacher trainers. In the United Kingdom (England), the need to have a sufficient number of qualified staff constitutes one of the accreditation criteria with which teacher education providers have to comply.

Professional experience

Around 15 countries have regulations requiring or recommending that teacher trainers should have experience themselves as teachers. In this respect, there are few differences between teacher trainers for primary education and for lower secondary level.

Figure 2.3: Teaching experience required of trainers responsible for the initial professional training of science teachers (ISCED 1 and 2), 2004/05



Source: Eurydice.

Additional notes

Belgium (BE de): Initial teacher education for secondary education is provided outside the German-speaking Community. Most teachers do their training in the French Community of Belgium.

Latvia: Experience acquired as teachers, or more broadly in the field of science, is required of trainers with no more than a bachelor's-level qualification.

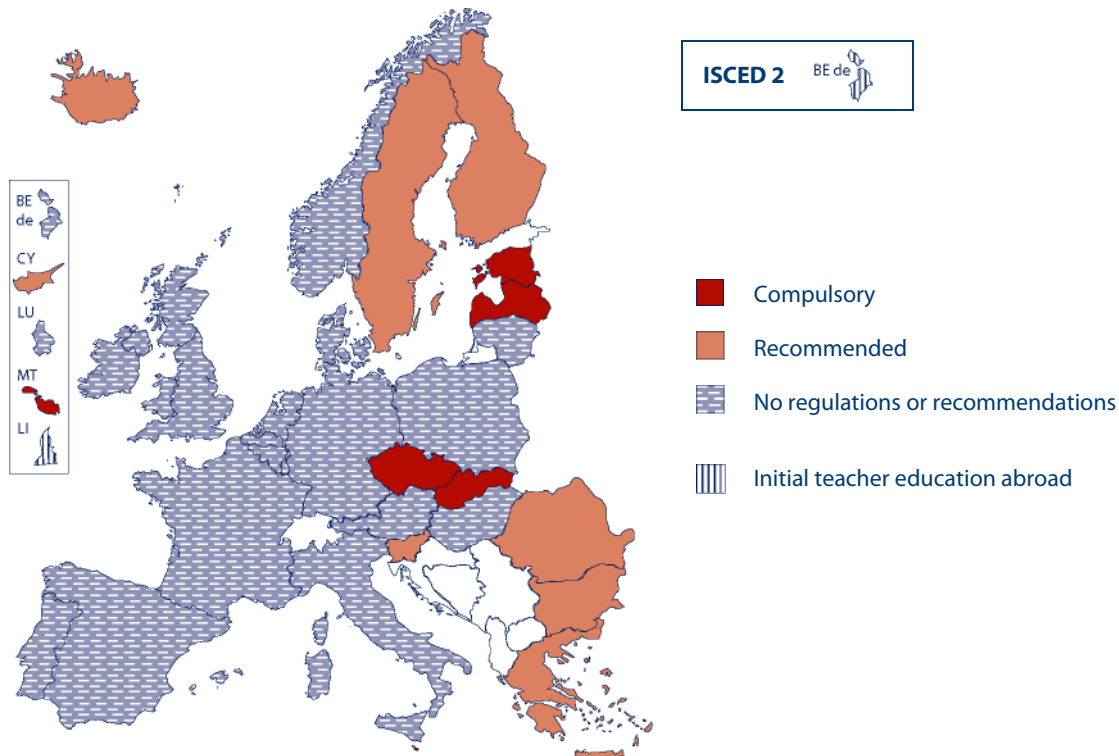
Malta: There are no official regulations or recommendations. The situation shown refers to the faculty of education (University of Malta), which is the only institution to provide initial teacher education.

Austria: There are no recommendations concerning the professional teaching experience of teacher trainers in the professional component of initial teacher education for the *allgemein bildende höhere Schulen*. At ISCED 2, the situation shown relates to recommendations regarding those who train *Hauptschule* teachers.

Romania: In the case of ISCED 1, information relates solely to staff working in training institutions at upper secondary level (ISCED 3). In the case of ISCED 2, it relates to teaching staff in colleges for teacher education (ISCED 5B) as well as in higher education institutions at ISCED level 5A.

Less than half of all countries have regulations on the need to possess experience in education research. This experience is compulsory in four countries of central Europe, namely the Czech Republic, Estonia, Latvia and Slovakia, as well as in Malta. Furthermore, in certain countries such as Poland and Norway, it is recommended that teacher trainers should have some experience of authoring science textbooks.

Figure 2.4: Experience in education research of teacher trainers responsible for the professional component of initial teacher education for science teachers (ISCED 1 and 2), 2004/05



Source: Eurydice.

Additional notes

Belgium (BE de): Initial teacher education for secondary education is provided outside the German-speaking Community. Most teachers do their training in the French Community of Belgium.

Hungary: Experience in education research has become mandatory under the new law on higher education which took effect on 1 March 2006.

Malta: There are no official regulations or recommendations. The situation shown refers to the faculty of education (University of Malta), which is the only institution to provide initial teacher education.

Romania: In the case of ISCED 1, information relates solely to staff working in colleges for teacher education (ISCED 5B). No regulations or recommendations apply to those who work in training institutions at upper secondary level (ISCED 3) and who train some ISCED 1 teachers. In the case of ISCED 2, the information relates to teaching staff in colleges for teacher education (ISCED 5B) as well as in higher education institutions at ISCED level 5A.

Explanatory note

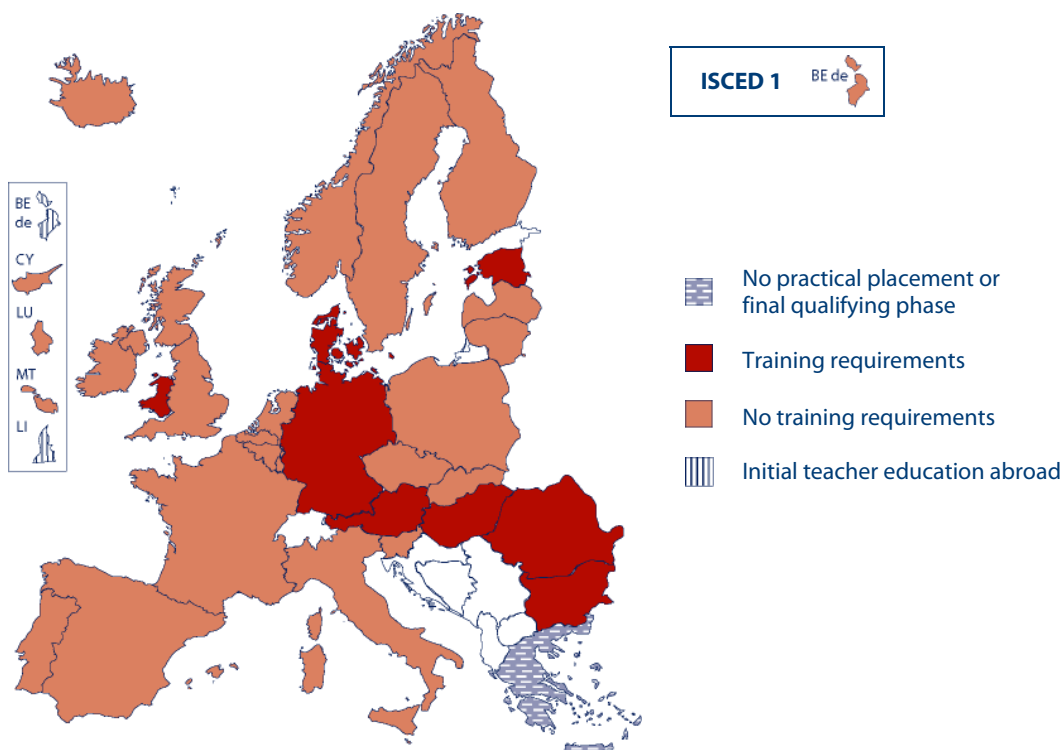
The experience concerned may have been acquired before obtaining the post as a trainer, or when trainers are already in service.

More generally, the experience and qualifications of university teachers are currently the subject of debate in Estonia. Here, higher education institutions are in the process of developing a qualifications blueprint incorporating all skills which academic staff should possess, including staff responsible for the professional component of initial teacher education. In France, the 2005 law on the future of schools states that a trainers' charter will be drawn up. Furthermore, by 2010, the National Committee for the evaluation of public institutions of a scientific, cultural and professional nature has to undertake an evaluation of the methods and results of integrating the *Instituts Universitaires de Formation des Maîtres* (IUFMs, or university teacher education institutes) within the universities. This evaluation is expected to have implications for the qualifications of those responsible for providing training in IUFMs.

2.2. Trainers responsible in schools

This section considers staff who mentor or support student teachers within schools during their practical placement and/or final 'on-the-job' qualifying or induction phase. It aims first to identify those concerned and then to indicate whether regulations or recommendations require them to have completed any special training in order to assume responsibility for mentoring or support.

Figure 2.5: Training requirements for mentoring or supervisory staff in schools that arrange practical placements for prospective science teachers (ISCED 1 and 2), 2004/05



Source: Eurydice.

Additional notes

Belgium (BE de): Initial teacher education for secondary education is provided outside the German-speaking Community. Most teachers do their training in the French Community of Belgium.

Spain: The situation depends on the particular Autonomous Community: in some Autonomous Communities, training is recommended or compulsory but, in the majority, there are no regulations on these matters.

Austria: Training requirements for mentoring or support staff are regulated at Land level. However, all such staff have to undergo training.

United Kingdom (WLS): The map shows the situation in the final 'on-the-job' qualifying phase (the *induction year*). In the case of the practical placement, there are no corresponding regulations.

Explanatory note

The final 'on-the-job' qualifying or induction phase/year, which exists in just some countries, is a compulsory period of transition between initial teacher education and the professional life of fully fledged teachers. It is treated here as the final phase of initial teacher education. This induction phase includes an important supportive and supervisory dimension, as well as a formal evaluation of teaching skills. During this period, teachers are still not fully qualified and are usually regarded as 'candidates' or 'trainees'. They spend a significant amount of time in a real working environment (a school) in which they carry out wholly or partially the tasks incumbent on fully qualified teachers, and are remunerated for their activity.

In all countries except Malta, the work of student teachers during their practical placement and/or final 'on-the-job' qualifying (or induction) phase is monitored by school staff members. In Malta, this supervision is carried out by members of the faculty of education at the University of Malta, where student teachers are trained. However, the latter also get informal support from schools during their placement.

In the majority of countries, teachers themselves are responsible for mentoring or support. However, in a few countries, this role is undertaken either by the head of the science department, as in Belgium (the Flemish Community), or the school head, as in the Czech Republic and Slovakia.

In two other countries, the situation varies depending on the context and phase of training. Thus, in Germany, responsibility for mentoring is assumed solely by the school head in the case of practical placements and is shared by the school head, the head of department and a teacher during the final 'on-the-job' qualifying (or induction) phase. In Austria, teachers supervise students during practical placements whereas, during the final qualifying phase, the final assessment of prospective *allgemein bildende höhere Schulen* teachers is conducted jointly by the teacher responsible for them and the school head.

In a minority of countries, most of them in central Europe, it is compulsory for persons who provide this mentoring or support to receive special training, or recommended that they should do so. In Estonia, for example, staff who act as mentors to prospective teachers during the final 'on-the-job' qualifying (induction) phase should have at least five years of experience and have completed a university course geared specifically to assuming this kind of responsibility. In Romania, they have to receive specialised in-service training in mentoring students on placements.

In several countries, decisions concerning this matter are taken at more decentralised levels of authority. Thus, in Spain the situation depends on the particular Autonomous Community: in some Autonomous Communities, training is recommended or compulsory but, in the majority, there are no regulations on these matters. In Sweden, school heads themselves decide whether to allocate resources for training mentors or support staff.

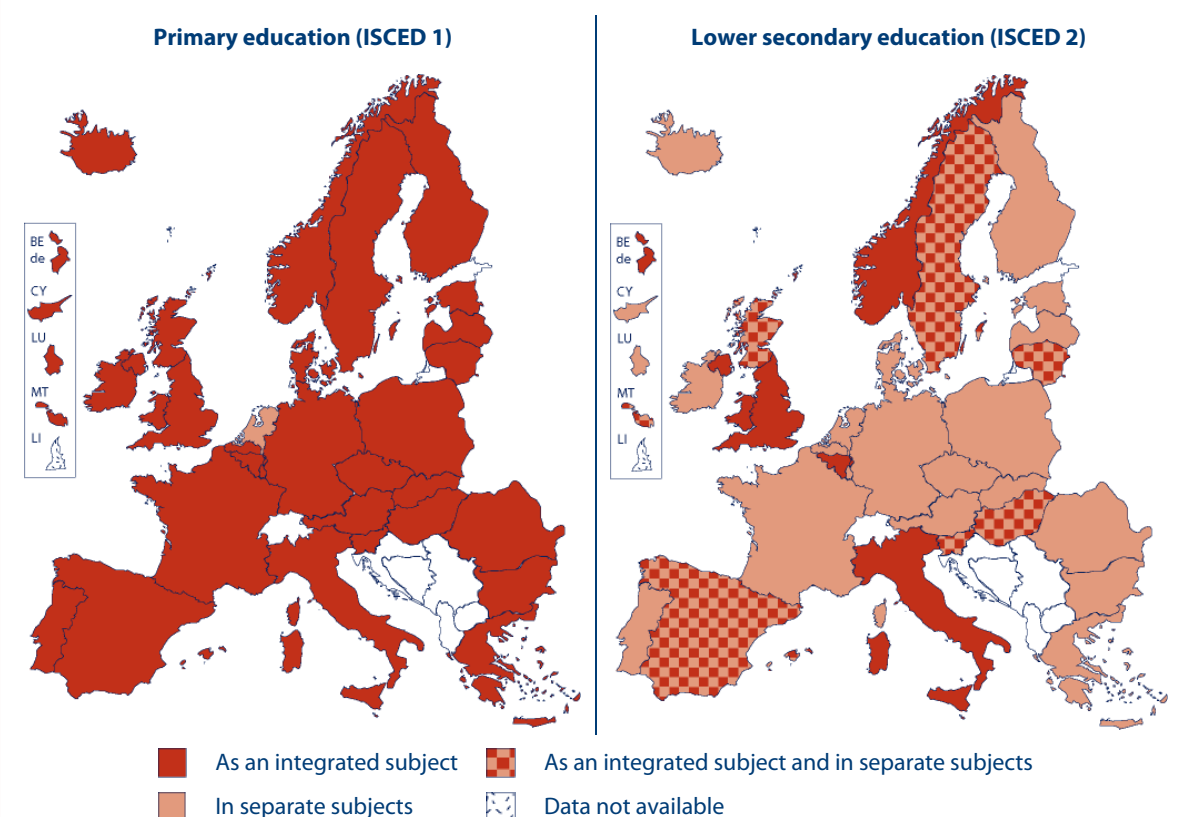
Some countries report the existence of local measures designed to ensure that supervisory responsibilities are given to persons with appropriate skills and experience. For example, in Belgium (the German-speaking Community) and Italy, mentoring and support are generally provided by outstanding teachers whose work is recognised both by their peers and those above them. In France, teachers responsible for monitoring students on placements are identified by members of the inspectorate and are selected for their professional excellence. In Latvia and Slovakia, the most experienced teachers monitor students on placements. In the United Kingdom (England, Wales and Northern Ireland) and France, some higher education institutions organise training for the teachers who are going to supervise students.

CHAPTER 3

THE SCHOOL SCIENCE CURRICULUM

This chapter is concerned with the position of science teaching in the prescribed or recommended curriculum for primary and general lower secondary education, together with the approaches advocated and the aims pursued. Depending on the level of detail in official documents on the types of activity to be provided and the skills that pupils should be encouraged to develop, the recommendations contained in them may have a considerable bearing on how science teachers organise their work. In many countries, moreover, such documents serve as a frame of reference in the initial training of these teachers, helping to guide them in their activity.

Figure 3.1: Organisation of science teaching according to the prescribed or recommended curriculum (ISCED 1 and 2), 2004/05



Source: Eurydice.

Additional notes

Czech Republic: The data are based on *Základní škola* programmes. The *Obecná škola* and *Národní škola* have their own distinct programmes.

Finland: From 2006/07, science subjects will be taught separately in the last two years of ISCED 1.

Luxembourg: In the ISCED 2 technical *lycées*, science is taught on an integrated basis.

Netherlands: At ISCED level 2, an integrated approach is encouraged. The aims of teaching, which are being introduced with effect from 2006, are being based on 'man and nature', instead of biology, physics and chemistry. However, schools are free to offer separate subjects or a more integrated approach.

Explanatory note

This Figure shows whether school curricula drawn up by the central (or top-level) authorities for education provide for the teaching of science as a single integrated subject, via separate subjects, or by means of both approaches. At ISCED level 2, only general-type teaching is included.

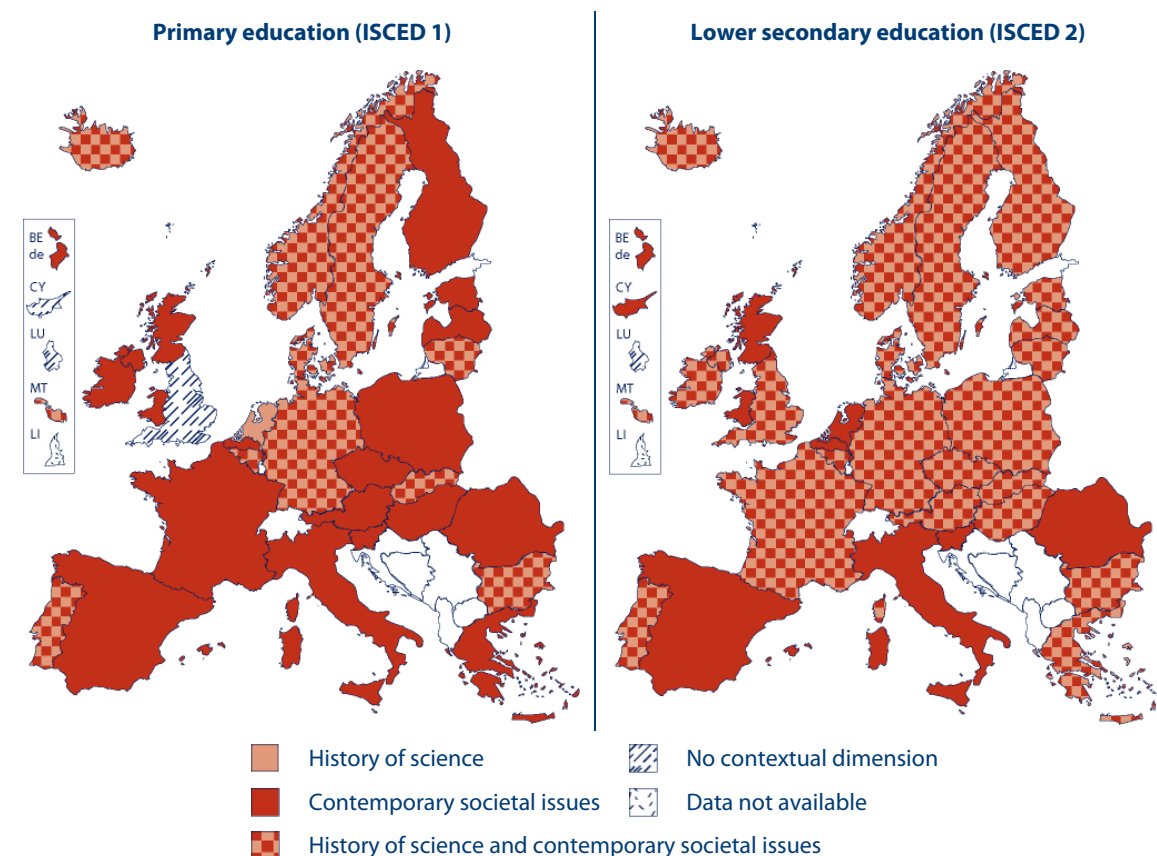
As Figure 3.1 indicates, science may be taught in a fully integrated approach or, conversely, in terms of separate subjects (such as physics, chemistry, biology, etc.). Except in the Netherlands, all curricula for primary education include science as an integrated subject. In lower secondary education, the trend is reversed, with separate science subjects identified in the great majority of curricula. In a few countries, both approaches are advocated at this level, as in the case of Spain, Lithuania, Hungary, Malta, Slovenia, Sweden and the United Kingdom (Scotland).

The first section of this chapter examines whether curricula include an approach that covers context-related aspects of science, mainly involving the history of science and contemporary societal issues. The second section deals with the content of official school curricula, as expressed in terms of prescribed or recommended activities or goals, focusing in particular on three aspects: practical or experimental work, information and communications technology (ICT), and communication. Finally, the last section provides an overview of ongoing reforms and debate concerned with school science curricula.

3.1. Teaching science in context

In most countries, the curriculum for science teaching in primary and lower secondary education refers to science in context, either in terms of the history of science or contemporary societal issues, or both. The curriculum for ISCED level 1 covers neither of these two aspects in three education systems. The same applies to just one country at ISCED level 2.

**Figure 3.2: Context-related aspects in science teaching
in the prescribed or recommended curriculum (ISCED 1 and 2), 2004/05**



Source: Eurydice.

Additional notes (Figure 3.2)

Belgium (BE nl): At ISCED level 2, data relate solely to the biology syllabus.

Czech Republic: The data are based on *Základní škola* programmes. The *Obecná škola* and *Národní škola* have their own distinct programmes.

Greece: At ISCED level 2, the Figure relates solely to the situation regarding the physics syllabus. The biology syllabus covers only contemporary societal issues.

Cyprus: In the case of ISCED 2, the map indicates solely the situation regarding the physics syllabus. The syllabus for biology covers both the history of science and contemporary societal issues.

Latvia: The new science curriculum for ISCED 1, which has been gradually adopted since 2005/06, refers to the history of science.

Luxembourg: The data relate to the curriculum for the general *lycée*.

Austria: In the case of ISCED 2, the situation regarding the physics syllabus in the *allgemein bildende höhere Schulen* is shown. The biology syllabus covers only contemporary societal issues. Physics and biology syllabuses in the *Hauptschulen* consider both the history of science and contemporary societal issues.

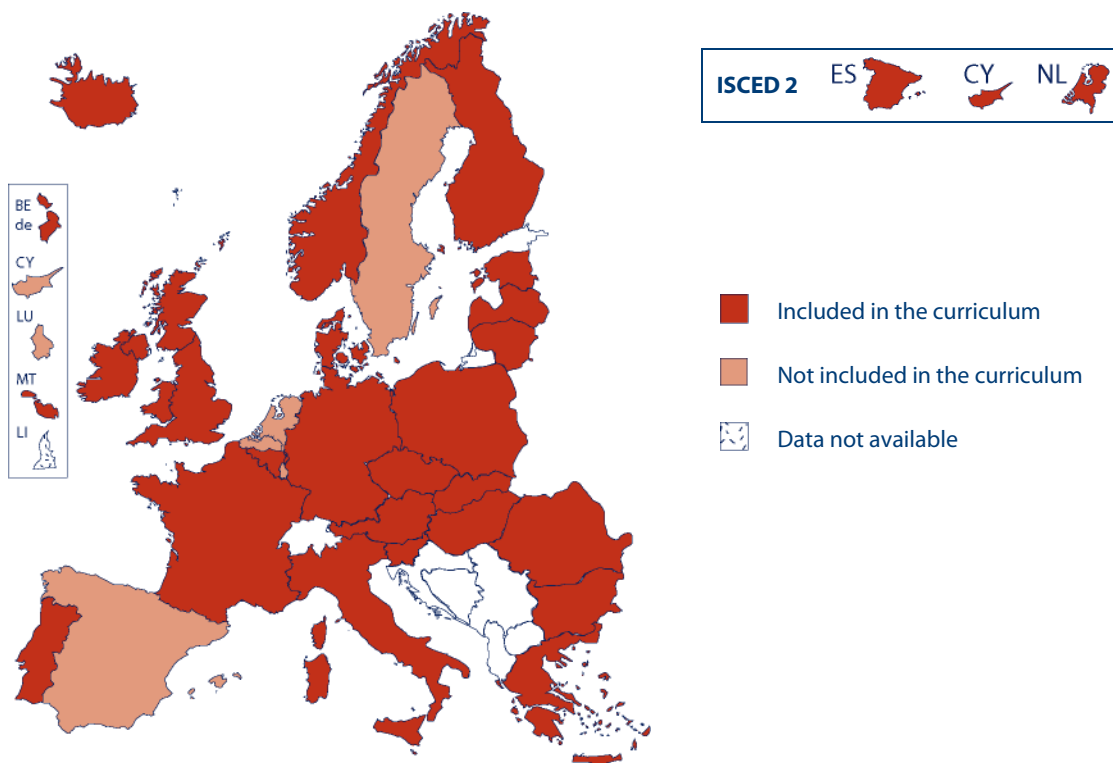
Slovenia: As regards ISCED 2, solely the position of the syllabus for integrated provision and for physics is illustrated. The biology syllabus covers both the history of science and contemporary societal issues.

Explanatory note

At ISCED level 2 (general lower secondary education), a difference in information for physics and biology syllabuses is indicated in an additional note, where this is the case.

The historical aspect of science is apparent in around ten curricula at primary level, and in twice as many in secondary education. The Netherlands is the only country where the ISCED 1 curriculum refers solely to the history of science. ‘Contemporary societal issues’ are included in the great majority of curricula. This aspect is reflected in the inclusion of ‘discussion related to everyday issues’ in countries where the curriculum refers specifically to learning activities.

Figure 3.3: Discussion activities related to issues of everyday life and society in the prescribed or recommended curriculum (ISCED 1 and 2), 2004/05



Source: Eurydice.

Additional notes (Figure 3.3)

Belgium (BE nl): At ISCED level 2, data relate solely to the biology syllabus.

Czech Republic: The data are based on *Základní škola* programmes. The *Obecná škola* and *Národní škola* have their own distinct programmes.

Spain: At ISCED level 1, syllabuses refer to activities involving ‘engaging in a discussion’ without giving any details on the type of activities envisaged.

Luxembourg: The data relate to the curriculum for the general *lycée*.

3.2. School curricula in science: learning outcomes and activities

School curricula in science can be presented in different ways. These include the broad areas of knowledge (concepts) to be covered, the specific activities to be carried out (what pupils are asked to do) and/or the learning outcomes to be achieved (the skills that pupils should acquire). A range of science learning activities can, of course, be designed to meet one particular objective; a single activity may also contribute to more than one learning outcome.

In all education systems – including those in countries without a national curriculum *per se* – science curricula are at least partly the focus of directives from top-level education authorities. Three countries, namely Belgium (the Flemish Community), the Netherlands (ISCED 1) and Sweden, do not prescribe or recommend science activities in the curriculum at all but express school science education in terms of teaching and learning objectives. Luxembourg, on the other hand, tends to identify teaching and learning activities rather than objectives. Some education systems include the full range of activities and learning objectives in their prescribed or recommended school science curricula.

A detailed breakdown of desirable outcomes and prescribed or recommended science activities is available in the annexe. In the case of each country, they indicate the range of activities that may be part of school science curricula and the skills that pupils are expected to acquire.

The areas covered here include knowledge of science concepts and theories, laboratory work, working with scientific documentation, discussions, using information technologies, project work, field trips, etc. The interplay between the content of science curricula and their learning outcomes must be approached with caution. It seems clear that the absence of prescribed activities should not be taken to mean that appropriate activities are not carried out to meet an expressed objective. The opposite is also true: the absence of an explicit learning outcome does not mean that there is no intended objective if these are only expressed in terms of learning activities that must be carried out in schools. To illustrate this point, the use of information technologies may be prescribed as an activity in schools (for example ‘communicating with other pupils’), but the ability to use ICT is not necessarily a learning outcome in itself.

Experimental or practical work

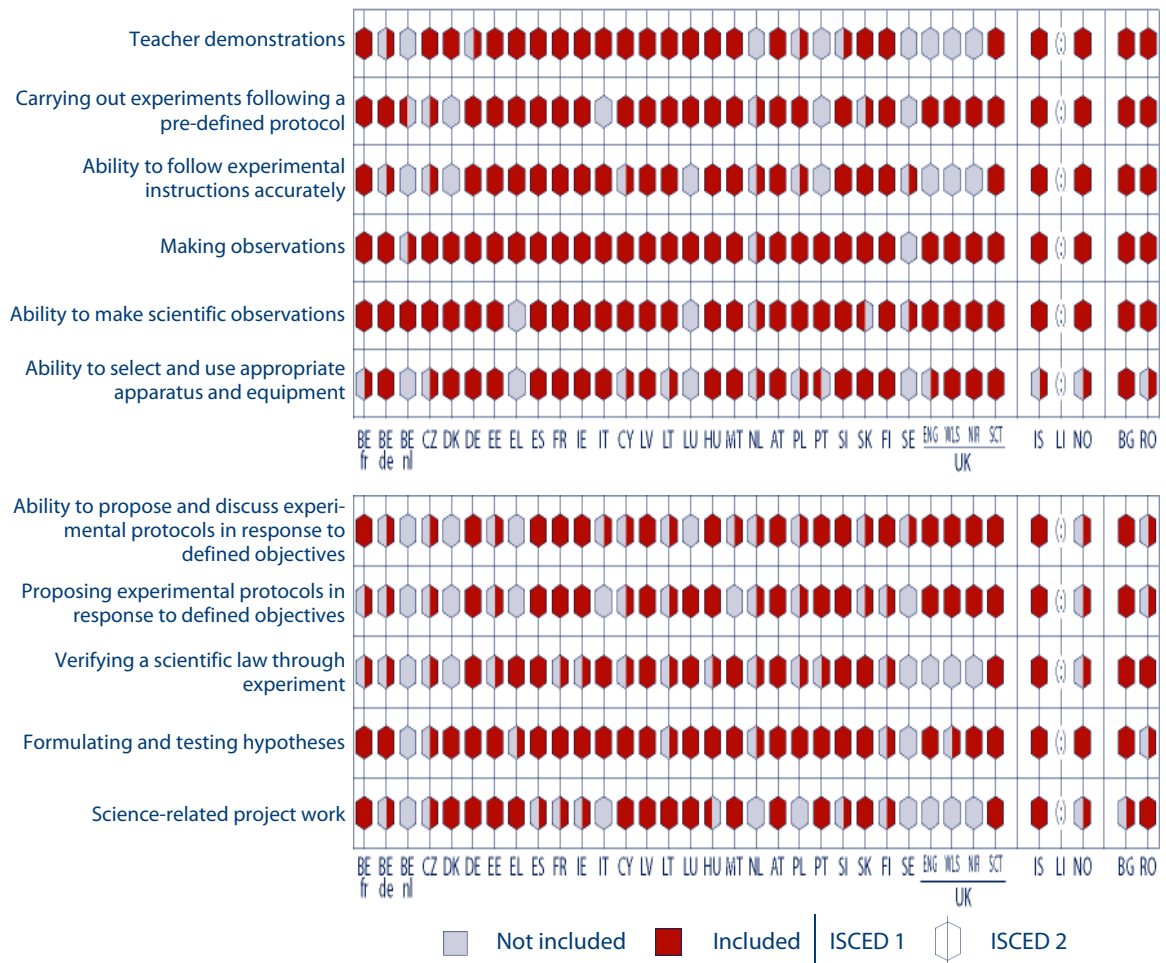
Experimental and practical work constitutes an important highly distinctive aspect of science teaching, and prescribed or recommended curricula all refer to it. ‘Making observations’ is included in almost all curricula as a form of activity or goal.

In research into science teaching, there has been much interest in complex cognitive skills. It is becoming increasingly vital to develop such skills during scientific training given that many operations requiring low-level cognitive skills, such as applying formulas, may be performed by computer equipment (‘Science Education Research and the Training of Science Teachers’, introduction). Activities requiring a complex body of knowledge and expertise as well as some degree of independence on the part of pupils are included in the majority of science curricula in lower secondary education. By contrast, they are less in evidence in primary-level curricula, as in the case of ‘proposing experimental protocols in response to defined objectives/ability to propose and discuss experimental protocols in response to defined

objectives’ and ‘verifying a scientific law through experiment’. This difference between primary and lower secondary levels also applies to other holistic activities that are demanding from the cognitive standpoint, such as ‘formulating and testing hypotheses’ and ‘science-related project work’.

This type of difference between the two levels of education may also be noted in the case of two less complex activities, namely the ‘ability to follow experimental instructions accurately’ and the ‘ability to select and use appropriate apparatus and equipment’.

Figure 3.4: Practical work in the prescribed or recommended curriculum (ISCED 1 and 2), 2004/05



Source: Eurydice.

Additional notes

Belgium (BE nl): At ISCED level 2, data relate solely to the biology syllabus.

Czech Republic: The data are based on *Základní škola* programmes. The *Obecná škola* and *Národní škola* have their own distinct programmes.

Greece: The ISCED 2 biology syllabus does not refer to either ‘verifying a scientific law through experiment’ or ‘formulating and testing hypotheses’.

France: The ISCED 2 physics syllabus encourages ‘science-related project work’, but does not make it mandatory.

Cyprus: The ISCED 2 biology syllabus does not refer to the ‘ability to select and use appropriate apparatus and equipment’, the ‘ability to follow experimental instructions accurately’, the ‘ability to propose and discuss experimental protocols in response to defined objectives’, ‘verifying a scientific law through experiment’ or ‘formulating and testing hypotheses’.

Luxembourg: The data relate to the curriculum for the general *lycée*.

Additional notes (Figure 3.4 – continued)

Netherlands: The ISCED 2 biology syllabus makes no reference to ‘verifying a scientific law through experiment’.

Austria: Physics and biology syllabuses for the *Hauptschulen* make no mention of the ‘ability to select and use appropriate apparatus and equipment’. The biology syllabus does not refer to ‘verifying a scientific law through experiment’ or ‘formulating and testing hypotheses’.

Slovenia: The ISCED 2 physics syllabus makes no mention of ‘science-related project work’.

Explanatory note

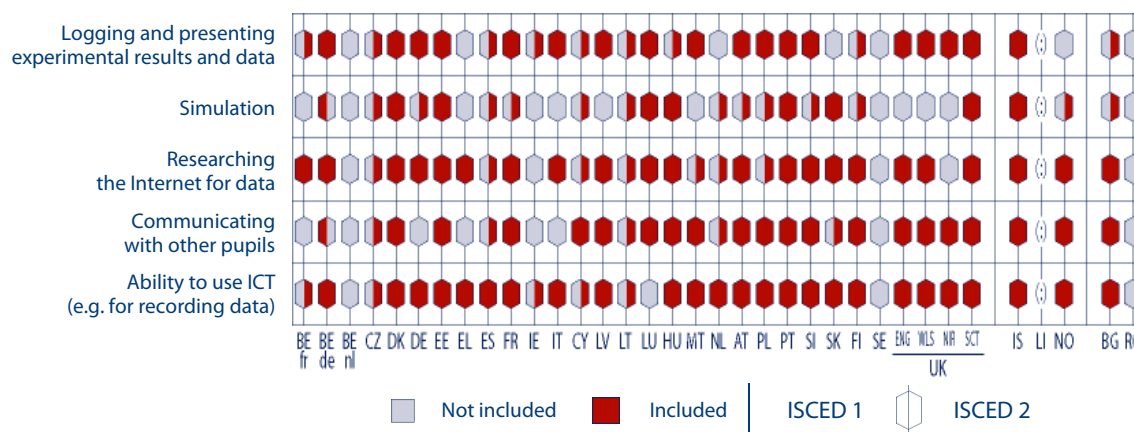
At ISCED 2, a difference in information for physics and biology syllabuses is indicated in an additional note, where this is the case.

‘Carrying out experiments following a pre-defined protocol’, ‘making observations’ and ‘proposing experimental protocols in response to defined objectives’ are classified as learning activities, whereas the ‘ability to follow experimental instructions accurately’, the ‘ability to make scientific observations’ and the ‘ability to propose and discuss experimental protocols in response to defined objectives’ are regarded as learning objectives.

Information and communications technology

The use of ICT is not the preserve solely of science courses. Thus ‘researching the Internet for data’ and ‘communicating with other pupils’ are activities that may be organised for learning any subject. In the case of science, they feature prominently in most curricula, especially at general lower secondary level.

**Figure 3.5: Use of ICT in the prescribed or recommended curriculum
(ISCED 1 and 2), 2004/05**



Source: Eurydice.

Additional notes

Belgium (BE nl): At ISCED level 2, data relate solely to the biology syllabus.

Czech Republic: The data are based on *Základní škola* programmes. The *Obecná škola* and *Národní škola* have their own distinct programmes.

Denmark: At ISCED level 2, the first three items are present solely in the physics syllabus.

Spain: At ISCED level 1, syllabuses refer to activities involving ‘use of ICT’ without giving any details on the type of activities envisaged.

Cyprus: In the case of the first four items, the information for ISCED 2 relates to the physics syllabus. The biology syllabus refers to all four except ‘logging and presenting experimental results and data’ and ‘researching the Internet for data’.

Luxembourg: The data relate to the curriculum for the general *lycée*.

Austria: At ISCED 2, the biology syllabus for the *Hauptschulen* does not refer to ‘simulation’ and the physics syllabus does not include ‘communicating with other pupils’. The biology syllabus for the *allgemein bildende höhere Schulen* makes no mention of any of the items.

Slovenia: At ISCED 2, the information shown relates to the biology syllabus. The syllabus for integrated provision refers to all items except the last, and the physics syllabus to all except the last two.

Explanatory note

At ISCED 2, a difference in information for physics and biology syllabuses is indicated in an additional note, where this is the case. The first four items are classified as learning activities, whereas the last one is regarded as a learning objective.

'Logging and presenting experimental results and data' and 'simulation' correspond to ICT activities more characteristic of science subjects. They – and simulation in particular – are less frequently referred to in curricula, especially at ISCED level 1, which includes them in only nine curricula. The use of relatively complex cognitive skills as well as the need for proficiency in the use of ICT no doubt account for this difference between ISCED levels 1 and 2. Research into science teaching focusing mainly on upper secondary level ('Science Education Research and the Training of Science Teachers', section A.4) reveals the considerable benefit to be gained from organising this kind of work at school, in that it encourages pupils to engage in theoretical activity and may help them form cognitive associations between theory and experience.

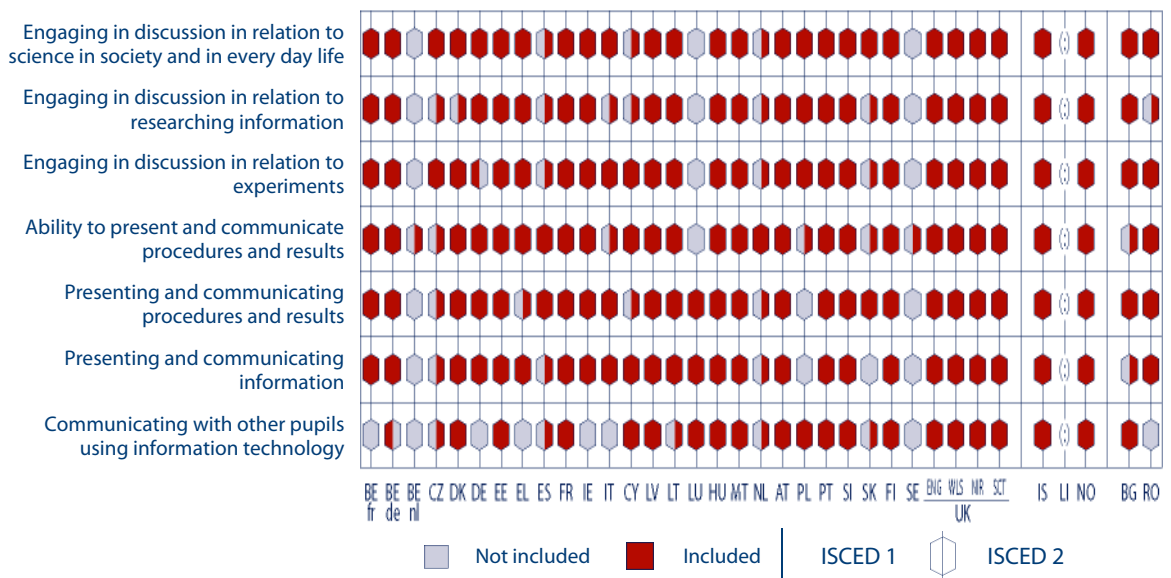
Romania is the only country where the curriculum includes no activity and no objective regarding the use of electronic technology at primary and lower secondary levels. In Belgium (the Flemish Community) and Sweden, it should be noted that no examples of any form of learning activity are referred to in the curricula.

Communication in science learning

Learning to talk about science and to communicate what is being or has been done is an important aspect of science education that runs right through the different areas of the school science curriculum and emerges as an aspect that is often given a high priority in Europe, at least within prescribed or recommended science programmes.

Science discussions can take at least three forms – discussing the role that science plays in society and the way it relates to everyday life, discussions about researching information and discussing experiments (Figure 3.6). Belgium (the Flemish Community) and Sweden do not refer to any type of science discussion activities at either ISCED 1 or 2 in the prescribed science curriculum, while Spain and the Netherlands do not include details of discussion activities in the prescribed curriculum at ISCED 1.

Figure 3.6: Communication in science learning in the prescribed or recommended curriculum (ISCED 1 and 2), 2004/05



Source: Eurydice.

Additional notes (Figure 3.6)

Belgium (BE nl): At ISCED level 2, data relate solely to the biology syllabus.

Czech Republic: The data are based on *Základní škola* programmes. The *Obecná škola* and *Národní škola* have their own distinct programmes.

Spain: At ISCED level 1, syllabuses refer to activities involving 'engaging in a discussion', 'use of scientific documentation' and 'use of ICT' without giving any details on the type of activities envisaged.

Cyprus: At ISCED 2, the biology syllabus refers neither to 'engaging in discussion in relation to experiments' nor to 'presenting and communicating procedures and results'.

Luxembourg: The data relate to the curriculum for the general *lycée*.

Austria: At ISCED 2, the physics syllabus does not refer to 'presenting and communicating information'. The physics and biology syllabuses for *Hauptschulen* do not refer to 'engaging in discussion in relation to researching information' and the biology syllabus for *allgemein bildende höhere Schulen* does not refer to 'communicating with other pupils using information technology'.

Explanatory note

At ISCED 2, a difference in information for physics and biology syllabuses is indicated in an additional note, where this is the case.

'Ability to present and communicate procedures and results' refers to prescribed or recommended learning outcomes in the curriculum, whereas 'presenting and communicating procedures and results' refers to the prescribed or recommended activity.

Elsewhere, it is interesting to note that, while pupils at ISCED 2 are always expected to engage in discussion on all three aspects of science work (with the exception of Germany), the pattern at ISCED 1 is more clearly differentiated. Almost everywhere (29 education systems), primary school pupils discuss science in relation to society and to everyday life. This is usually coupled with discussions about researching information (24 education systems). The association between researching information (which is a data handling skill and implies some understanding of different sources and the quality of information) and discussing broader societal issues is thus already strong in primary education. Science in everyday life may also, of course, point to discussions about a 'common-sense understanding' of science, allowing teachers to establish what level of comprehension their pupils have and, consequently, what learning activities are most appropriate for them (see Figure 1.2a and 'Science Education Research and the Training of Science Teachers').

Discussions about science experiments are also covered extensively in prescribed or recommended primary-level science curricula (Cyprus is the only system to focus exclusively on this type of discussion).

An analysis of data handling skills, or more specifically activities associated with using scientific documentation (see the annexe which gives a detailed breakdown of these activities), further underlines the importance attached to presenting and communicating information. Where education systems include one or more of these kinds of activities in prescribed or recommended curricula, presenting and communicating information is always referred to, with the exception of Slovakia at ISCED 1. Because lower secondary school curricula tend to be more extensive in general, this pattern is most apparent once again at primary level. Whereas the other activities are included in just under half of prescribed or recommended curricula, presenting and communicating information is included in 26 education systems and is the only activity identified in relation to the use of scientific documentation at ISCED 1 in Ireland, Italy, Malta, Finland, Norway and Romania.

Learning to present and communicate procedures and results is a further aspect of communication in science education. This falls into the group of practical activities shown in Figure 3.4: the procedures and results indicated here form part of scientific experimental or investigative work. Every single education system, without exception, includes this aspect in lower secondary education. At primary level, only seven education systems do not include it.

3.3. Debate and reforms

School science curricula are currently the subject of debate and reforms in the great majority of European countries. Discussion centres on a wide range of matters (methodological approaches, the amount of teaching time, etc.) and, in some countries, is associated with a blanket reform of the curriculum.

Reforms concerned with curricular content often mean that changes have to be made in other areas, such as pupil assessment (section 4.4) and, at a prior stage, in teacher education. For example, revised syllabuses were introduced in Ireland (in 2003) with comprehensive programmes of in-service teacher training. Teachers in primary education whose training in science has generally been limited have thus been able to participate in courses that help them to satisfy the latest requirements of the curriculum, which attaches greater importance to science. In the case of teachers in secondary education, training has been more concerned with methodological approaches. To help teachers in Portugal establish the new curriculum, a new in-service training programme for science teaching is being introduced in 2006/07 in all primary schools to improve the teaching of experimental work in science. However, this section focuses solely on the content of reforms and debate concerned with school curricula during the 2004/05 school year.

Several countries undertake comprehensive reform affecting all school curricula. Thus in Belgium (the German-speaking Community) and Lithuania, the definition of key competencies resulted in a process of school curricular revision that is due to end in 2007. Although reforms in Latvia relate to all subjects in the curriculum, they focus essentially on the social sciences and science subjects. The general aim is to achieve a curriculum structured with respect to skills, and not a set of facts to be memorised as previously. In 2004, Germany introduced educational standards for certain subjects in primary and secondary education, including physics, chemistry and biology at ISCED 2. As a result, school curricula are currently undergoing radical changes. In Norway, the 2004 reform for the promotion of knowledge (*Kunnskapsløftet*) provides for the introduction of a new curriculum with effect from 2006. This is less detailed and includes clear aims that specify the level of ability expected of pupils at each level of education.

In Estonia too, all school curricula are in the process of being modified. Different aspects of science teaching are the subject of discussion, including its content, the skills that should be acquired, its methodology and, in particular, the role of teacher and pupil in the learning process. In the United Kingdom (Scotland), an overhaul of the entire curriculum got under way in 2004 with the revised version due to begin piloting in the 2006/07 school year.

In a still more general approach, the Czech Republic has begun a structural reform of all its curricula, introducing a system in which schools will henceforth be obliged to draw up their own curriculum with reference to the framework curriculum produced by the ministry. With effect from 2006, schools and teachers in the Netherlands are being granted greater freedom to devise school curricula as they wish. For example, they may decide whether to teach science as an integrated subject or in separate (science) subjects. In Bulgaria, discussions are taking place on the national 2006-2015 curriculum for the development of school education. This curriculum plans for changes in the structure and content of courses.

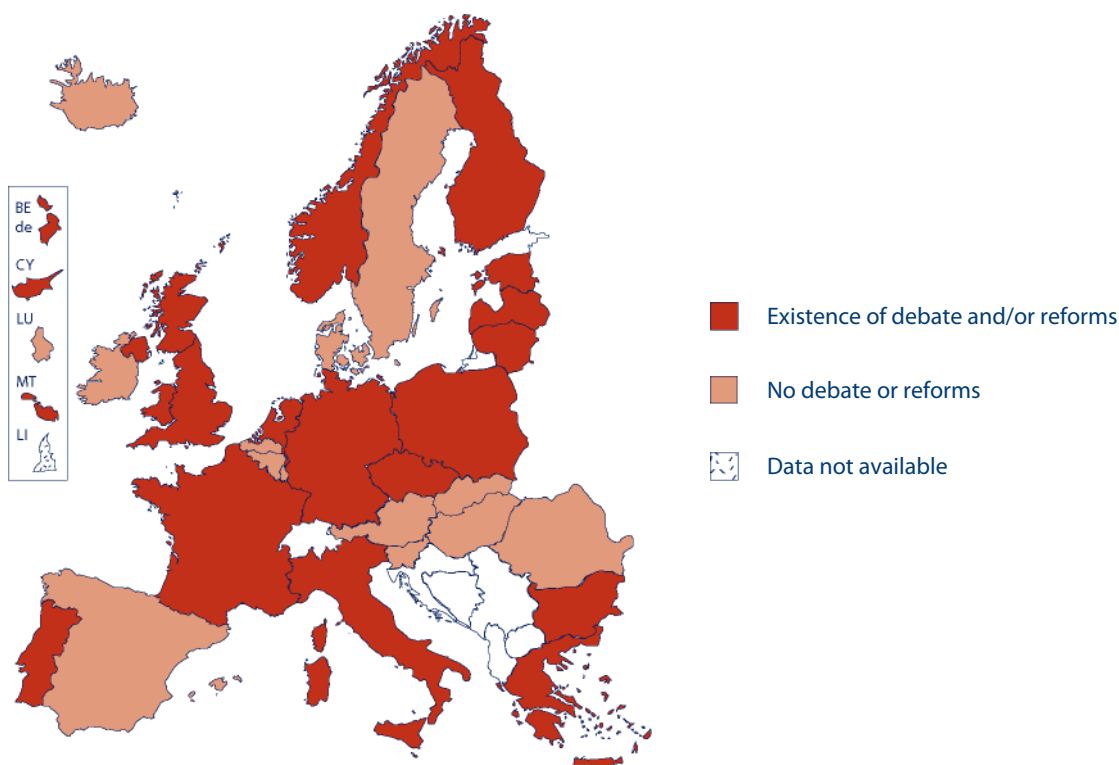
In the United Kingdom (England), the 2005 White Paper 14-19 Education and Skills set out the government's aim to reform the curriculum, assessment and the range of opportunities on offer to 14 to 19-year-olds. At the same time, it highlighted the importance of ensuring that more young people reach the age of 14 with a strong grounding in the basics and engaged by education. The current review of the Key Stage 3 science curriculum aims to move away from a long shopping list of facts to be learnt and to produce a more relevant and flexible curriculum, with an emphasis on key conceptual underpinnings and

on key processes such as investigation and evaluation. The proposed new curriculum is currently undergoing extensive consultation with a view to phased introduction in schools from September 2008.

In Italy, new curricula formulated in terms of specific learning objectives have been introduced at primary and lower secondary level as part of more general education reforms. Moreover, in relation to science more specifically, the education minister launched the *Insegnare Scienze Sperimentali* project in 2006. This project aims, on the one hand, to raise ability levels in mathematics and science for pupils aged between 6 and 16 and, on the other hand, to support the continuing professional development of teachers in these subjects.

Current reforms in Bulgaria more specifically concerned with science have to do with the content of provision (the curriculum and textbooks) at primary level and during the first year of lower secondary education. Debate on the subject of the school curriculum in Poland, which is focused solely on science, will very probably soon lead to the introduction of a reform in this area.

Figure 3.7: Ongoing reforms or debates concerning the science curriculum (ISCED 1 and 2), 2004/05



Source: Eurydice.

In a few countries, the position and curricular organisation of science is at the heart of the debate. Thus, in Latvia and Finland, reforms are concerned with the amount of teaching time for science. Furthermore, in the latter, science subjects are being taught separately in the last two years of ISCED 1 with effect from 2006/07. In Malta, the debate is concerned with how science should be offered in lower secondary education. Should it be taught as an integrated subject or in separate subjects and, in the latter case, should two or three subjects be identified? In Portugal, the reform of the primary and lower secondary school curriculum will lead to a revision of the currently used syllabuses.

Reforms may also be concerned with methodology. In France, the new approaches adopted since the start of the 2005 school year in the first year of lower secondary education relate to the syllabuses for life and earth sciences, physics and chemistry and will gradually be extended to all provision at ISCED level 2.

They seek to introduce an investigative dimension already present in syllabuses at primary level under the heading of *la main à la pâte* (a 'hands-on' approach) and give pupils an important part to play in developing their own knowledge. Furthermore, the new syllabuses provide an incentive to adopt a multidisciplinary approach in so far as certain topics such as health or the sustainable environment, which incorporate several subjects, are studied throughout lower secondary education. In the Netherlands, the committees responsible for revising school curricula base their activity on a conception of science education in which teachers have to take as their starting point the common-sense conceptions and reasoning of pupils, and then develop a more accurate and refined understanding of scientific phenomena.

New materials are now being developed to support science teaching in Greece, Lithuania and Latvia. Debate in Cyprus is currently concerned with reducing the content of the syllabus, which is excessive compared to the amount of time available to teach it.

Science curricula are the subject of reforms or debate in many countries. These reforms are concerned with matters as varied as the organisation, content and methodology of provision. Where they relate to the entire school curriculum, they seek to establish educational standards, for example in the form of key competencies, and may also broaden the discretion of schools in actually determining curricula. Reforms of this kind generally go hand in hand with the introduction or strengthening of external pupil assessment based on tests to measure their proficiency and knowledge with respect to the standards established (see Chapter 4).

CHAPTER 4

STANDARDISED PUPIL ASSESSMENTS

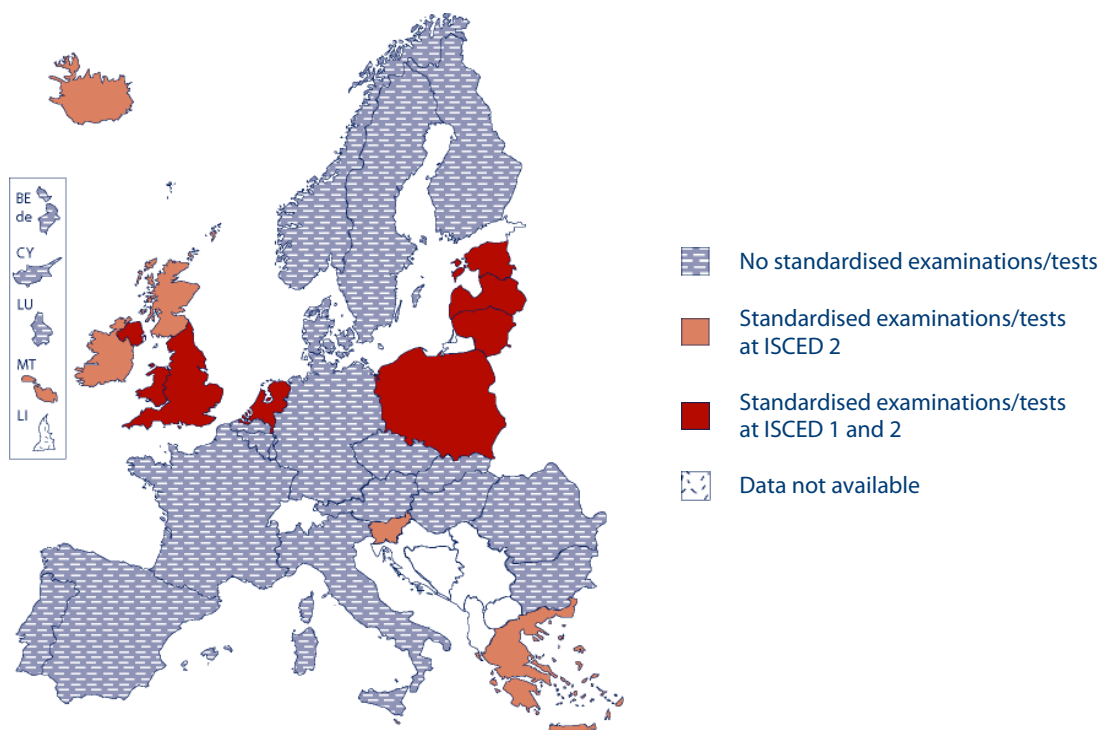
Assessment of pupils can take a number of different forms (e.g. written, oral, computer-administered or practical tests) and can have several different functions. *Formative assessment* is an integral part of the everyday processes of teaching and learning. It focuses attention on the day-to-day reciprocal feedback in which teachers and pupils engage and uses such feedback to meet its principal objective, the enhancement of student learning. It is usually distinguished from *summative assessment*, which seeks to measure what pupils know, understand and are able to do, i.e. to evaluate their level of achievement. While the outcomes of summative assessment may also be used to promote learning, its principal function is evaluation. The results of such evaluation may be used, for example, to determine whether a student has reached a sufficiently high standard of performance in order to proceed to a more advanced class or to the next stage of schooling. When conducted by a national or regional agency in the form of standardised tests or examinations, summative assessment sometimes leads to formal certification. Summative evaluation, whether certificated or not, is also used by policy makers as an indicator of how well an education system is performing and thus of what changes may be necessary. So-called continuous assessment refers to the fact that assessments are carried out over a period of time and throughout a course. When a course is organised on a modular basis, assessment may take place at the end of each module (summative assessment) or on a continuous basis. Continuous assessment may serve formative and/or summative purposes.

Assessment, in whatever form, is intimately connected with the curriculum and with the processes of teaching and learning. The interactions between these aspects of schooling are complex and powerful, and experience has established that reforming school science curricula requires a sympathetic and supportive system of assessment if the goals of the reforms are to be realised. Science teachers, like their colleagues teaching other subjects, are well aware that the knowledge and skills that their pupils are required to display in their standardised examinations or tests are powerful influences upon what they teach and how they teach it. They also influence pupils' attitudes towards learning and, more particularly, what it means to them to learn science at school. Given this, standardised examinations or tests can act as either a powerful brake on curriculum and pedagogical reform or a powerful agent for change. It is thus important to identify the knowledge and skills that are assessed by standardised tests or examinations used for the purposes of evaluation and/or certification. However, it is also important to acknowledge that the absence of a system of standardised testing at any level of an education system does not imply that pupils are not taught any or all of the skills associated with such testing. It can be safely assumed, for example, that all school science education programmes require pupils to acquire and demonstrate some knowledge of scientific concepts, laws and theories (see Chapter 3). The precise content to be learnt, however, will vary from country to country, as will the emphasis to be placed on knowledge relative to some of the other outcomes associated with learning science at school, such as an ability to present results or summarise data.

4.1. Standard science examinations/tests

In the majority of countries, there are no standardised pupil assessments in integrated science subjects and/or physics and/or biology at either ISCED 1 or ISCED 2. Where such tests are conducted, they are slightly more common at ISCED 2 (Figure 4.1). No country has standardised pupil assessments only at ISCED 1 and six countries have standardised pupil assessments only at ISCED 2. Eight education systems conduct standardised pupil assessments at both levels.

Figure 4.1: Standardised national science examinations/tests (ISCED 1 and 2), 2004/05



Source: Eurydice.

Additional notes

Denmark: Science subjects will be assessed at the end of compulsory schooling starting from 2007.

Germany: Standardised pupil assessments in physics and biology at ISCED 1 and 2 will be developed by the *Institut zur Qualitätsentwicklung im Bildungswesen* (Institute for Quality Development in Education).

France: Standardised pupil assessments in science are to be organised at the end of ISCED 1 and 2 on a rolling basis from 2007.

Latvia, Netherlands and Poland: There are no standardised tests in science per se at ISCED 1, although science topics form part of a national testing programme.

Netherlands: Standardised tests at the end of ISCED 2 are taken by pupils enrolled in pre-vocational secondary education (VMBO) only.

Portugal: National assessment at ISCED 2 will shortly be extended to include science subjects.

Slovenia: From 2005/06, national examinations are no longer compulsory at the end of the second cycle and have been abolished at the end of the first cycle.

Explanatory note

'Standardised examinations/tests' refers to national examinations (or parts of examinations) or tests designed by central or higher education authorities for certification or for the purposes of pupil evaluation.

A number of other countries are also considering introducing standardised science assessments, and an overview of current debates and reforms is given in section 4.4. For example, in Germany, standardised pupil assessments in physics and biology are under development in all *Länder*. Baden-Württemberg, Bavaria and North Rhine-Westphalia have announced the introduction of such tests. Similarly, the French ministry of education directorate for evaluation and forward planning (DEP) is setting up standardised evaluation in science at the end of ISCED 1 and 2, to take place on a rolling basis approximately once every five years starting in 2007.

In the eight education systems where there are standardised pupil assessments at ISCED 1, the assessments are conducted for the purpose of evaluating pupil progress rather than for certification. Certification at the end of ISCED 1 is no longer a usual feature of schooling in most countries.

Where such assessments are conducted at ISCED 2, certification plays a more prominent role. Certification is identified as the purpose of standardised pupil assessments at this level in five countries. In four countries, the purpose of standardised pupil assessments at ISCED 2 is that of evaluation only. For six other countries, the purpose of standardised pupil assessments at ISCED 2 is described as both certification and evaluation. However, it needs to be noted that in the case of Malta, standardised pupil assessments at ISCED 2 take two forms. The annual school examinations are conducted for evaluation purposes, whereas the Secondary Education Certificate Examination is conducted for the purpose of certification. In Slovenia, national examinations have been abolished at the end of the first cycle and are no longer compulsory at the end of the second.

4.2. Types of skills/knowledge assessed

Tests and examinations in school science evaluate a variety of skills. In all cases, such tests and examinations are likely to require pupils to recall important scientific concepts such as Newton's laws of motion or the basic ideas underlying photosynthesis. Pupils may also be tested on the depth of their understanding of these concepts and their ability to apply them in familiar or unfamiliar contexts. Science, however, is also a practical subject and school science courses place an emphasis on the acquisition of a number of practical scientific skills, although this emphasis varies from one country to another. These practical skills are augmented by a variety of other competences such as the ability to process and present data, to think scientifically and to present a problem in scientific terms (see Chapter 3). All the skills assessed by standardised science examinations/tests can be associated with one of the following categories:

- an ability to recall and apply scientific knowledge and theories;
- practical skills such as the ability to select appropriate apparatus and equipment;
- data handling skills such as the ability to summarise and present results and data;
- scientific thinking skills such as the ability to formulate scientific hypotheses.

These various skills can be tested in a variety of ways. Teachers do so orally on a regular basis when they question their pupils as part of the everyday processes of teaching and learning in the science classroom or laboratory. As part of standardised tests conducted for the purposes of evaluation and/or certification, many skills are normally assessed using written examinations, although computer-assisted testing has been piloted in the Netherlands and will be used in national examinations in physics from 2007.

While some skills strongly associated with practical science can be assessed by written or computer-assisted examinations, e.g. an ability to formulate and/or test a scientific hypothesis on the basis of given data, many practical skills cannot be assessed in this way. Doing so requires other forms of testing based upon science teachers' structured observations of their pupils' work, formal practical examinations or science-based projects. However, the last two of these forms of testing are more difficult to organise and administer than standardised written tests, especially on a large scale. They are also more expensive and require different procedures to establish their reliability and validity ⁽¹⁾.

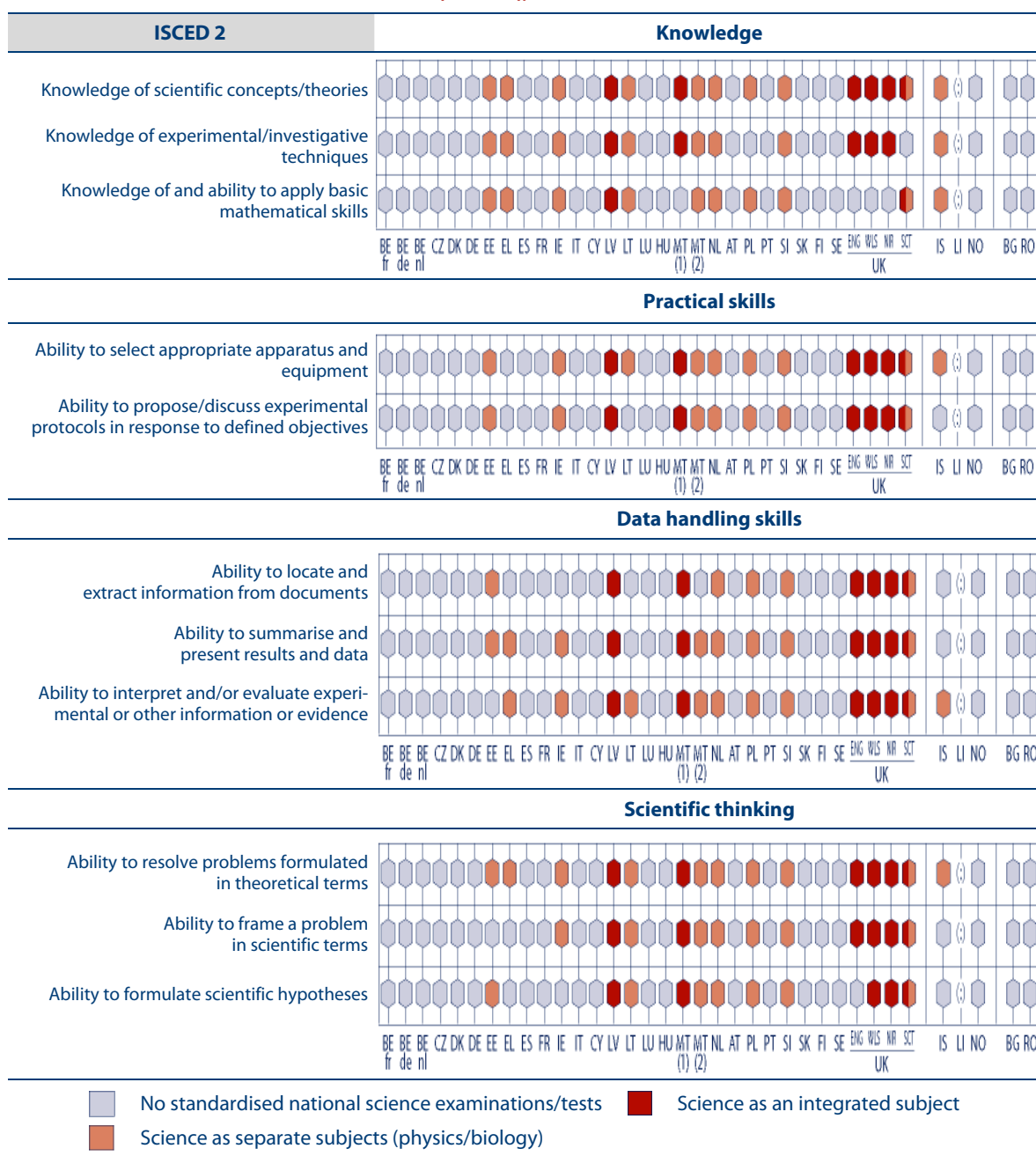
⁽¹⁾ The notions of validity and reliability are fundamental to all forms of testing. A test is valid if it measures what it is intended to measure: there are several ways of estimating this. Reliability is an indicator of the accuracy of the outcome of an assessment. Knowledge of the validity and reliability of any standardised test is essential to understanding the level of confidence that can be placed in the results of such a test.

Figure 4.2a: Type of skills assessed by standardised national science examinations/tests (ISCED 1), 2004/05



Source: Eurydice.

Figure 4.2b: Type of skills assessed by standardised national science examinations/tests (ISCED 2), 2004/05



Source: Eurydice.

Additional notes

Greece: 'Knowledge of and ability to apply basic mathematical skills' applies to assessment in physics only.

Latvia: Physics and biology are taught as separate subjects at ISCED 2, although the standardised examination at the end of this level is in science as an integrated subject.

Latvia, Netherlands and Poland: There are no standardised tests in science per se at ISCED 1, although science topics form part of a national testing programme.

Explanatory note

'Standardised examinations/tests' refers to national examinations (or parts of examinations) or tests designed by central or higher education authorities for certification or for the purposes of pupil evaluation.

It also needs to be remembered that testing a pupil's ability to frame a problem in scientific terms tells us nothing about the kind of problem under consideration; likewise, an ability to select appropriate apparatus and equipment gives no indication of the apparatus and equipment from which the selection has to be made. The type of knowledge and skills that are assessed has been investigated rather than the content of science tests and examinations.

At ISCED 1, eight education systems test pupils' knowledge of scientific concepts/theories. Knowledge of experimental/investigative techniques is required of pupils in six education systems. The United Kingdom (England, Wales and Northern Ireland) and Latvia appear to test the widest range of skills at ISCED 1.

At ISCED 2, knowledge of scientific concepts/theories remains an important assessment objective, although for more countries in the case of physics and biology than integrated science. In the case of those countries conducting national tests, there is also a considerable emphasis on testing pupils' scientific thinking and practical skills, e.g. the ability to frame a problem in scientific terms, to formulate hypotheses and to select appropriate apparatus and equipment. In five education systems, these skills are tested in the context of science as an integrated subject.

Also noteworthy is the importance attached by some of the recent members of the European Union, such as Estonia, Latvia, Poland and Slovenia, to assessing a wide range of skills at both ISCED 1 and ISCED 2.

Knowledge of scientific concepts and theories is required in national tests at both ISCED 1 and ISCED 2, although more countries have such a requirement when physics and biology are added to the list of subjects taught. The precise concepts and theories tested at these two levels are, of course, likely to be different, reflecting the different ages of the pupils involved and their differing abilities to handle sophisticated ideas. There is less emphasis at ISCED 1 than at ISCED 2 on the other skills referred to above: only Estonia, Latvia, the Netherlands, Poland and the United Kingdom (England, Wales and Northern Ireland) test practical, data handling and scientific reasoning skills at primary level. Differences between countries in the balance among the different types of skills demanded by standardised tests at ISCED 2 are relatively minor, especially in the context of physics and biology.

Viewed overall, the range of skills assessed in those countries with standardised school science examinations at ISCED 1 and, more widely, at ISCED 2, reflect the skills commonly associated with acting and thinking as a scientist would when planning, carrying out and reporting a scientific investigation. They also reflect the international nature of scientific inquiry and the universality of the scientific knowledge that forms the staple of school science courses.

4.3. Science-related project work

Science-related project work involves experimental or other work in the laboratory or elsewhere and has an investigative character. It may be undertaken on a whole class basis or by pupils working individually or in small groups. It extends over a period of time, perhaps several weeks, and provides an opportunity for pupils to engage in a science-related study with a particular focus. It may involve collaboration with people in other institutions via the Internet or by other means and the write-up is likely to take the form of a report.

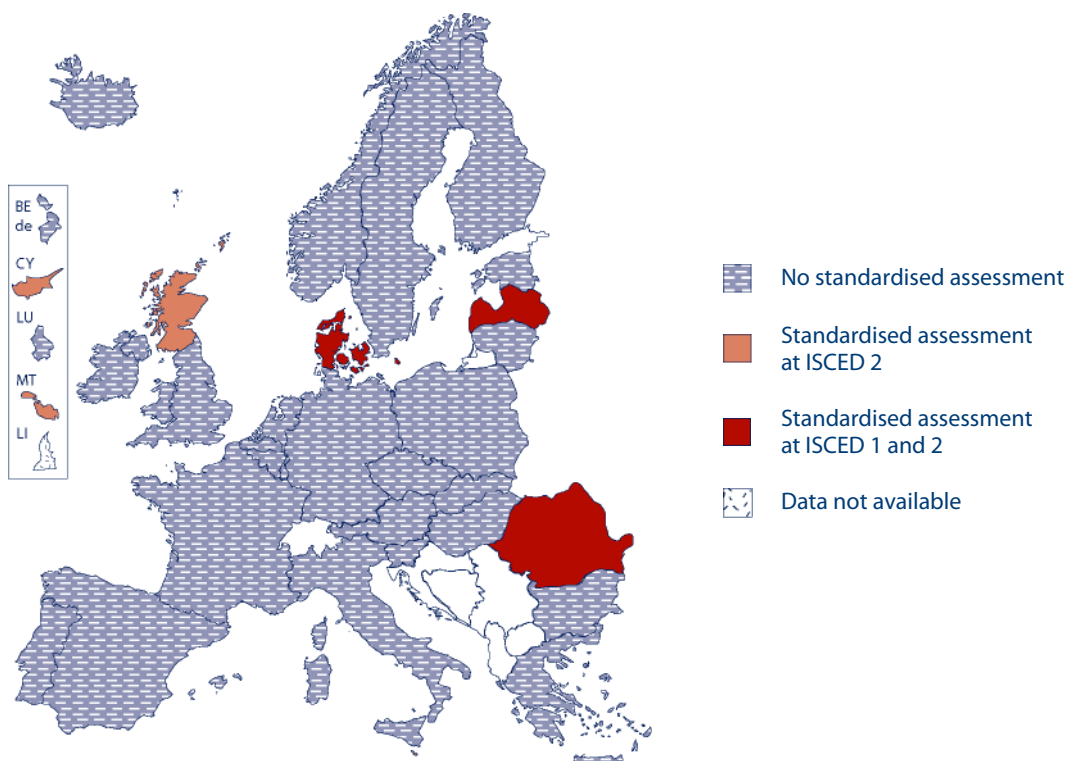
Standardised assessment of such project work is not a significant feature of school science education at either ISCED 1 or ISCED 2 as Figure 4.3 shows.

Three countries, Denmark, Latvia and Romania, have science-related project work with standardised assessment criteria at both levels of schooling, while three have such work only at ISCED 2. Ireland is to introduce this approach to teaching and learning science at ISCED 2 in 2005/06.

As with standardised tests and examinations, the absence of standardised assessment criteria for project work cannot be taken to mean that pupils are not required to acquire any of the skills commonly associated with such work, e.g. a knowledge of scientific concepts/theories or the ability to make scientific observations. It is also important to recognise that identical assessment objectives can reflect significantly different types of project work. For example, requiring pupils to display an ability to formulate scientific hypotheses in their project work tells us nothing about the precise hypotheses being formulated or about the nature of the scientific project to which they relate. Likewise, an ability to make scientific observations can be developed in the context of very different kinds of project work, even within a given scientific discipline such as physics or biology.

In the six countries where these assessments take place, the context is different at ISCED 1 (integrated subject) from ISCED 2 (physics and biology). The range of skills/knowledge assessed is greater at ISCED 2 than at primary level except in Denmark, where the same skills are assessed at both levels.

Figure 4.3: Standardised assessment of science-related project work (ISCED 1 and 2), 2004/05



Source: Eurydice.

Explanatory note

'Standardised assessment of science-related project work' means that the assessment criteria are specified by central or higher education authorities.

The fact that an identical range of skills/knowledge is assessed through project work in biology and in physics at ISCED 2 in Latvia, the United Kingdom (Scotland) and Romania is noteworthy. The same applies to Malta at this level, although there are some differences between the three countries in the skills/knowledge assessed. The similarity in the skills assessed by project work reflects an underlying common commitment to an investigative approach to teaching and learning science.

Latvia tests a much wider range of skills through science-related project work in the context of integrated science at ISCED 1 than either Cyprus or Romania. Denmark also assesses a wide range of knowledge and data handling skills both at ISCED 1 and ISCED 2.

The data from four of these six countries suggest a greater degree of uniformity among the skills assessed through science-related project work at ISCED 2 in physics rather than in biology.

4.4. Current debates about assessment

The data presented in earlier sections relate to the situation in the year 2004/05. This section seeks to identify debates or planned changes relating to the assessment of the outcomes of school science.

Figure 4.4 summarises the position. It shows that debate about such assessment is common to almost all respondent countries, often at both ISCED 1 and ISCED 2. This level of interest does not stand in isolation. It is intimately connected with debates about the form and content of school science education, about how science teachers should be trained and about how to effect systemic change within schooling. It is also part of a wider global phenomenon that reflects the concern of government and others to raise the standards of science education, to promote scientific literacy and to ensure that systems of assessment that are supportive of these objectives are in place. When a science curriculum is specified in terms of competences or learning outcomes rather than the more traditional list of scientific topics, the assessments undertaken closely reflect the specification of what pupils are required to know and be able to do. In all cases, however, a system of assessment should reflect and support the learning outcomes associated with the curriculum.

The changes/debates under way in various countries are of different types, although in some cases, a country is involved with more than one type of change.

Creating national standards and/or tests/testing agencies

In countries with no tradition of national testing, it has been necessary to develop appropriate organisations or agencies to assume responsibility for such testing. In many cases, such developments are associated with the specification of educational standards and/or tests that prescribe what pupils should know and be able to do at particular stages of their school science education. In Germany, for example, a new Institute for Quality Development in Education (*Institut zur Qualitätsentwicklung im Bildungswesen*) was founded in 2004 by the *Länder*. The *Länder* have just begun to develop standardised pupil assessments in biology and physics (ISCED 1 and ISCED 2) and these will be introduced in the next few years. They follow the introduction of education standards in biology, chemistry and physics at ISCED 2 in December 2004. These educational standards are binding on all *Länder* and the Institute has responsibility for further development of, and creating and administering standardised pupil assessments.

In Latvia, new standards in integrated science, as well as in physics and biology, are to be phased in over a period of three years from 2005/06. These standards will place greater emphasis on research/investigative work, making this a key objective for pupils.

In Austria, where national education standards are currently being tested in pilot schools in German and mathematics at the end of ISCED 1 and 2 and in English at the end of ISCED 2, steps are being taken to develop similar standards for physics, chemistry and biology, although no detailed timetable or project plan currently exists.

In the Czech Republic, a Centre for the Evaluation of Educational Achievement has been established to develop a system for monitoring and evaluation. A four-year project, due to end in 2008, will focus attention, among much else, on the assessment of pupils at key points during compulsory schooling (the fifth and ninth years). Pilot projects (the first between 2001 and 2003 and the second from 2004 to 2006) on pupil assessment (and specifically, on recorded assessment) have also been under way in Lithuania. A Finnish Education Evaluation Centre was also established in 2003 for the purpose of evaluating education and learning, contributing to the development of evaluation and promoting evaluation research. This specification of educational standards is part of an international phenomenon, although the extent to which such standards can be enforced and their relationship to the science curriculum vary from country to country. In federal systems where education is devolved, or is the responsibility of Communities or regions, the latter are likely to respond individually to the publication of 'national' standards. In contrast, in a centralised system, a national curriculum is able to specify and mandate the knowledge and levels of performance expected of all pupils at various stages of compulsory schooling. In most cases, the specification of standards has required school science curricula to be radically revised or even rewritten. In Finland, for example, although there are no national tests at either ISCED 1 or 2, the new national core curriculum specifies assessment criteria.

Extending existing assessment arrangements to include science

In some countries, national assessment of pupils is already undertaken but such assessment does not include science subjects.

In Denmark, all science subjects will be assessed at the end of compulsory schooling starting from 2007. It is expected that these tests will be made electronically. Also in 2007, standardised science assessments will be organised in France and repeated approximately once every five years. In Portugal, national assessment at ISCED 2 will shortly be extended to include science subjects, and the ministry of education is studying the implementation of a final national assessment at the end of the fourth year of schooling.

In Malta, the National Minimum Curriculum (1999) includes science as one of its core subjects, but science is not included in the subjects currently tested at the end of primary education. Debate about such inclusion is ongoing but no timescale has been set. Also in Malta, a review of the current National Certificate system has just been undertaken by the MASTEC Unit within the University of Malta and a number of proposals regarding assessment have been put forward.

Discussions about pupil assessment in science are also ongoing within Poland alongside a debate about core curricula for science at all levels of the education system. In Italy, the *Istituto Nazionale per la Valutazione del Sistema Educativo di Istruzione e di Formazione* is examining the use of tests in science (as well as in Italian and mathematics) at ISCED 1 and 2, but it is not yet clear whether these tests will be used for evaluation or certification purposes.

Broadening the range of skills assessed

Several countries report a broadening of the objectives of pupil assessment in school science and/or changes in assessment techniques. In Estonia, the Curriculum Development Centre of the University of Tartu is developing a new curriculum. Scheduled for introduction in 2007, the assessment system will reflect the emphasis in the new curriculum on inquiry-oriented and discovery learning, and the ability to formulate hypotheses and to engage in the discussion of scientific topics.

In the United Kingdom (England), a review of pupil assessment in science forms part of the current review of the National Curriculum for Key Stage 3. It is proposed that the level descriptions – which provide a standardised basis for making judgements about pupils' performance – be revised to reflect a new emphasis on the 'big ideas' and key processes in science, and also to support formative assessment by teachers more effectively. Other changes being considered include the balance between enquiry skills and knowledge recall/understanding and the balance between teacher assessment and externally marked tests. New tests for 14-year-olds will be used in school from 2011 following the introduction of the new programme of study for 11-year-olds in 2008.

In Greece, the passage of a bill before the Greek Parliament seems likely to lead to a system of pupil assessment that places an increased emphasis on the competences associated with science rather than simply the recall of scientific content.

Using innovative assessment techniques

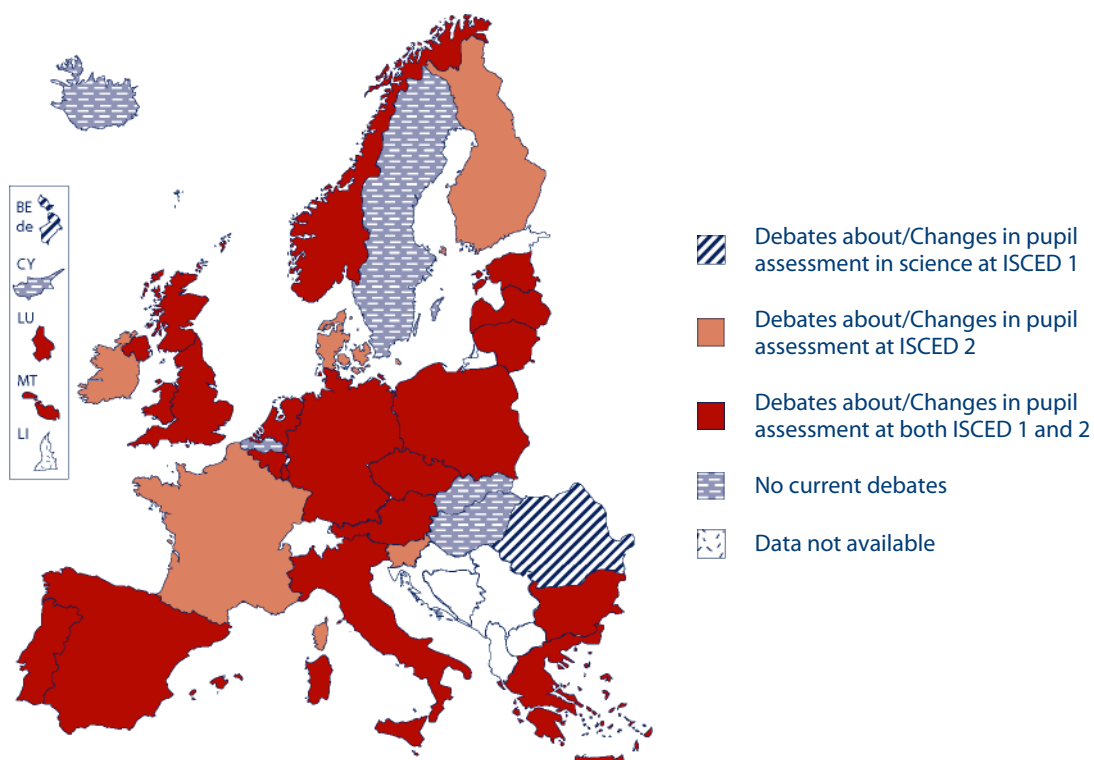
In the Netherlands, the CITO assessment centre has developed new types of evaluation and assessment techniques to reflect a curriculum and pedagogical emphasis on inquiry-based learning. In addition, the outcome of a recent pilot study has led to a decision that, from 2007, the use of computers will be an integral component of the national VMBO examinations in physics. This will also be the case for biology in 2008. The use of computers will allow new kinds of skills to be tested, e.g. the ability to perform virtual experiments and examine animal behaviour. In Ireland, an increased emphasis on practical work in school science at ISCED 2 will lead to the direct assessment of such work and account for 35 % of each pupil's final mark: 10 % will be awarded for records of work carried out over the three years of the science course and 25 % allocated to specified projects.

In Slovenia, the Department of Science Advisory Committee of the National Education Institute has developed a system of 'authentic assessment' and engaged in the training of 'teacher multipliers' with responsibility for disseminating innovative practice in pupil assessment and for explaining its influence on teaching methods. A wide range of assessment techniques have been developed. These include the use of computers for testing, group performance assessment, interviews, observation, the production of portfolios, the exhibition or demonstration of projects and a range of non-traditional test items. Also in Slovenia, with effect from 2005/06, the national examinations at the end of the first cycle of schooling have been abolished, those of the end of the second cycle cease to be compulsory and those at the end of the third cycle are no longer used for certification purposes.

In Finland, the high level of performance of pupils in the international study of pupil achievement (PISA) in 2003 and 2006 has not led to changes in the assessment system but has prompted research into the reasons underlying this success.

Changes being considered for assessment at age 14 in the United Kingdom (England) include the introduction of electronic testing (with the possibility this offers for testing on demand).

Figure 4.4: Debates/Reforms in pupil assessment in science (ISCED 1 and 2), 2004/05



Source: Eurydice.

Names and purpose of standardised national science examinations (parts of examinations)/tests (Figures 4.1 and 4.2), (ISCED 1 and 2), 2004/05

	ISCED 1		ISCED 2	
	Name/ Nature of examination/test	Purpose of examination/test	Name/ Nature of examination/test	Purpose of examination/test
DE	Tests are under development in all <i>Länder</i> with a view to their introduction in the near future. Baden-Württemberg, Bavaria and North Rhine-Westphalia have announced the introduction of such tests.			
EE	National standardised tests at the end of stage II (grade 6). Subject of tests decided annually by the Ministry of Education and Research. In 2002 and 2003, the subject was science.	Evaluation	Basic school final examination. Mother tongue and mathematics are compulsory. Pupils may choose between physics, chemistry, biology, history and geography.	Evaluation and certification
EL	(-)	(-)	(i) End of year advancement examination: first two years of ISCED 2 (ii) End of year discharge examinations: last year of ISCED 2	Evaluation Certification
IE			Junior Certificate Examination	Certification
LV	National test with natural sciences as integrated subject	Evaluation	National Test in Natural Sciences	Certification and evaluation

	ISCED 1		ISCED 2	
	Name/ Nature of examination/test	Purpose of examination/test	Name/ Nature of examination/test	Purpose of examination/test
LT	Integrated sciences (Grade 4)	Evaluation	Integrated sciences (Grade 6); biology, physics and chemistry at Grades 8 and 10	Evaluation in each case
MT		(-)	(i) Annual School Examinations (ii) National Secondary Education Certificate at the end of compulsory education	(i) Evaluation (ii) Certification
NL	End of Primary School Test (part) and pupil monitoring system world orientation (part)	Evaluation in each case	National examinations in physics and biology (pre- vocational secondary education – VMBO)	Certification in each case
PL	National test at the end of primary education	Evaluation	National examination at the end of lower secondary education (<i>gymnasium</i>)	Certification and evaluation
SI	(-)	(-)	National tests in physics and biology	Certification in each case
UK- ENG	National Curriculum Assessment at age 11	Evaluation	National Curriculum Assessment at age 14	Evaluation
UK- WLS	National Curriculum Assessment at age 11 (optional from 2004/05, teacher assessment only from 2005/06)	Evaluation	National Curriculum Assessment at age 14 (teacher assessment and standard assessment tasks only from 2005/06)	Evaluation
UK- NIR	Key Stage 1 Assessment (teacher assessment). The optional transfer tests taken at age 11 cover science. These will not be taken after 2008.	Evaluation	Key Stage 3 Northern Ireland Curriculum Assessment (teacher and external assessment) at age 14	Evaluation
UK- SCT	(-)	(-)	Standard Grade Science, Biology and Physics Intermediate 1 and 2 Science, Biology and Physics	Certification in each case
IS	(-)	(-)	<i>Samræmt próf í náttúrufræði</i> / Nationally coordinated exami- nation in the natural sciences	Evaluation and certification

Source: Eurydice.

SCIENCE EDUCATION RESEARCH AND THE TRAINING OF SCIENCE TEACHERS

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Introduction

Science education research is concerned with the development of high-level skills (concept formation, modelling, problem solving and scientific procedures), and is a field whose importance is growing rapidly within science education.

Behavioural skills (knowing how to handle equipment) and low-level cognitive skills (e.g. the ability to learn and repeat definitions and laws, apply formulae, resolve standard problems) are accorded a lower priority partly as a result of developments in computing and automatic processing systems. Science education is thus changing to give more attention to those higher cognitive skills which cannot be acquired by methods based principally on learning by repetition and a transmission model of teaching.

There is a need to consider research in science education in a wider social context and, in particular, a need to enable as many people as possible to play their full part as citizens in scientifically and technologically advanced societies. This requires an understanding not only of scientific knowledge and the associated technical developments, but also of the nature of science and its methods, together with an ability to deploy a range of scientific arguments in wide-ranging public debates that are likely to involve environmental, economic, social and ethical issues. Such a perspective is reflected in various science curricula and teaching standards that have been developed since 1990. It finds a particularly explicit expression in such projects as Science for All Americans (AAAS 1989, NRC 1996), Science in the New Zealand Curriculum (Ministry of Education 1993), the English National Science Curriculum (www.curriculumonline.gov.uk), the Pan Canadian Science Project (Council of Ministers of Education 1997) and PISA (OECD 2001).

It is obviously necessary to determine some priorities among the many objectives for science education that this perspective offers: the choice is not one simply to be made by the researchers. Researchers in science teaching and learning are seeking to open up this perspective and to bring insights into the feasibility and effects of different approaches to science teaching. By drawing on other disciplines, in particular psychology, the philosophy and history of science, and linguistics, they are seeking to explore the potential of various ways of enhancing students' motivation, their pleasure in learning, their perception of science, and the effectiveness of various methods of teaching and learning in the development of the desired competences.

The general issues can be broken down into several different questions.

- What approaches to teaching and learning are to be preferred?

This assumes some reflection about the various sciences and raises a question about the possible stages in the development of scientific knowledge and competence. Attention is thus focused on research relating to the teaching and learning of scientific concepts (A.1 and A.2), the development of scientific procedures (A.3) and the skills associated with argumentation (A.5).

- What are the specific contributions that computers can make to science teaching and learning?

The use of communication and information technologies in teaching has had many consequences. The question here (A.4) is what these technologies have brought to science teaching, when used for gathering and processing data on the one hand, and for simulations on the other.

- How are pupils to be motivated?

Attention will be given here to the factors likely to increase the interest of children and adolescents in scientific studies (A.6).

One might equally ask about the dissemination of new approaches to teaching science, and thus about the training of teachers, a question which appears in a variety of forms according to the focus of the relevant research.

- What are the conceptions commonly held by trainee science teachers and those already in service about science and about how it should be taught (B.1)?
- What is the nature of the professional knowledge that contributes to the development of science teaching skills (B.2)?
- How are teachers to adopt the innovations that are suggested to them (B.3)?

This report cannot exhaust the subject. Given the richness of the research domain and the time available, some choices have had to be made. The approach has been to present some research themes that are particularly relevant to the training of science teachers, since this offers, for each of the various themes, an insight into the questions that have been asked and the results that have been obtained.

A. Research into learning scientific disciplines

A.1. Common sense conceptions and reasoning

Misconceptions, preconceptions, mental images, types of understanding, phenomenologically naïve ideas, spontaneous reasoning, common sense thinking: many studies have revealed a range of different ways of 'seeing' the world and accounting for phenomena that are significantly different from scientific ways of explaining and reasoning (see, for example, Tiberghien 1984; McDermott 1984; Driver, Guesne and Tiberghien 1985; Shipstone 1985; Johsua and Dupin 1993; Viennot 1996; Galili and Hazan 2000).

Some of these studies illustrate ways in which a particular phenomenon or type of phenomenon is represented. There are, for example, many studies concerned with the understanding of concepts associated with current electricity, mechanics, optics, chemistry and biology.

Other studies have been more concerned to identify the general reasoning structures that underpin the different models used to interpret various phenomena.

A.1.1. Some examples of concepts

Numerous studies undertaken in different countries (Tiberghien 1984; Shipstone 1985) involving students of different ages and levels of science education, have shown the stages involved in the development of the understanding of simple electric circuits, prior to the achievement of a level of understanding that is compatible with the scientific laws as presently taught.

- Single wire: electricity is 'consumed'; the 'electricity' leaves a source (a battery, a socket) and travels towards the item of equipment or apparatus where it is 'used up'. According to this model, a single wire linking the source and an appliance is sufficient to ensure that the appliance will work. Thus, connecting a light bulb to the terminal of a battery by means of a wire is sufficient to ensure that the bulb will light.
- Sequential circulation: the 'electric current' leaves the source then feeds the various components of the circuit in sequence, weakening all the while before returning to the source in order to 'regain the energy' that it has lost.
- Circulation at constant current: the value of the current delivered by a source is very much the same at all points in a series circuit and does not depend on the circuit used.

These types of reasoning present electricity and electric current as having properties which, in some cases, resemble those of the concept of energy, and, in others, the concept of current flow. The focus of the first stage of concept development in the field of current electricity must thus be concerned with the construction and differentiation of the concepts of current, voltage and electrical energy.

In the field of optics, the stages of development involved in image formation have been established in a variety of contexts (age, country) (Galili and Hazan 2000):

- a 'holistic conception', also known as 'a travelling image'; if a lens is partially obscured, only part of the image of an object can pass through the lens (i.e. one part of the image 'cannot pass');
- light rays conceived as 'railway lines'; a single ray leaving a point object is sufficient to carry the information relating to that point and thus to obtain its image.

In the field of chemistry, research involving pupils between the ages of 10 and 15 in a variety of countries (Andersson 1990) has revealed a failure to distinguish physical from chemical changes, and has shown that students can confuse combustion and melting, and combustion and evaporation, because of the presence of a flame. A chemical reaction between a solution and a solid can be interpreted as dissolution, and a reaction between two solids or two solutions as mere mixing. These erroneous ways of interpreting the phenomena of melting, evaporation, dissolution and mixing endure for a long time in students' explanations of material changes.

The results of such research enable the focus of the first stages of concept development in chemistry to be specified: distinguishing between physical and chemical changes and the construction of distinctive ideas such as the concept of a pure substance and a chemical element.

A.1.2. Structures of reasoning

The issue here is that of characterising the general reasoning structures associated with the way various phenomena are conceptualised. Research undertaken from this perspective has highlighted the role of time in pupils' explanations of phenomena and, in particular, the role of linear causal reasoning (Viennot 1996). Whereas science reasons in terms of the relationships between variables, which brings about co-variation (one variable does not change before another nor does it play a causal role in changing the other), common sense reasoning involves a narrative, constructed in terms of a succession of events and in which the inter-relationship of cause and effect plays an important part.

These narratives can be about entities of different degrees of abstraction: electricity, current electricity, images and light. Thus, for example (see A.1.1), in interpreting the way an electric circuit operates, pupils describe how an 'electric current' flows through a circuit and undergoes successive modification as it meets the various constituents of that circuit on its journey. In the case of light, the image leaving the illuminated object meets a range of obstacles (a lens, mirror, screen) and is modified as a result of doing so: in particular, it may be stopped or inverted.

The same kind of reasoning (linear and causal) can occur at a more sophisticated level when the elements of the narrative themselves become the variables. An event (a change in a variable) can appear to be the cause of what follows. When several variables change simultaneously, a single change is taken into account at each stage of the reasoning (Viennot 1996).

Thus, for example, in explaining the displacement of a surface due to a difference in pressure on the two sides (Méheut 1997), pupils at first only take into account the pressure which has been initially changed (the 'cause' of the displacement) and forget the pressure exerted on the other face. It is only at a second stage of reasoning that they realise that this latter pressure may have changed as a result of the displacement of the surface (they presume that a change in pressure on one side causes the displacement of the wall and thus a change of pressure on the other side). Likewise, in order to interpret the increase in volume of a gas with increased temperature (at constant external pressure), pupils do not use the relationships governing the variables of pressure, volume and temperature of a system, i.e. the equations of state, in which time is not a variable. Rather, they reason in a 'linear' and sequential manner: the variation in temperature causes a change in pressure which then leads to a change in volume and this, in turn, produces a further change in pressure. Instead of managing the concomitant changes in the two variables, they reason in stages, each stage taking into account a single variable and the outcome of one stage leading 'logically' to the next.

A.2. Conceptual change

The concepts and modes of common sense reasoning and their resistance to change by traditional methods of teaching, shed light on the difficulties of learning that are specific to a given domain. This has led to research into the teaching strategies likely to develop scientific ways of thinking.

A large number of studies of this type have been undertaken and have involved the development and testing of teaching approaches in a variety of domains, notably mechanics, current electricity, optics, energy, chemistry and the structure of matter (Méheut and Psillos 2004).

Some of the research undertaken emphasises the autonomy of pupils in the process of constructing knowledge, especially their responsibility for the development of the problems to be addressed and the organisation of the procedures for solving them (Lijnse 1995). Others have accorded an important place to cognitive conflict, i.e. making pupils aware of the limitations of their understanding of the world by contradicting their predictions with suitable experiences provided by the teacher (Dewey and Dykstra 1992; Ravanis and Papamichael 1995). Yet other researchers rely on a detailed analysis of the

knowledge already possessed by pupils and their replies to questions, to suggest activities likely to lead to the desired learning outcomes (Lemeignan and Weil Barais 1994; Robardet 1995).

From this body of work (Arnold and Millar 1996; Chauvet 1996; Galili 1996; Barbas and Psillos 1997; Gilbert and Boulter 1998; Komorek, Stavrou and Duit 2003; Viiri and Saari 2004), a consensus is gradually emerging about the importance of undertaking two types of prior analysis in order to devise appropriate learning and teaching strategies:

- an analysis of the relevant scientific knowledge in play, its development and the way it may be used (to make predictions or offer explanations);
- an analysis of the difficulties encountered in learning and of students' own concepts.

The outcomes of analyses of this type are then used in a revised teaching and learning situation based upon an 'educational reconstruction' or an 'engineered' approach to teaching that takes into account both the content to be learnt and the teaching situation (Méheut and Psillos 2004).

Research studies of this kind produce different types of outcome. They provide methodological benchmarks for the construction of teaching situations specified in terms of intended learning outcomes, based on the scientific knowledge to be learnt compared with pupils' knowledge.

They indicate the impact of different learning situations on cognitive development in a variety of scientific domains.

Looking further ahead (B.2), the results of the research will be able to contribute to the development of the professional knowledge needed by teachers to introduce teaching strategies that take full account of pupils' ways of thinking.

A.3. The role of practical work in learning science

A.3.1. Existing practice

There seems to be no shortage of purposes claimed for experimental work in science teaching: they include motivating pupils, developing manipulative skills and enhancing the learning of scientific knowledge, methods and attitudes (Jenkins 1999).

Those relating to experimental procedures still appear too often in a stereotypical form (Leach and Paulsen 1999). However, while contemporary primary education seems more open to investigative activities, among which the testing of hypotheses plays a significant part (Haigh and Forret 2005), practical activities at the secondary level are used mainly:

- to illustrate scientific concepts;
- to verify a scientific law; or
- in an inductivist manner (experiment, observation, measurement and conclusion).

The pupil is thus required to carry out a series of prescribed practical tasks, make observations and measurements and form conclusions that seem self-evident, always assuming they are not known in advance.

One study, based on an analysis of the notes of guidance for practical work in several disciplines (physics, chemistry, biology) in seven European countries, reveals an objective common to both the countries and the disciplines, namely, familiarisation with apparatus and phenomena (manipulating apparatus, causing something to happen and observing it). One objective that is less common to these countries and disciplines is that of organising a strategy for conducting an investigation. Practical work in physics

appears more oriented than in chemistry or biology towards learning scientific laws and manipulating the relationships between variables (learning to handle data and using the data to reach a conclusion). In chemistry, the main objective is 'learning to follow an experimental protocol', whereas in biology more attention is given to how to conduct an investigation (Tiberghien *et al.* 2001).

The many studies undertaken in different countries reveal the difficulties encountered by pupils in making the link between experiment and theory. Practical activities provide few occasions for pupils to discuss physics. Manipulating apparatus and making measurements take up an important part of pupils' time (Niedderer *et al.* 2002) and lead to activities that are routine, to the detriment of reflection upon their experiments or upon related theoretical issues (Hucke and Fischer 2002).

The criticisms and suggestions are suggestive of two main strands for the development of experimental work:

- providing a richer and more diverse picture of what is involved in doing science: formulating and reformulating a question or a problem, formulating a hypothesis, planning experiments, improving a protocol, controlling a range of variables, gathering, analysing and interpreting data, using simulations, discussion, etc.;
- giving more autonomy to pupils: engaging them in more open-ended tasks and allowing them to develop activities of a higher cognitive level.

Some of these suggestions form part of the idea of developing a scientific culture, a culture that gives an important place to pupils' development of an understanding of scientific activities and procedures.

A.3.2. Formulating and testing hypotheses

Following the work of Piaget, much research has been done on the development of hypothetico-deductive reasoning in learning science. Different types of task have been investigated. In some cases, the emphasis has been on studying the effect of changing given variables (Millar 1996): in others, the problems are more open, with the choice of variables to be studied being left to the pupils themselves (Cauzinille *et al.* 1985; Flandé 2000).

The following points emerge from the research undertaken with pupils aged 9 to 14 (Cauzinille *et al.* 1985; Millar 1996; Flandé 2000; Millar and Kanari 2003):

- pupils hardly ever consider referring to an experiment or to measurement spontaneously when seeking support for an assertion;
- conducting an experiment can appear to raise doubts and resolve different opinions: it appears that pupils tend to use experiments to verify a hypothesis about which there is no consensus;
- at this age, pupils tend to take only one variable into account and in consequence, ignore changes in other variables;
- pupils do not feel the need to repeat a measurement; they seem not to ask questions about its quality or about the possibility of improving it;
- every difference between two measurements which are intended to test the effect of changing one variable is regarded as significant; it is much easier for pupils to think of variables as dependent (two measurements will be adequate for them) than as independent;
- the spread in the results of making measurements presents a problem; it is necessary to obtain the same result when a measurement is repeated;

- pupils pay attention to possible sources of the spread of results (uncertainty of measurement) only when their predictions are at odds with their results.

The experiments undertaken by Flandé (2000), in which charts are used to support pupils' reasoning, describe the progression made by pupils aged 10 to 11 in terms of the separation of variables, the formulation of hypotheses, and the construction and analysis of procedures to test those hypotheses.

The research that has been done therefore reveals the 'spontaneous' procedures followed by pupils, the possible stages in the development of experimental/investigative procedures, and the kinds of situations likely to promote the latter. Thus, for example, pupils can suggest resorting to an experiment in order to resolve differences of opinion, and thinking about the scattering and quality of measurements which can arise from a conflict between the anticipated and the actual results of an experiment. The research relates pupils' progress to a framework of strategies for teaching them the required stages, taking their level of cognitive development into account.

A.3.3. The nature of scientific investigation

It is clear that the role of experimental work in science curricula has changed since the 1990s. Initially centred on the learning of manipulative skills on the one hand and concept formation on the other, and organised in accordance with stereotypical accounts of 'scientific method', such curricula have gradually given increased attention to the nature of open-ended investigations as conducted in science itself: the formulation of hypotheses, the development of apparatus and experimental procedures, the selection of data to be collected and their treatment, and the organisation and communication of results.

Studies undertaken with pupils aged 15 to 17 show that such an approach can create a sense of insecurity among teachers and pupils, the latter finding particular difficulty in devising experimental procedures and presenting their data. This prompts the question of how best to help pupils overcome their difficulties. When such help is carefully structured, positive effects have been observed both in terms of learning scientific concepts and of pupils' understanding of the nature of science (Haigh and Forret 2005).

The notion of progressive development in pupils' competence at scientific investigation over several years has followed from studies (Butler-Songer, Lee and McDonald 2003) of the use of standards in science education (NRC 2000). The authors of this study establish that a curriculum takes several different forms depending upon context (type of school and number of pupils), the teacher and the level of schooling of the pupils. They suggest, therefore, engaging pupils in activities that correspond to the levels of increasing independence required for scientific investigation. From this same perspective, Windschitl (2003) proposes a progression in the stages of investigation, from the most familiar (verification experiments and prescribed procedures) towards more authentic forms of investigation, either guided (the pupils are presented with the questions) or open (the pupils themselves formulate the questions to be investigated).

According to Millar (1996), it seems that pupils aged 9 to 12 place themselves more readily in a situation of optimising one effect or one phenomenon, and that subsequently (aged 12 to 14) they are able to move towards adopting a more scientific approach to exploring the relationships between variables.

Research of this kind makes it necessary to clarify a number of epistemological issues. What are the essential features of experimental work? Is it possible that a hypothesis can be verified, refuted or corroborated by a single experiment? If so, under what conditions? In reality, the answers to these questions are rarely unequivocal, although the development of research into teaching and learning science is gradually leading to more precise responses. This demand for clarification becomes more urgent when one wishes to teach the nature of science, which today constitutes an important point of

curricula that seek to promote science as an element of general knowledge (Osborne *et al.* 2003; Rudolph 2003; Abd-El-Khalick 2005; Hipkins and Barker 2005).

This same body of research indicates possible stages in the development of increasingly open scientific investigations. Equally, they show the work that remains to be done in this field, both in the clarification of objectives and in suggesting possible ways for pupils to acquire the necessary competences and for teachers to devise appropriate teaching strategies.

A.4. The specific contribution of information and communication technologies (ICT)

Information and communication technologies (ICT) are able to make a number of different contributions to education. Some are not specific to science, for example, acting as a data-base, facilitating individual training exercises, or allowing the transfer of information and distance learning. The attention of researchers in science education has been focused on two ways of using ICT that are more specific to teaching science, namely, the logging and automatic processing of experimental data (the computer as a laboratory tool) and the use of computers for simulation purposes.

Hucke and Fischer (2002) have queried the contribution that computers make to science education when used for either data handling or simulation. They conclude that the former do not help students to engage in theoretical reflection. They perhaps also reduce the attention students give to the experiments themselves, their attention being diverted towards the working of the computer itself. In contrast, the use of computers for simulation purposes encourages theoretical reflection.

Several studies (Beaufils and Richoux 2003) are concerned with the possibility of visualising theoretical models and the development of activities that:

- explore and manipulate models aimed at developing knowledge of their characteristics and adopting the rules that govern their function;
- lead to modelling, i.e. using ICT tools to develop models of physical phenomena.

These perspectives are also found in a study on learning basic models of the structure of matter (Méheut 1997). The focus adopted here involves the gradual development by pupils aged 12 to 13, attending *collèges* in France, of a particular model of matter, constructed in the light of activities designed to predict and explain the thermo-elasticity of gases. Reference can also be made to the work of Buty (2003), which explores the learning potential and limits of the use of software that simulates geometrical optics in order to understand how lenses lead to the formation of images.

Testing has shown that when experimental and simulation activities are coordinated, the latter are able to act as a 'cognitive bridge' between theory and practical experience. Thus Niedderer *et al.* (2002) report that while the usual experimental activities attach importance to the manipulation of apparatus and the making of measurements, the use of appropriate computer simulations encourages theoretical reflection. Goldberg and Otero (2001) describe some of the cognitive activities that accompany the processes involved in the task of conceptualisation. These are initially more intense when engaged in simulation (the phase of model construction), than in experimental activities (relating the model and experiment).

Bisdikian and Psillos (2002) are particularly interested in the role that graphs might play as intermediaries between physical phenomena and theory, and have investigated students' cognitive processes in a series of activities which involve making predictions, the manipulation of apparatus, making measurements, simulation and the comparison of experimentally determined and simulated graphs. The same kind of integrated activities can be found in the sequence proposed by Zacharia (2003) involving prediction, simulation and explanation.

These various studies cast some doubt on the benefits gained from some types of ICT use (data logging and the automatic processing of data) in science education, and they suggest some means of integrating others (simulations) in those procedures that seem particularly productive in terms of the cognitive activity of pupils.

A.5. Discussions between pupils and the development of argumentation skills

The emphasis since the 1990s on promoting science as an element of general knowledge has led to an interest in the argumentation skills deployed in the context of socio-scientific debates, which are also regarded as an opportunity to acquire a conceptual and epistemological understanding of science (Sadler and Zeidler 2005). The relevant studies (Bell and Lederman 2003) reveal the importance of considering other dimensions germane to such debates – notably emotional, social and moral – and raise questions about links made in some curricula between the acquisition of epistemological ideas (understanding the nature of science) and the development of the skills used in socio-scientific debates (an ability to recognise pseudo-scientific claims and to apply scientific knowledge to everyday life).

Simmoneaux (2003) compares the kinds of arguments developed by pupils in lessons based on role-playing with those acquired in lessons focused on more formal discussions. She shows that the former favour some rhetorical skills (provocation, suspicion, irony) whereas the latter are more conducive to rational argument.

Grace and Ratcliffe (2002) have studied the values and concepts among pupils engaged in debates about the conservation of species. They compare the results obtained in terms of the concepts expected by experts and teachers and show the importance of value judgements in the debates. They conclude that it is important to use debates of different kinds in order to promote conceptual development. Sadler and Zeidler (2005) distinguish different types of reasoning likely to arise in these various contexts and endorse the importance of the choice of topics for debate, some of which may privilege the emotional at the expense of the rational.

Zohar and Nemet (2002) report the outcomes of a teaching unit aimed at developing pupils' understanding of genetics and their skill at argumentation. This unit includes the teaching of genetics as well as the principles of argumentation and the role they play in debating. The authors conclude that the unit is effective both in promoting an understanding of genetics and in improving pupils' skills at argumentation (conclusions reached less readily, better quality of argument, more sophisticated content).

Mork (2005) reviews possible reasons for teachers' limited use of activities designed to promote argumentation skills: such skills are difficult to acquire and need to be specifically learnt; the necessary activities are time-consuming and the resources that teachers need to plan and manage them are poorly developed. Drawing on the typology suggested by Mortimer and Scott (2003), she proposes a kind of 'interactive and dialogic' communication that stands in contrast to the non-interactive and authoritarian, and is likely to improve the quality of classroom debate. She analyses the teacher's interventions in terms of their purpose; ensuring the correctness of the information exchanged, refocusing and widening the debate, reopening the debate when it is deadlocked, encouraging pupils' involvement, and managing the use of words.

The research outlined above can be used to help teachers choose the sort of debate likely to lead to the kinds of argumentation skills they wish to promote and to direct their interventions during classroom discussions. It can also suggest criteria for the evaluation of pupils' competence at argumentation.

A.6. The significance of the topics taught for pupil motivation

This issue arose during the 1960s and 1970s as a result of research into pupils' interests in, and attitudes towards, science at school. At that time, there appeared to be no major developments, perhaps because of the lack of appropriate theoretical and methodological tools (Ramsden 1998).

More recently, various studies have revealed a more general picture of the aspects of scientific disciplines (biology, technology, astrophysics, earth science, chemistry and physics) that pupils find more or less attractive. They have also revealed that pupils like practical work and linking school science with everyday life, and dislike science teaching that gives them little opportunity to express their own opinions (Dawson 2000; Osborne and Collins 2001; Baram Tsabari and Yarden 2005).

The approach adopted by Häussler and his co-workers (1987, 1998, 2000) relies on drawing a distinction between the personal and the situational. The intention is to distinguish qualities that are intrinsic to the pupil from those that derive from the learning situation. Häussler (1987) proposes to characterise the latter in terms of three components: science domains (light, mechanics), context (science as an intellectual endeavour, application of science to everyday life, preparation for the world of work, the social relations of science) and teaching approach (transmission reception, problem solving, class discussion). Issues surrounding pupil motivation can then be reformulated in terms of personal (age, gender) and contextual factors that relate to the learning situation. It thus becomes a question of investigating how these factors interact in terms of pupils' motivation.

As far as scientific disciplines are concerned, it appears that girls between the ages of 8 and 14 are more interested in biology than either chemistry or physics, whereas interests are more diverse among boys of the same age, who become slightly more interested in physics than in biology (Stark and Gray 1999).

Research led by Häussler (1987) with pupils aged 11 to 16 in different *Länder* in Germany shows that:

- girls have less interest than boys in physics, this difference narrowing with increasing age;
- there is a small decrease in interest in physics with increasing age, for boys as much as for girls;
- boys and girls are interested in different aspects of science, with girls being equally or a little less interested than boys in light, sound and heat, and much less interested in mechanics, electricity and radioactivity;
- gender differences are equally evident in terms of the teaching and learning context, with girls being drawn strongly towards careers in art, medicine or counselling, and boys towards physics as an intellectual endeavour and as a basis for work in research or technical fields.

The researchers conclude that, overall, the differences in interest stemming from gender are not very significant but that one consistent feature emerges from their work: the interest of girls in physics lies in its usefulness, its relations to other disciplines and its significance in everyday life. Such a finding agrees with that reported by Jones, Howe and Rua (2000) who show that the out-of-school experiences of boys are relevant to physics (electronic games, rockets, microscopes), whereas those of girls are more closely associated with biology (bird watching, sowing seeds, planting). The interests of boys and girls in the science subjects taught at school divide rather differently with boys preferring technical subjects (aeroplanes, computers, new sources of energy) and girls preferring subjects that have a bearing upon perception and everyday life (colour, diet, communication with animals and AIDS).

A re-interpretation (Häussler *et al.* 1998) of the findings of this earlier study (Häussler 1987) had led to the identification of three different pupil profiles: profile A, which might be labelled 'techno-scientific', profile B, 'humanist', and profile C, 'citizen'. Pupils with profile A (about one quarter of the total) show a

strong interest in science as an intellectual pursuit and in technological artifacts and careers. Boys make up most of this group (4/5). Those fitting the second profile (a little less than half of all the pupils) are mainly interested in understanding natural phenomena and their consequences for humanity. Boys and girls make up this group in equal numbers (1/2). The principal interest of the remaining group (profile C, about one quarter of all pupils) is in the impact of physics on society, and most of the pupils in this group (3/4) are girls. Gender-related differences are thus marked in the first and third profiles, the second being equally divided among the two sexes and also the most stable in terms of age. In contrast, the first profile shows a clear decrease, and the third an increase, in gender difference with increasing age.

Complementary studies have enabled Häussler and Hoffmann (2000) to establish that there is a consensus among 'experts' (scientists, engineers, teachers) that science teaching should give attention to socio-economic issues and the preparation of pupils for future employment. However, there is also some divergence of view: one group would place the emphasis on scientific concepts and methods, another on the technical and practical aspects of science. The pupils themselves are very interested in the socio-economic, practical and personal aspects of science, and which are not found in traditional science curricula. These results have been used to design teaching units that have led to cognitive and affective benefits in the medium term, particularly in the case of girls.

This research in the field of science education illustrates and adds to what is known about cognitive style as a result of other work in the field of gender differences. These differences can generally be described in terms of oppositions such as analytic/systemic, quantitative/qualitative, outcomes/processes, competition/cooperation and objective/subjective (Hildebrand 1996). For girls, context is particularly important, with boys being more focused on the task itself, independent of context. Girls also show a preference for collaborative styles of working and for discussion.

We should also mention the Relevance of Science Education Project (ROSE) directed by C. Schreiner and S. Sjöberg of the University of Oslo (<http://www.ils.uio.no/forskning/rose/>). The project's aim is to explore the links between pupils' cultural backgrounds and their responses to a series of questions. 35 countries are involved and the questions address such issues as pupils' interests, the criteria they invoke when thinking about a future job and their attitudes towards school science. The first results of this ongoing project seem to confirm the conclusions of previous research, especially with respect to gender-related differences.

We should also draw attention to two issues that emerge from a research review undertaken by Osborne, Simon and Collins (2003):

- The importance of the teacher: the effectiveness of a curriculum is negligible when compared with what can be achieved by an enthusiastic and competent teacher. In other words, mastery of the subject to be taught by the teacher is a determining factor.
- The relationship between attitudes and learning outcomes: the research evidence here seems to be contradictory. Whereas some studies show a positive correlation between pupil motivation and the quality of learning (Zusho *et al.* 2003), others have failed to do so (Osborne, Simon and Collins 2003).

B. Research into the work and training of science teachers

The particular interest here is science teachers, the factors that determine their teaching methods and the means by which these methods are developed, and thus the way in which the teachers are trained. The relevant issues are tackled from different angles.

Some studies focus attention on science teachers' understanding of science on the one hand, and on the learning of science by pupils on the other, the hypothesis being that a teacher's own conceptual framework shapes the way in which he or she teaches science.

Other studies are directly concerned with teachers' professional practice. It is necessary here to investigate what determines different pedagogical practices and the ways in which they change. Yet other research has explored the way in which innovative practice is diffused, with the science teacher regarded as a recipient and modifier of the intentions and teaching strategies devised by others.

B.1. Teachers' knowledge of science and science teaching, and their development

Among the numerous studies showing that science teachers persist in holding qualified empirical or naïvely empirical views about the nature of science (Van Driel, Verloop and De Vos 1998; Glasson and Bentley 2000; Abd-El-Khalick 2005), one consistent feature concerns the role that they accord to experimental work in their teaching (A.3). Pride of place is given to observation, which is seen as giving experimental data an absolute value. Teachers underestimate the role played by theory in conducting experiments and in making observations, along with the value of scientific knowledge as a means of explaining and predicting.

These conclusions must be qualified by the results of other studies which show that teachers can present contradictory views, depending upon the questions they are asked. An empirical view, stemming from their initial training, is able to co-exist with a constructivist perspective that stems from their own cultural background and attaches more importance to theoretical frameworks, *a priori* knowledge and thinking, and social issues (Guilbert and Meloche 1993).

The relationships between teachers' knowledge of science, the way in which they conceptualise learning and their professional working practice are matters of debate, with some authors affirming a strong link between these elements, others noting some divergence. This may perhaps be interpreted as a lack of integration of the different kinds of knowledge that determine the way teachers teach, with novice teachers displaying less consistency in their views than their experienced colleagues (Van Driel, Verloop and De Vos 1998).

Thus, for example, Martinez Aznar *et al.* (2001) show that, despite a degree of divergence in epistemology, science teachers commonly regard scientific knowledge as objective, neutral and context free. Learning science can be thought of as the outcome of the accumulation of elements of understanding from two main sources: the transmission of knowledge by the teacher and activity on the part of the pupils (experiments, observation).

Following Koballa and Gräber (2001), it has proved possible to refer to three possible ways of learning and teaching science at the second stage of training at two universities, one American, the other German. Learning may be regarded as the acquisition of scientific knowledge, the solving of scientific problems or the development of meaningful understanding. The corresponding modes of teaching are respectively the transmission of knowledge, the engagement of students in problem-solving and the constructive interaction of teachers and students.

Abd-El-Khalick and Lederman (2000) distinguish two types of training aimed at conceptual development: an 'implicit' approach which assumes that students' conceptual understanding improves as they

themselves engage in 'doing' science, and an 'explicit' approach that calls upon elements of the history and philosophy of science. They discuss the naïve nature of the first approach and affirm the need to suggest to pupils the ways in which their work can be interpreted. Analysing the results obtained by several researchers working within one or other of these approaches, they conclude that the second approach is better as judged by the evaluation instrument (multiple choice, Likert and fixed response items). Nevertheless, any gains remain modest. They discuss the bearing of the evaluation instrument upon the principal objective, which is to develop pupils' understanding of the nature of science. They urge the development of training programmes that include scientific activities and the tools for reflecting upon them, together with the development and implementation of teaching activities along these lines for use with pupils.

Working within this perspective, Abd-El-Khalick (2005) has examined the effect of adding an element of the philosophy of science to a science methods teaching course. He concludes that there are significant benefits which student teachers can turn to advantage when teaching pupils. Equally, we should note the research of Windschitl (2003) who cautions against making strong links between understanding the nature of science and the practice of science teaching. He concludes that personal experience of scientific research is more effective than formal statements about the nature of science in bringing about scientific investigations in the classroom.

B.2. Analysing the determining factors in science teachers' practice; bringing about professional development

The research presented here shows the diversity of the factors likely to influence the way science is taught, the complexity of the professional skills needed, and the different training programmes directed towards professional development.

A range of studies show that there are links between teachers' scientific knowledge and skills, the ways in which they teach science and the consequences for the pupils. It seems that a low level of scientific competence is linked with teaching that leaves little room for questions or discussion (the use of prescriptive work sheets, simplified experimental activities and a limited range of equipment) (Harlen and Holroyd 1997). In addition, the cognitive level achieved by pupils has been shown to be related to the competence of their teachers in the relevant discipline (Jarvis and Pell 2004). Work of this kind has led to an emphasis on the science component of teacher training.

Studies involving the notion of Pedagogical Content Knowledge (PCK), proposed by Schulman (Gess-Newsome and Lederman 1999) or that of professional context-specific knowledge (Morge 2003a), seek to develop among teachers the knowledge that is specific to teaching a given subject. The emphasis is placed on the diversity of the elements needed to teach the subject: experience, knowledge and personal competence, an understanding of the difficulties encountered by pupils in learning, understanding of the goals of science teaching and the science curriculum, and familiarity with the range of methods available for teaching, together with competence in evaluating them.

Such studies show that science teachers are unaware of some of the misconceptions held by their pupils (especially those that they share), and that they persist after teaching (as a result of inappropriate pedagogy). Also, even when teachers are more generally aware of these difficulties, they do not always know how to help pupils to overcome them. The importance of knowledge of the relevant scientific discipline for the development of PCK is revealed in numerous studies. However, such knowledge cannot be considered a sufficient condition for effective teaching; some teachers with a high level of disciplinary knowledge show themselves incapable of helping their pupils to acquire it (Magnusson, Karcjik and Borko 1999).

In their review of curricula that include teaching about the nature of science, Hipkins and Barker (2005) show that such curricula lack clarity, therefore calling for discussion and clarification. They also emphasise the fact that, even if teachers have good general knowledge for addressing the relevant issues, it is still difficult for them to respond appropriately in their teaching, since they lack the resources that permit them to develop the necessary professional teaching skills.

Numerous strategies have been designed to promote the development of such skills in different subject areas.

Applying the notion of PCK, Aaltonen and Sormunen (2003) use four dimensions to investigate the effect of a training module on the ways in which science teachers prepare for their classes: knowledge of the curriculum, pedagogical methods, students and resources and tools for presenting the content.

De Jong (2003) studies the development of PCK among teachers in training, with particular regard to models and modelling. This study highlights the difficulties that teachers encounter in giving practical effect to their ideas about these two aspects of science. Morge (2003b) suggests a procedure for training teachers in the management of activities that use the insights obtained by research into the teaching of early ideas about the structure of matter.

Also using the notion of PCK, Haefner and Zembel-Saul (2004) suggest a programme of science teacher education designed to promote the learning of the various stages involved in scientific activities and their subsequent deployment in teaching pupils. They show that the development of teachers' ideas about science owes much to their own experience as pupils. In order to allow intending science teachers to develop a sufficiently broad understanding of the nature of science, it therefore seems desirable to place them in a variety of situations which, by confronting them with a range of appropriate difficulties, enables them to come to understand the many aspects involved. The researchers are also able to show a net growth in ideas about the teaching/learning process, which, at the start of training, is described by teachers mainly in terms of pupils' practical tasks and the transmission of knowledge by the teacher; at the completion of training, teachers describe this process as according a more important role to questioning and experimental work. From a similar perspective, Windschitl (2003) studies the effect of involving teachers in the various stages of an open-ended scientific investigation on the way they teach. He notes that experience prior to the research weighs heavily on the extent to which the teachers introduce their pupils to these stages in their lessons.

Morge is particularly interested in the management of pupils' output by teachers. His study offers an example of a subtle analysis of 'professional context-specific knowledge', unique to each teaching situation (the ways in which concepts are expressed, the ways in which pupils learn and the arguments available to teachers) (Morge 2003a). He suggests training situations that simulate 'class management' while seeking the reactions of the student teachers to pupils' output and permitting them to analyse it (Morge 2003b).

This collection of research studies thus places emphasis on the importance of teachers' disciplinary competence and their personal experience of the processes that they would have to teach, while also stressing that such competence and experience constitutes a necessary condition for effective teaching which is not sufficient in itself. The various studies show that it is also essential to devise and deploy the pedagogical resources appropriate to teaching the topic at hand, which draw upon general pedagogical theories and take into account the specifics associated with the intended learning outcomes, the known learning difficulties and the constraints imposed by the teaching context.

B.3. Teachers as recipients and transformers of intentions

Research here stems from concern about the relative ineffectiveness of different types of innovation (new courses and, in particular, information and communication technologies) in changing the way teachers work. In this case, teachers are regarded as the recipients of instructions formulated in terms of courses or communicated by electronic means.

Research undertaken from this perspective within the framework of a European project, STISS, (Pinto 2005; Stylianidou, Boohan and Ogborn 2005; Viennot *et al.* 2005) indicates the different factors likely to influence the way teachers respond to innovation; once again, teachers' mastery of scientific content, their views about the nature of science and about teaching and learning, along with various constraints (the number of pupils, the timetable, equipment), all play a part.

As an example, an Italian team (Stylianidou *et al.* 2000) has shown the importance of the different factors that govern the use of microcomputers as laboratory tools to teach experimental procedures. Disciplinary competence, personal experience of laboratory work and of using information and communication technologies, together with an understanding of the processes involved in teaching and learning, are once again important.

A French team (Stylianidou 2005) suggests that the reaction of teachers to a computer product depends on the 'distance' between that product and the contents, on teachers' practice and on the convictions they hold. When this 'distance' is small (the subject is familiar to the teacher and matches the teacher's usual practice and convictions), then the teacher can readily adopt the product and use it successfully. If the 'distance' is large, the product is misused and its purpose frustrated. Thus, for example, the use of computers to collect and process experimental data is more easily assimilated into teachers' practice than that of computer simulations, which call upon modelling processes that even today are poorly developed in science teaching. This is confirmed by Zacharia (2003) who shows that teachers are less familiar with the use of computers for simulation than they are with their use for logging and processing data; their opinion about the potential of such simulation shows a marked improvement once they have used computers in this way.

All this leads to a number of suggestions about the training of science teachers. They should be given opportunities to reflect upon the ways in which they use computer simulations, note the practice and recommendations of others, then to plan, evaluate and compare their own attempts with what is achieved by other teachers (Stylianidou, Boohan and Ogborn 2005).

Viennot *et al.* (2005) suggest helping teachers to become aware of the importance of some 'details' regarded as critical in light of the intentions of the innovators, the difficulties facing the pupils and the success of the proposed procedures, by:

- explaining the objectives, the various perspectives on learning and the importance given to the ideas shared by pupils;
- supplying teachers with books that enable them to take account of their own conceptual frameworks and those of their pupils;
- emphasising the critical points of the innovation by analysing the suggestions formulated by other teachers.

Other studies (e.g. Davis 2003) present in more general manner the issue of the compatibility between a prescribed curriculum and the concepts and values held by teachers. Given that curriculum reform has little effect on the way teachers teach, they suggest adopting a 'constructivist' approach to training teachers. They insist on the importance of starting with the teachers' own knowledge, concepts and skills

and on allowing teachers to reflect upon their own conceptions of teaching and learning. They also insist on offering teachers the opportunity to train in an interactive context that links classroom practice and discussions between teachers with insights from research. On the basis of these studies, which concern the implementation of a curriculum devised by others and imposed upon teachers, they warn that effecting reform is difficult and that it is necessary to take a long-term view of success (more than three years). Distinguishing two approaches to reform - curriculum implementation (CI) and curriculum development and adaptation (CDA) - they argue in favour of the latter, involving the various stakeholders within education and bringing about change through the gradual development of practice.

Conclusion

Arising from the concern to improve science teaching and science teacher training, science education research has, since its emergence in the 1970s, developed a number of different strands: studies of the concepts and forms of reasoning associated with 'common sense' thinking; the development and validation of situations for learning; pupils' motivation towards learning science; the construction and use of electronic information systems; the diffusion of innovative practice; teacher training; etc.

Addressing the issues associated with these different strands has led to the gradual integration of the contributions of a range of disciplines, especially the history and philosophy of science and psychology:

- cognitive psychology, in particular with respect to pupils' spontaneous concepts, modes of reasoning and procedures, and their development;
- affective and social psychology, especially for those studies concerning pupil motivation and the teaching/learning context.

Within Europe, debate involving the national research communities interested in science teaching and learning is relatively recent. It has been genuinely effective only since the 1980s, mainly through international journals and symposia. The European Science Education Research Association (ESERA) was created in 1994, and its regular meetings (conferences and summer schools) are seminal events. Some projects funded by the European Union such as 'Labwork in Science Education' (Séré 2002) or 'Science Teacher Training in an Information Society' (Pinto 2005) have provided opportunities for fruitful interaction. At present, the theoretical and methodological research frameworks still show some geographically and culturally specific features, although the contacts between different lines of research allow the issues of common interest to be revealed.

Important research findings relating to science teaching and the training of science teachers are now available. On the one hand, there are the outcomes of research into the difficulties of learning science and the concepts and types of reasoning associated with common sense thinking. On the other, research has exposed the factors governing pupils' interests in science and the role played by age and gender. Together, they shed light on the choice of content, objectives and teaching strategies and thereby contribute to more effective training of science teachers.

Research involving the devising and trialling of teaching/learning situations has yielded valuable information about pupils' cognitive abilities and their development. Such information constitutes a resource for teachers to improve their own practice by offering them examples of activities that are established by *a priori* arguments (involving an explanation of objectives and the underlying epistemological and pedagogical perspectives) which have been tried and tested. The research also provides criteria for the management of those open learning situations intended to guide pupils in the construction of their own knowledge and understanding.

Research into teacher practice and training allows the needs of such training to be identified. It reveals the importance of teachers' mastery of the concepts and procedures specific to the discipline being taught. While this appears to be necessary for the development of non-stereotypical, innovative pedagogical practice, it is, however, not sufficient. Making use of teaching expertise involves the deployment of other kinds of knowledge. This points towards the development and study of the effects of teacher training programmes based on different ways of relating training in science and pedagogy to what is known about teaching and learning, and about how to promote the latter. It is necessary to develop and test such programmes in order to meet the recognised needs of teachers to become competent in their discipline and to make use of their competence. One sees in particular how research into the scientific procedures recently introduced into curricula (scientific investigation, modelling, argumentation) can provide resources needed to design and manage the open learning situations likely to favour the development of high-level skills by pupils.

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SUMMARY AND CONCLUSIONS

This study set out to look at some of the key factors that influence school science teaching in Europe. From the policy-maker's perspective, at least three broad areas – teacher education, school science curricula and pupil assessment in science – are open to influence from central level to some extent, depending on the particular configuration of the education system and the nature of the authority exercised by the ministry of education.

In spite of the general independence of teacher education institutions with respect to devising and managing their training activities, a first conclusion that can be drawn from the study is that top-level recommendations and regulations for teacher education programmes for primary and lower secondary levels of education (both in general terms and science-specific teaching knowledge and skills) are very extensive. Prescribed or recommended school curricula also tend to contain considerable detail.

The data collected sought to differentiate between science taught as an integrated (single) subject and physics and biology at lower secondary level (Figure 3.1). There appears to be very little difference in official documents between physics and biology. To a very limited extent (mainly in Cyprus), top-level regulations give more attention to physics than biology. An example of this is demonstrating a scientific law through experiment, which is not part of the lower secondary biology syllabus in Greece, Cyprus, the Netherlands and Austria. These types of differences are very slight, however.

Innovation in science teaching: (trainee) teachers and teacher trainers

Teacher education, whether initial or in-service, represents the main link between the theory and practice of teaching. Teacher trainers play a central role in transmitting ideas not only about what to teach but also about how to teach it. It is of interest, therefore, to look at the sort of qualifications and experience held by teacher trainers for science. The analysis shows that central regulations are much more concerned with content-related science qualifications than with experience in education research. Thus, teacher trainers are required to hold a science degree (often at master's level or above) in most countries, while about half of Eurydice Network countries require or at least encourage them to hold a teaching qualification. Very few countries, however, specify the requirement to have experience in education research. Also less common is the requirement to hold specific qualifications as teacher trainers or to train mentors responsible for school-based placements. The general approach, consistent with the autonomy of teacher education institutions, is on quality provision without necessarily prescribing how this is to be achieved (Chapter 2).

The low level of central regulation in this area (teaching skills and education research) raises questions about how well trainee teachers are being equipped to teach in innovative ways. The factors influencing science teachers' responses to innovation have been explored recently (Section B.3). The need to close the gap (where it exists) between science education research and innovation on the one hand, and science teachers' beliefs and practices on the other, is the focus here. The relative ineffectiveness of different types of attempted innovation (for example, the use of computer-based simulations) is ascribed to the 'distance' between innovatory practices and teachers' existing practices and beliefs. If the distance is small, adapting to change is easier. Science teachers should be given opportunities to train in an interactive context that links classroom practice and discussions with teachers with insights from research. They can thus 'construct' appropriate values and concepts likely to improve the quality of school science education.

Developing scientific ways of thinking through investigation

The contribution of practical work to learning science has been well documented in science education research (Section A.3). The kinds of activities expected of pupils in science laboratories can be relatively prescriptive or more open-ended, allowing pupils to develop more complex cognitive skills. Developing a scientific way of thinking is understood to involve teaching and learning that places importance on developing a holistic (and therefore complex) understanding of scientific activities and procedures, reflecting the approach of professional scientists.

Research suggests that secondary-level science sometimes shows a more ‘stereotypical’ approach to practical activities (meaning that activities are designed to lead to prescribed or self-evident conclusions), while primary education seems more open to investigative activities (Section A.3.1). However, the analysis of school curricula in this study identifies lower secondary curricula as requiring a more complex body of knowledge and expertise as well as more independent pupil activity than primary curricula in most countries (Figure 3.4). This, of course, corresponds to the principle of progressive development in pupils’ competence at scientific investigation (Section A.3.3).

A related, and very important, issue is the development of scientific ways of thinking by and for teachers themselves. The links between teachers’ scientific knowledge and skills, the ways in which they teach science and the consequences for the pupils are established in a number of studies (Section B.3). The cognitive level achieved by pupils has been shown to be related to the competence of their teachers in the relevant discipline. This highlights the importance of teacher education, and more specifically training in science content. Figure 1.4 shows that scientific concepts and theories and experimental/investigative activities are very much part of teacher education. Figure 1.5 looks at what types of experimentation/investigation work are required or recommended as part of science teacher education and shows that teachers at secondary level are especially likely to have had experience of this type of work, particularly laboratory and project work.

The contextual dimensions of science learning

School curricula at both primary and lower secondary level seek to add a contextual dimension to science teaching almost everywhere. Science and contemporary societal issues are covered especially widely, more so than the history of science (Figure 3.2). This can be related to teacher education programmes, which also focus less frequently on the history of science (Figure 1.4). Discussions about science in society and about researching information are already well embedded in school curricula at primary level (Figure 3.6). This approach seems consistent with the fairly recent emphasis on promoting science as an element of general culture (Section A.5). As well as learning how to engage in scientific discussion, pupils are also expected to know how to present and communicate the processes and results of their science learning; this skill emerges as a key part of school science curricula throughout Europe. There is an emphasis on encouraging pupils to be articulate and capable of understanding their work in a broader context.

Facilitating discussions and addressing broader context-related questions require that teachers be able to manage interactive and dynamic learning situations. What does teacher education tell us about how these types of skills are acquired? The analysis shows that teachers are required to keep up to date with scientific developments almost everywhere (Figure 1.3) and that teaching skills such as the choice of meaningful learning contexts are very much part of science teachers’ education.

Applying information technology

The use of computer applications is a rich resource for enhancing the learning of science. Studies conducted mainly in upper secondary education have shown that appropriate computer simulations offer pupils the opportunity to visualise theoretical models, providing a ‘cognitive bridge’ between theory and practical experience and improving cognitive understanding (Section A.4).

However, computer simulations are seldom included as a prescribed activity on primary school curricula. The absence of this type of activity is perhaps linked to the level of development of primary-age children, meaning that these types of activities are not yet appropriate for them. Even at lower secondary level, however, it appears that simulation is seldom part of prescribed science activities (Figure 3.5).

Other uses of information technology, although less productive in terms of cognitive activity according to research (Section A.4), are more widespread. This includes activities such as the use of computers for recording experimental results and data as well researching the Internet for information and communicating with other pupils (Figure 3.5). These are perceived as being more ‘familiar’ uses of information technology for science teaching (the use of computers for collecting and processing experimental data, in particular).

Science teachers and ‘common sense understanding’

The ‘common sense understanding’ that pupils have of many scientific phenomena is a cognitive challenge that science teachers must meet in order to teach effectively. Children start out with spontaneous ways of accounting for phenomena that are different from scientific ways of explaining and reasoning (Section A.1). If teachers fail to appreciate these spontaneous interpretations and to respond in appropriate ways, science learning is less confident and less effective – an important consideration in view of the stated need to improve interest in science and increase recruitment to scientific disciplines. However, the study of top-level programme guidelines for teacher education shows that regulations covering training in knowledge of ‘common sense understanding’, and the ability to take account of it when teaching science are missing in almost half of the education systems studied (Figure 1.3).

Some recent reforms reflect the need to revise teaching methods. For example, the new Dutch approach requires teachers to take account of their pupils’ common-sense conceptions and reasoning in order to develop accurate and refined understanding of scientific phenomena.

Responding to gender differences

The need to redress gender imbalances in recruitment to scientific fields and to encourage young people in general but young women in particular to pursue an interest in science careers is part of the Lisbon strategy (Education and Training 2010 detailed work programme; this is also one of the five benchmarks setting out quantified targets for 2010). Early experiences of science learning – at primary and lower secondary levels – have a formative role in determining whether girls (and boys) maintain and develop their interest in this area.

Although gender differences in pupils’ attitudes towards science, and what motivates them in terms of learning science, are well documented (Section A.6), the data show that teaching awareness of these differences are less often part of top-level guidelines for teacher education (Figure 1.1 shows that only around half of education systems include a reference to this dimension). This may have important implications. If teachers are not being trained to take account of different learning styles and preferences evidenced by boys and girls (only detailed teacher education programmes from individual institutions

can corroborate), does this mean that one or other group is falling behind because their potential has not been fully explored? The question remains as to whether science curricula and teaching methods favour boys, or whether they are sufficiently flexible to take account of all types of learning preferences.

The role of assessment in determining what is taught

The study looked at the types of skills and knowledge assessed in examinations or tests designed by top-level education authorities (for certification or evaluation purposes). Standardised pupil testing is not common in Europe (Figure 4.1) although the way science is assessed is under review at policy level almost everywhere. Figure 4.4 shows that nearly all countries are engaged in debate about assessment and, in particular, several countries are developing national standards and/or tests in science subjects. In most cases, the specification of standards has also required school science curricula to be revised or even rewritten (Figure 3.7).

The study shows that, where it exists, standardised assessment is generally consistent with the activities and learning outcomes expressed in the science curriculum (meaning that pupils are effectively tested on what they have been taught), but also that the kinds of skills and knowledge assessed tend to be fairly broad, spanning knowledge, practical skills, data handling skills and scientific thinking (Figure 4.2).

The heightened emphasis on science standards evidenced by the expansion of centralised monitoring and evaluation systems in a number of countries has implications for science teaching within a prescribed curriculum. Reform should not, of course, act as a brake on innovatory ways of teaching but should contribute to making science education more effective. The study shows that several countries are working to broaden the range of skills assessed and are adopting innovative assessment techniques (Section 4.4).

GLOSSARY

Country codes

EU	European Union	PL	Poland
BE	Belgium	PT	Portugal
BE fr	Belgium – French Community	SI	Slovenia
BE de	Belgium – German-speaking Community	SK	Slovakia
BE nl	Belgium – Flemish Community	FI	Finland
CZ	Czech Republic	SE	Sweden
DK	Denmark	UK	United Kingdom
DE	Germany	UK-ENG	England
EE	Estonia	UK-WLS	Wales
EL	Greece	UK-NIR	Northern Ireland
ES	Spain	UK-SCT	Scotland
FR	France	EFTA/EEA	The 3 countries of the European Free Trade Association which are members of the European Economic Area
IE	Ireland	IS	Iceland
IT	Italy	LI	Liechtenstein
CY	Cyprus	NO	Norway
LV	Latvia	Candidate countries	
LT	Lithuania	BG	Bulgaria
LU	Luxembourg	RO	Romania
HU	Hungary		
MT	Malta		
NL	The Netherlands		
AT	Austria		

Classification

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 ⁽¹⁾ distinguishes seven levels of education. Empirically, ISCED assumes that several criteria exist which can help allocate education programmes to levels of education. 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 0: Pre-primary education

Pre-primary education is defined as the initial stage of organised instruction. It is school- or centre-based and is designed for children aged at least 3 years

ISCED 1: Primary education

This level begins between 5 and 7 years of age, is compulsory in all countries and generally lasts from four to six years.

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.

ISCED 4: Post-secondary non-tertiary education

These programmes straddle the boundary between upper secondary and tertiary education. They serve to broaden the knowledge of ISCED level 3 graduates. Typical examples are programmes designed to prepare pupils for studies at level 5 or programmes designed to prepare pupils for direct labour market entry.

ISCED 5: Tertiary education (first stage)

Entry to these programmes normally requires the successful completion of ISCED level 3 or 4. This level includes tertiary programmes with academic orientation (type A) which are largely theoretically based and tertiary programmes with occupation orientation (type B) which are typically shorter than type A programmes and geared for entry into the labour market.

ISCED 6: Tertiary education (second stage)

This level is reserved for tertiary studies that lead to an advanced research qualification (Ph.D. or doctorate).

(1) <http://unesco.stat.unesco.org/en/pub/pub0.htm>

Definitions

Accreditation

Process by which an initial teacher education institution or a programme is judged by the relevant legislative and professional authorities as having met predetermined standards in order to provide teacher education and to award the corresponding qualifications.

'Common sense' understanding of scientific concepts and phenomena

Forms of spontaneous/pre-scientific reasoning show important differences from scientific reasoning. These forms of reasoning have given rise to explanations of phenomena known as naïve conceptions or representations/common-sense understanding. As an example, pupils frequently think of an electric circuit in terms of a current that is used up (becomes weaker) as it passes through the different components of that circuit.

Concurrent teacher education model

A teacher education programme which, from the outset, combines general education in one or more subjects with theoretical and practical professional teacher education.

Consecutive teacher education model

Students first receive general education in order to obtain a degree in a particular subject or branch of study. At or near the end of this period of study, they enrol in a programme of initial professional training, enabling them to qualify as teachers.

Final 'on-the-job' qualifying or induction phase

A compulsory period of transition between the initial education of teachers and their entry into professional life as fully-fledged teachers. It generally constitutes the final phase of initial teacher education. This induction phase includes an important mentoring, supportive and supervisory dimension, as well as a formal evaluation of teaching skills. During this period, teachers are still not fully qualified and are usually regarded as 'candidates' or 'trainees'. They spend a significant amount of time in a real working environment (a school) in which they carry out wholly or partially the tasks incumbent on fully qualified teachers, and are remunerated for their activity.

Formative pupil assessment

This type of assessment is carried out during the learning process for the purpose of evaluating progressive learning and teaching in order to inform, modify and improve them.

General teacher education

This is devoted to the general courses and mastery of the subject(s) that students will teach when qualified. The purpose of these courses, therefore, is to provide students with a thorough knowledge of one or more subjects and good general knowledge.

Generalist (non-specialist) teacher

S/he is trained to teach all subjects in the curriculum.

Laboratory work

Work carried out in a laboratory or elsewhere as part of a science course. Such work may be routine (for example, involving simple observations or measurements) or have something of an investigative character (e.g., what is the effect of temperature on the solubility of a solute in water?) The task may be

undertaken by a whole class and/or by student teachers/pupils working in pairs or other small groups and is likely to be completed within one or two teaching sessions.

Meaningful learning contexts

This means contexts likely to make sense to the pupils. This may be done by using historical examples (e.g., accounts of different models of the atom, dialogues of Galileo) or by relating scientific ideas to problems of everyday life or social issues (e.g., teaching mechanics with reference to road safety, or the structure of the atom with respect to energy production).

Mentoring/support

Assistance with all tasks related to teaching as such (planning of lessons, class management, pupil assessment, etc.), as well as with other more interpersonal activities designed to draw prospective teachers into life at their school (relations with parents, familiarity with school management, etc.). Prospective teachers are also often observed at work in the classroom, in order to assess their progress and help them overcome any difficulties. The support offered to prospective teachers is multi-faceted: it includes, first, a training dimension (involving supervision as part of an integrated approach to training that is both theoretical and practical); secondly, concern for socialisation (the integration of prospective teachers within their school environment with the support of school staff); and, finally, monitoring and supervision (evaluating the progress of prospective teachers during and on completion of their placement).

Professional training

Provides future teachers with both a theoretical and practical insight into their future profession. In addition to courses in psychology and teaching methodology, it includes short and (usually) unremunerated in-class placements (supervised by the teacher in charge of the class concerned and with periodic assessment by teachers at the training institution). This may also include an 'on the job' qualifying or induction phase.

Qualification standards

Qualification standards are defined by the central or top-level education authority as being the set of core competencies, relevant knowledge and skills that a teacher must possess (a teacher profile) in order to obtain his or her initial teaching qualification.

Qualifications as a teacher trainer

A degree, diploma or certificate testifying that its holder has the knowledge and skills necessary to train teachers. It is awarded by an institution for teacher education and/or the central or top-level education authorities, in official recognition of the skills and knowledge of its holder.

Science-related project work

Involves experimental or other work in the laboratory or elsewhere and will have always an investigative character. The project may be undertaken on a whole class basis or by student teachers/pupils working individually or in small groups. It will extend over a period of time, perhaps several weeks, and provide an opportunity for student teachers/pupils to engage in a science-related study with a particular focus, e.g., how does the rate of growth of a plant species depend on the acidity of the soil? There may be collaboration via the Internet with people in other institutions. The write-up is likely to take the form of a report.

Scientific experimentation/investigation

This refers to experiment-based work that introduces students/pupils to the various processes and activities that lead to the formulation of a problem and of a scientific hypothesis or model, the gathering of data, the conducting of appropriate experiments and the analysis and presentation of results. In some education systems, the term 'scientific investigation' has come into recent use in order to emphasise the speculative, exploratory and progressive nature of scientific work.

Simulation

Use of a computer program, perhaps interactively, to present scientific theories, concepts and procedures and to promote understanding and learning. Pupils may be required to input a range of data to see what effect changing parameters may have on the outcome (e.g., change the mass or force acting on a object to observe graphically the effect on its rate/direction of motion). Pupils may be asked to draw their own conclusions from the results of a simulation. Computer-based simulations may also be used to illustrate experiments and/or properties that are regarded as unsafe for presentation in schools.

Specialist teacher

S/he is trained to teach just one or two specific subject(s), one of which is normally subsidiary. In certain cases, a specialist teacher is trained for three subjects, the third of which is subsidiary.

Standardised pupil assessment

This refers to standardised national exams (or parts of exams) or tests designed by central or higher education authorities for certification or for the purposes of pupil evaluation, or standardised assessment criteria for science-related project work.

Summative pupil assessment

This type of pupil assessment is designed to measure the acquisition of knowledge and skills through tests and examinations. It occurs at the end of a learning module/cycle or the end of a level of education.

Teaching qualifications

A degree, diploma or certificate in education and teaching. It is awarded by an institution for teacher education and/or the central or top-level education authorities, in official recognition of the skills and knowledge of its holder.

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Figure 1.2a (continued): Regulations in initial teacher education for general teaching knowledge and skills (ISCED 1), 2004/05

	Science as an integrated subject																			Physics		Biology		>> Study abroad											
Working with diverse pupil groups	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	SI	SK	FI	SE	UK ENG WLS NIR SCT				IS	LI	NO	BG	RO
Taking account of the social and cultural background of pupils	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<div><input checked="" type="checkbox"/> <input type="checkbox"/></div>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<div><input checked="" type="checkbox"/> <input type="checkbox"/></div>	>>		<input type="checkbox"/>	
Sensitivity towards/taking account of gender variation	<input type="checkbox"/>		<input type="checkbox"/>			<div><input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/></div>	<input type="checkbox"/>			<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<div><input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/></div>	>>		<input type="checkbox"/>	

Collaborative approaches to teaching	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	SI	SK	FI	SE	UK ENG WLS NIR SCT				IS	LI	NO	BG	RO
Interdisciplinary work	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<div><input checked="" type="checkbox"/> <input type="checkbox"/></div>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<div><input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/></div>	>>		<input type="checkbox"/>	<input type="checkbox"/>
Working as part of a team with other teachers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<div><input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/></div>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<div><input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/></div>	>>		<input type="checkbox"/>	<input type="checkbox"/>

Figure 1.2b: Regulations in initial teacher education for general teaching knowledge and skills (ISCED 2), 2004/05

[illegible]

Figure 1.2b (continued): Regulations in initial teacher education for general teaching knowledge and skills (ISCED 2), 2004/05

[illegible]

☐ Science as an integrated subject
 ☒ Physics
 ☐ Biology
 >> Study abroad

ISCED 1	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	SI	SK	FI	SE	UK ENGWLSNIRSCT				IS	LI	NO	BG	RO		
Knowledge of different teaching approaches and their history																																					
Knowledge of school science curricula and their objectives																																					
Scope for experimental/investigative activities																																					
Knowledge of children's 'common sense' understanding of scientific concepts and phenomena																																					
Taking account of children's 'common sense' understanding of scientific concepts and phenomena																																					
Ability to keep up to date with recent scientific developments																																					

ISCED 2	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	SI	SK	FI	SE	UK ENGWLSNIRSCT				IS	LI	NO	BG	RO		
Knowledge of different teaching approaches and their history																																					
Knowledge of school science curricula and their objectives																																					
Scope for experimental/investigative activities																																					
Knowledge of children's 'common sense' understanding of scientific concepts and phenomena*																																					
Taking account of children's 'common sense' understanding of scientific concepts and phenomena																																					
Ability to keep up to date with recent scientific developments																																					

Figure 1.4: Regulations in initial teacher education for scientific knowledge and skills (ISCED 1 and 2), 2004/05

	<input type="checkbox"/> Science as an integrated subject														<input checked="" type="checkbox"/> Physics	<input type="checkbox"/> Biology	>>	Study abroad																	
ISCED 1	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	SI	SK	FI	SE	UK ENG WLS NIR SCT				IS	LI	NO	BG	RO
Knowledge of scientific concepts and theories	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	>>		<input type="checkbox"/>	<input type="checkbox"/>
Knowledge of and competence in scientific experimentation/investigation	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	>>		<input type="checkbox"/>	<input type="checkbox"/>
Knowledge of history and epistemology of science		<input type="checkbox"/>			<input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>					<input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	>>		<input type="checkbox"/>	

ISCED 2	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	SI	SK	FI	SE	UK ENG WLS NIR SCT				IS	LI	NO	BG	RO
Knowledge of scientific concepts and theories	<input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>	>>			<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>		<input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>			<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>		<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	>>		<input type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>
Knowledge of and competence in scientific experimentation/investigation	<input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>	>>			<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>			<input checked="" type="checkbox"/> <input type="checkbox"/>			<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>		<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	>>		<input type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>
Knowledge of history and epistemology of science	<input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>	>>			<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>			<input checked="" type="checkbox"/> <input type="checkbox"/>		<input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>			<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	>>		<input type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>

Figure 1.5: Regulations in initial teacher education for scientific experimental/investigative skills (ISCED 1 and 2), 2004/05

	<input type="checkbox"/>	Science as an integrated subject																<input checked="" type="checkbox"/>	Physics										<input type="checkbox"/>	Biology										>>	Study abroad									
ISCED 1		BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	SI	SK	FI	SE	UK ENG WLS NIR SCT				IS	LI	NO	BG	RO														
Type of activity not specified							<input type="checkbox"/>				<input type="checkbox"/>				<input type="checkbox"/>																	<input checked="" type="checkbox"/> <input type="checkbox"/>	>>	<input type="checkbox"/>		<input type="checkbox"/>														
Placement in research laboratories						<input type="checkbox"/>													<input type="checkbox"/>													>>			<input type="checkbox"/>															
Science-related projects		<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>							<input type="checkbox"/>		<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>							>>			<input type="checkbox"/>															
Laboratory work			<input type="checkbox"/>			<input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>									<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>							>>			<input type="checkbox"/>															
Other			<input type="checkbox"/>																<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>								>>																			

ISCED 2		BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	SI	SK	FI	SE	UK ENG WLS NIR SCT				IS	LI	NO	BG	RO
Type of activity not specified			>>												<input checked="" type="checkbox"/> <input type="checkbox"/>																	<input checked="" type="checkbox"/> <input type="checkbox"/>	>>			
Placement in research laboratories			>>			<input checked="" type="checkbox"/> <input type="checkbox"/>								<input checked="" type="checkbox"/>					<input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>				<input checked="" type="checkbox"/>									>>			<input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>
Science-related projects		<input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>	>>			<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>							<input checked="" type="checkbox"/> <input type="checkbox"/>				<input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>		<input checked="" type="checkbox"/> <input type="checkbox"/>		<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>						>>		<input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
Laboratory work			>>			<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>				<input checked="" type="checkbox"/> <input type="checkbox"/>			<input checked="" type="checkbox"/>				<input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>		<input checked="" type="checkbox"/> <input type="checkbox"/>		<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>					>>		<input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
Other			>>																<input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>		<input checked="" type="checkbox"/> <input type="checkbox"/>		<input checked="" type="checkbox"/> <input type="checkbox"/>							>>				<input checked="" type="checkbox"/> <input type="checkbox"/>		

Science activities expressed in school curricula, ISCED 1, 2004/05

☐ Science as an integrated subject ☒ Physics ☐ Biology (:) Data available not

1. Formulating problem	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	SI	SK	FI	SE	UK ENG	WLS	NIR	SCT	IS	LI	NO	BG	RO
In scientific terms	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(:)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. Engaging in discussion in relation to:	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	SI	SK	FI	SE	UK ENG	WLS	NIR	SCT	IS	LI	NO	BG	RO
Science in society and in every day life	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(:)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Researching information	<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(:)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Experiments	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(:)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. Experimental work	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	SI	SK	FI	SE	UK ENG	WLS	NIR	SCT	IS	LI	NO	BG	RO
Teacher demonstrations	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(:)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Carrying out experiments following a pre-defined protocol	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(:)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Making observations	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(:)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Proposing experimental protocols in response to defined objectives						<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(:)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Verifying a scientific law through experiment						<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>						<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(:)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Formulating and testing hypotheses	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(:)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Presenting and communicating procedures and results	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(:)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Science activities expressed in school curricula, ISCED 1, 2004/05 (continued)

☐ Science as an integrated subject ☒ Physics ☐ Biology (-) Data not available

4. Using scientific documentation	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	SI	SK	FI	SE	UK ENG WLS NIR SCT				IS	LI	NO	BG	RO	
Researching documents for a defined purpose	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(-)				
Identifying information within documents	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					<input type="checkbox"/>		<input type="checkbox"/>	(-)				
Summarizing information for defined objectives		<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					<input type="checkbox"/>		<input type="checkbox"/>	(-)				
Presenting and communicating information	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(-)	<input type="checkbox"/>		<input type="checkbox"/>	

5. Using electronic technologies	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	SI	SK	FI	SE	UK ENG WLS NIR SCT				IS	LI	NO	BG	RO	
Logging and presenting experimental results and data		<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(-)				
Simulation		<input type="checkbox"/>			<input type="checkbox"/>		<input type="checkbox"/>									<input type="checkbox"/>	<input type="checkbox"/>					<input type="checkbox"/>		<input type="checkbox"/>					<input type="checkbox"/>		<input type="checkbox"/>	(-)				
Researching the Internet for data	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>				<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(-)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Communicating with other pupils		<input type="checkbox"/>			<input type="checkbox"/>		<input type="checkbox"/>			<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(-)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

6. Outside activities	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	SI	SK	FI	SE	UK ENG WLS NIR SCT				IS	LI	NO	BG	RO	
Visits to museums, research laboratories, science-based industry, etc.	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	(-)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Field work	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>		<input type="checkbox"/>	(-)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		

7. Projects	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	SI	SK	FI	SE	UK ENG WLS NIR SCT				IS	LI	NO	BG	RO
Science-related project work	<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>				<input type="checkbox"/>		<input type="checkbox"/>	(-)				<input type="checkbox"/>

Science activities expressed in school curricula, ISCED 2, 2004/05

☐ Science as an integrated subject ☒ Physics ☐ Biology (-) Data not available

1. Formulating problem	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT HS	AT AHS	PL	PT	SI	SK	FI	SE	UK ENG WLS NIR SCT				IS	LI	NO	BG	RO	
In scientific terms	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

2. Engaging in discussion in relation to:	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT HS	AT AHS	PL	PT	SI	SK	FI	SE	UK ENG WLS NIR SCT				IS	LI	NO	BG	RO	
Science in society and in every day life	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Researching information	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Experiments	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

3. Experimental work	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT HS	AT AHS	PL	PT	SI	SK	FI	SE	UK ENG WLS NIR SCT				IS	LI	NO	BG	RO	
Teacher demonstrations	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Carrying out experiments following a pre-defined protocol	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Making observations	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Proposing experimental protocols in response to defined objectives	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Verifying a scientific law through experiment	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Formulating and testing hypotheses	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Presenting and communicating procedures and results	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Science activities expressed in school curricula, ISCED 2, 2004/05 (continued)

□ Science as an integrated subject ■ Physics ■ Biology (-) Data not available

4. Using scientific documentation	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT HS	AT AHS	PL	PT	SI	SK	FI	SE	ENG	UK WLS	UK NIR	UK SCT	IS	LI	NO	BG	RO	
Researching documents for a defined purpose	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
Identifying information within documents	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>				<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
Summarizing information for defined objectives	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>				<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Presenting and communicating information	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

5. Using electronic technologies	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT HS	AT AHS	PL	PT	SI	SK	FI	SE	ENG	UK WLS	UK NIR	UK SCT	IS	LI	NO	BG	RO	
Logging and presenting experimental results and data	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
Simulation				<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>			<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>				<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
Researching the Internet for data	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Communicating with other pupils				<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>			<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

6. Outside activities	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT HS	AT AHS	PL	PT	SI	SK	FI	SE	ENG	UK WLS	UK NIR	UK SCT	IS	LI	NO	BG	RO	
Visits to museums, research laboratories, science-based industry, etc.	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>			<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>					<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Field work			<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>			<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

7. Projects	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT HS	AT AHS	PL	PT	SI	SK	FI	SE	ENG	UK WLS	UK NIR	UK SCT	IS	LI	NO	BG	RO	
Science-related project work	<input type="checkbox"/>	<input type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>			<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>					<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

Outcomes of science learning expressed in school curricula, ISCED 1, 2004/05

☐ Science as an integrated subject ☒ Physics ☐ Biology (:) Data not available

1. Knowledge	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	SI	SK	FI	SE	UK ENG WLS NIR SCT				IS	LI	NO	BG	RO	
Knowledge of scientific concepts/theories	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(-)		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Knowledge of experimental/investigative techniques		<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	(-)		<input type="checkbox"/>	<input type="checkbox"/>
Knowledge of and ability to apply basic mathematical skills	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>		<input type="checkbox"/>	(-)		<input type="checkbox"/>	<input type="checkbox"/>	

2. Practical skills	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	SI	SK	FI	SE	UK ENG WLS NIR SCT				IS	LI	NO	BG	RO
Ability to propose/discuss experimental protocols in response to defined objectives	<input type="checkbox"/>					<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>			<input type="checkbox"/>			<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(-)		<input type="checkbox"/>	
Ability to select and use appropriate apparatus and equipment		<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		(-)		<input type="checkbox"/>	
Ability to follow experimental instructions accurately	<input type="checkbox"/>					<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>		<input type="checkbox"/>	(-)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ability to make scientific observations	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(-)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

3. Data handling skills	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	SI	SK	FI	SE	UK ENG WLS NIR SCT				IS	LI	NO	BG	RO
Ability to locate and extract information from documents	<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>				<input checked="" type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(-)			
Ability to interpret and/or evaluate experimental or other information or evidence		<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		(-)		<input type="checkbox"/>	<input type="checkbox"/>
Ability to research and present information from a range of sources	<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(-)			

Outcomes of science learning expressed in school curricula, ISCED 1, 2004/05 (continued)

☐ Science as an integrated subject ☒ Physics ☐ Biology (:) Data not available

4. Scientific thinking	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	SI	SK	FI	SE	UK ENGWLSNIRSCT				IS	LI	NO	BG	RO
Ability to resolve problems formulated in theoretical terms	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>		<input type="checkbox"/>			<input type="checkbox"/>							<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>			<input type="checkbox"/>		<input type="checkbox"/>		(-)		<input type="checkbox"/>	
Ability to frame a problem in scientific terms		<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>								<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		(-)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ability to formulate scientific hypotheses	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>		(-)		<input type="checkbox"/>		

5. Ability to present and communicate procedures and results	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	SI	SK	FI	SE	UK ENGWLSNIRSCT				IS	LI	NO	BG	RO	
Ability to engage in scientific discussions	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<div><div></div><div></div></div>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(-)		<input type="checkbox"/>	<input type="checkbox"/>
Ability to plan, execute and report the results of a science-related project	<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<div><div></div><div></div></div>	<div><div></div><div></div></div>		<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		(-)		<input type="checkbox"/>	<input type="checkbox"/>
Ability to present and communicate procedures and results	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>			<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(-)		<input type="checkbox"/>	<input type="checkbox"/>	
Ability to use ICT (e.g. for recording data)		<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<div><div></div><div></div></div>	<div><div></div><div></div></div>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	(-)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

1. Knowledge	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT				PL	PT	SI	SK	FI	SE	UK				IS	LI	NO	BG	RO
																				HS	AHS							ENG	WLS	NIR	SCT							
Knowledge of scientific concepts/theories	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Knowledge of experimental/investigative techniques	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Knowledge of and ability to apply basic mathematical skills	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		

2. Practical skills	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT				PL	PT	SI	SK	FI	SE	UK				IS	LI	NO	BG	RO
																				HS	AHS							ENG	WLS	NIR	SCT							
Ability to propose/discuss experimental protocols in response to defined objectives	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Ability to select and use appropriate apparatus and equipment	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Ability to follow experimental instructions accurately	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Ability to make scientific observations	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		

3. Data handling skills	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT				PL	PT	SI	SK	FI	SE	UK				IS	LI	NO	BG	RO
																				HS	AHS							ENG	WLS	NIR	SCT							

Outcomes of science learning expressed in school curricula, ISCED 2, 2004/05 (continued)

4. Scientific thinking	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT HS	AHS	PL	PT	SI	SK	FI	SE	UK ENG	WLS	NIR	SCT	IS	LI	NO	BG	RO
Ability to resolve problems formulated in theoretical terms																																	(-)			
Ability to frame a problem in scientific terms																																	(-)			
Ability to formulate scientific hypotheses																																	(-)			

5. Ability to present and communicate procedures and results	BE fr	BE de	BE nl	CZ	DK	DE	EE	EL	ES	FR	IE	IT	CY	LV	LT	LU	HU	MT	NL	AT HS	AHS	PL	PT	SI	SK	FI	SE	UK ENG	WLS	NIR	SCT	IS	LI	NO	BG	RO	
Ability to engage in scientific discussions																																	(-)				
Ability to plan, execute and report the results of a science-related project																																		(-)			
Ability to present and communicate procedures and results																																		(-)			
Ability to use ICT (e.g. for recording data)																																		(-)			

Figure 4.2: Type of skills assessed by standardised national science examinations/tests, ISCED 2, 2004/05

[illegible]

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