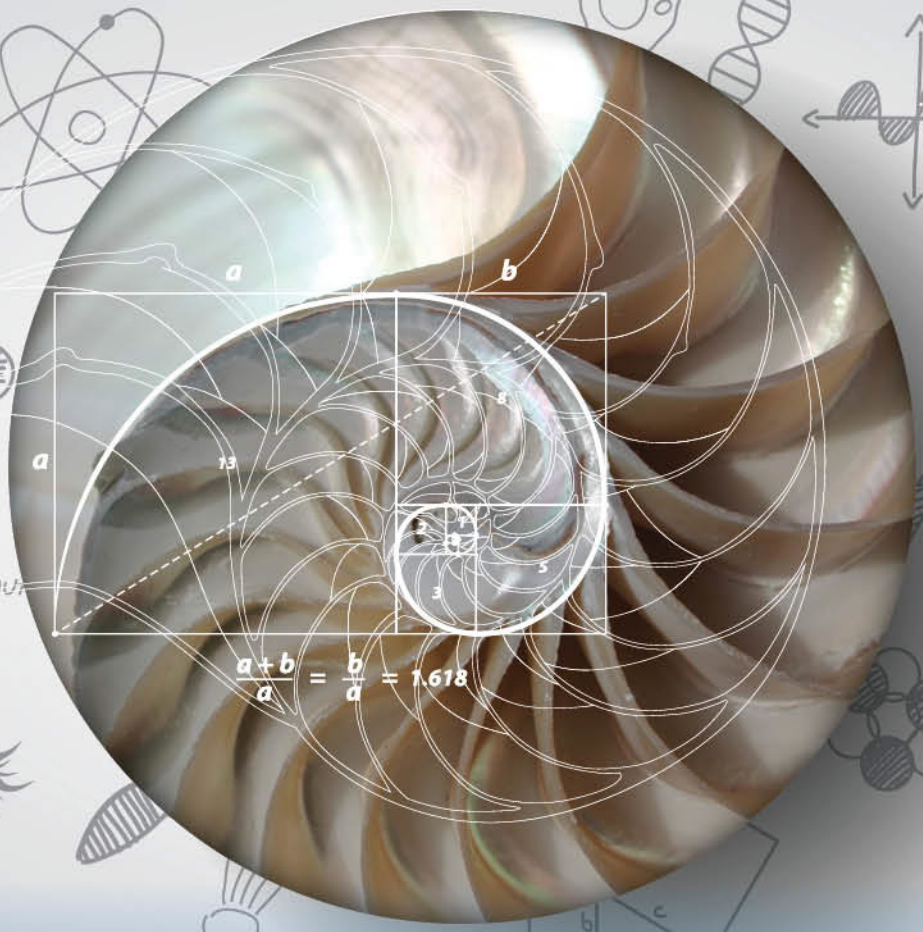
European Commission

Increasing achievement and motivation in mathematics and science learning in schools

Eurydice report



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CHAPTER 4: CURRICULUM ORGANISATION, TEACHERS AND ASSESSMENT

The way in which mathematics and science are taught in schools greatly influences students' attitudes towards these subjects, as well as their motivation to study and, consequently, their achievement. Official documents such as curricula and similar steering documents usually specify, in addition to the time that should be devoted to the teaching of mathematics and science (see Chapter 3), how instruction in these subjects should be organised. Generally, mathematics tends to feature as a separate subject in curricula for compulsory education, whereas science may be taught as an integrated curriculum subject or as separate subjects such as biology, physics and chemistry (European Commission / EACEA / Eurydice, 2021a).

There has been an ongoing academic debate about the effectiveness of integrating schools subjects such as science. With the shift to information and knowledge societies as well as new economic challenges, there has been an increase in demand for skills and competences such as creativity, problem-solving and critical thinking (Treacy, 2021). Some analyses have concluded that these skills and competences could be developed by schools through meaningful integration of subjects. For example, scientific models can provide physical or visual representations of abstract mathematical concepts, while mathematics can promote deeper understanding of scientific concepts through numerical representations of such phenomena (West, Vasquez-Mireles and Coker, 2006).

Some empirical studies support the integration of subjects in schools, showing positive outcomes for learning (e.g. Hurley, 2001) and positive feedback from the teachers involved (Treacy and O'Donoghue, 2014). In particular, studies that looked at the effects of an integrated approach to science, technology, engineering and mathematics found that integration leads to increased student interest and learning (Becker and Park, 2011; Gardner and Tillotson, 2019).

However, although the integration of subjects has found some empirical support, there are also barriers to it. These include the need for additional time, planning for instruction as a team, coordination of student assessments, and availability of instructional models and appropriate teaching materials (Treacy, 2021; West, Vasquez-Mireles and Coker, 2006). Teacher knowledge in the different subjects has also been found to be a key issue. Integrating subjects requires that teachers have a certain level of both content and pedagogical knowledge to teach students successfully in each discipline (Beswick and Fraser, 2019; Frykholm and Glasson, 2005; Ní Ríordáin, Johnston and Walshe, 2016).

There are thus a range of important aspects to consider when it comes to the organisation of teaching subjects such as mathematics and science in schools, and this chapter aims to investigate how top-level education authorities across Europe address them. The first section presents an overview of the guidelines provided in current national curricula concerning the organisation of science education in primary and lower secondary education, i.e. whether science should be taught as a separate or an integrated subject (as mentioned above, mathematics tends to be taught as a separate subject).

The second section then looks at the types of teachers (generalists or specialists) who, according to curricula, should teach science and mathematics respectively. This section also investigates the supply of fully qualified mathematics and science teachers across Europe, as well as their need for future professional development in teaching these subjects, according to international survey data.

In addition to the aforementioned aspects, there are other critical factors affecting student learning and achievement, including student assessment. Two specific types of assessment, namely certified examinations and national tests are addressed in the third section of this chapter. This section also shows how the COVID-19 pandemic affected the implementation of these assessments during the 2020/2021 school year.

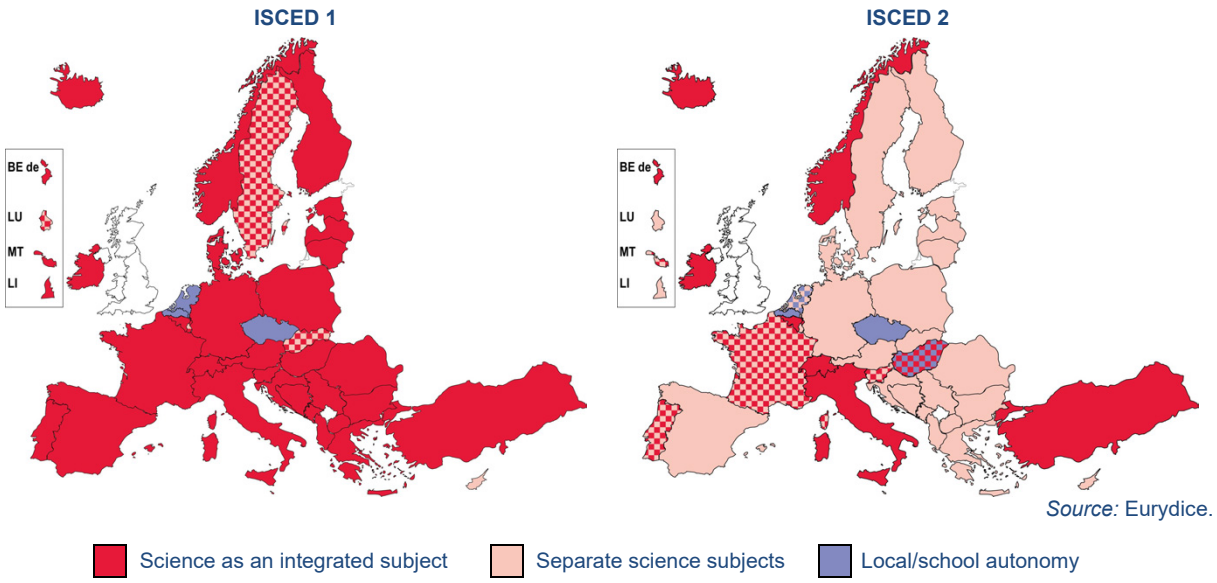
4.1. Organisation of science teaching in compulsory education

Science education in schools may be organised in two main ways: either as a single, integrated subject or split into separate subjects. An analysis of curricula for compulsory education across European education systems shows that almost all systems prescribe the teaching of science as an integrated subject for at least some part of primary education (see Figure 4.1 and Annex I).

At the primary education stage, the aim is to promote children's curiosity, provide them with basic knowledge of the world and give them the tools to investigate further. Many curricula for primary education use the term 'science education' or 'natural sciences' to refer to instruction that includes elements of biology, physics and chemistry. Others refer to broader learning areas, such as 'environmental studies', 'learning about the world' or 'nature and society'. These broader areas may cover, in addition to the core science subjects, elements of geography, technology, history and geology.

In Belgium (Flemish Community), Czechia and the Netherlands, top-level education authorities do not specify in the curricula for primary education how science teaching should be organised. Instead, they provide local authorities / schools with the autonomy to decide on this matter. However, Czechia and the Netherlands report that, as in most European countries, science is, in practice, usually taught as an integrated subject at this educational stage.

Figure 4.1: Organisation of science teaching according to curricula, ISCED 1-2, 2020/2021



Source: Eurydice.

Explanatory note

For more information regarding the organisation of science teaching in European education systems, in particular in those that combine the teaching of science as an integrated subject and as separate science subjects (or in those combining either approach with local/school autonomy) at primary and/or lower secondary level, see Figure 4.2 and Annex I.

Country-specific notes

Hungary: There is no science teaching at ISCED 1/grades 1–2 (see also Figure 4.2). The information reflects the new National Core Curriculum in all grades for an overall picture, although it is being phased in gradually and changes were implemented just in grades 1 and 5 in the 2020/2021 school year.
Switzerland: The maps present the situation in the 21 German-speaking and bilingual cantons (i.e. reflecting the most widespread approach). In the French-speaking cantons, science is a separate subject in most grades.

A few education systems follow a different approach in primary education compared with the main trend mentioned above, i.e. they prescribe separate-subject science teaching (in Cyprus) or both integrated and separate-subject science teaching (in Luxembourg, Slovakia and Sweden).

According to the curriculum in **Cyprus**, science should be taught as separate subjects at primary level.

Luxembourg, **Slovakia** and **Sweden** advise first teaching science as an integrated subject, followed by separate-subject science teaching towards the end of primary education (see also Figure 4.2).

The curricular approach in Luxembourg, Slovakia and Sweden marks a change from 10 years ago (i.e. in 2010/2011; see EACEA/Eurydice, 2011b). At that time, science was taught only as an integrated subject throughout primary education in Luxembourg and Slovakia, and in Sweden local authorities / schools were autonomous in deciding how science instruction was organised. These changes are therefore at odds with some of the empirical findings mentioned at the beginning of this chapter, which supported the integration of subjects such as science. Conversely, in 2010/2011, Finland was the only European country where the separation of science teaching into several subjects began during the last years of primary education (EACEA/Eurydice, 2011b); however, the country has now moved to integrated science teaching (environmental studies) throughout primary education.

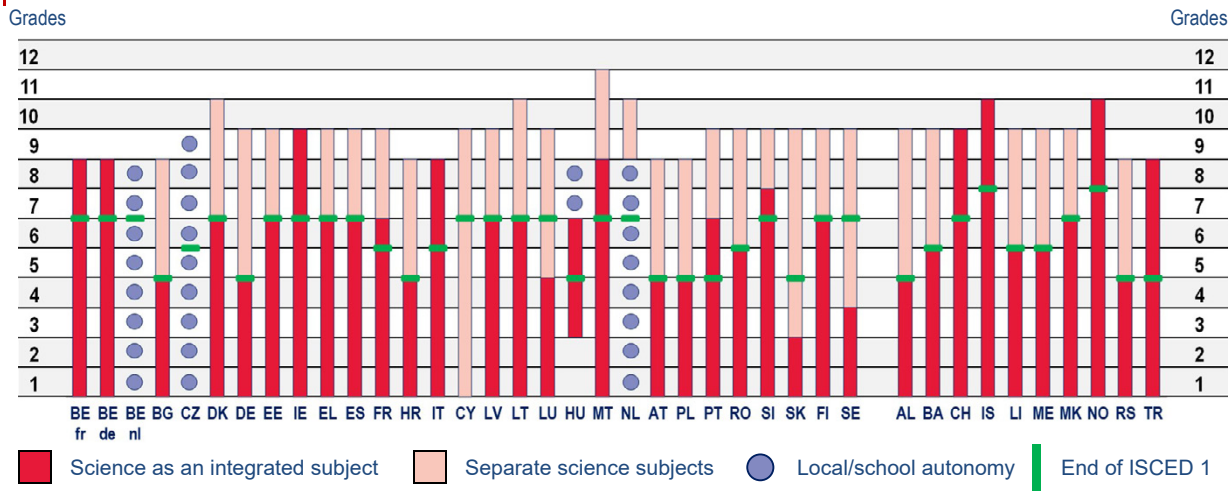
At the level of lower secondary education, the majority of European education systems prescribe in their curricula the teaching of separate science subjects. These are usually biology, physics, chemistry or geography. However, some education systems deviate from this general trend. For example, top-level education authorities in Belgium (French and German-speaking Communities), Ireland, Italy, Switzerland, Iceland, Norway and Turkey advise the teaching of science as an integrated subject from primary education until the end of lower secondary education.

Four other education systems – France, Malta, Portugal and Slovenia – prescribe in their curricula the teaching of science as an integrated subject in the first year(s) of lower secondary education, followed by a move towards teaching separate science subjects during the remaining years of this education level (see also Figure 4.2). This is actually a downward trend (i.e. fewer education systems advise teaching science as an integrated subject in lower secondary education) compared with the situation in 2010/2011, when nine of the education systems covered in this analysis advised integrated subject teaching followed by separate-subject science at lower secondary level (EACEA/Eurydice, 2011b). There thus seems to be a slight overall shift towards more separate-subject science teaching in lower secondary education across Europe.

Finally, in Hungary, the curriculum advises the teaching of science as an integrated subject during the first 2 years of lower secondary education; however, for the final 3 years of this education level, local authorities / schools have the autonomy to decide how science instruction is organised. In Belgium (Flemish Community) and Czechia, the autonomy of local authorities / schools to organise science spans from primary education to the end of lower secondary education. However, in Czechia, separate-subject science teaching is, once again, the most common approach in practice.

Figure 4.2 provides some further information about the organisation of science teaching by school grade. In most European education systems, curricula prescribe that integrated science teaching should begin in grade 1, except in Hungary, where it is supposed to start in grade 3. In addition, in most education systems, curricula indicate that integrated science teaching should last for 4–6 years. However, in Slovakia, it is prescribed for only 2 years. Belgium (French and German-speaking Communities), Ireland, Italy, Malta, Switzerland, Iceland, Norway and Turkey are situated at the other end of the spectrum, with 8–10 years of integrated science teaching.

Figure 4.2: Organisation of science teaching by grade according to curricula, ISCED 1-2, 2020/2021



Source: Eurydice.

Explanatory note

For more information regarding the organisation of science teaching in the European education systems, see Annex I.

Country-specific notes

Bulgaria: Grade 8 is included here, even though it is part of upper secondary education (ISCED 3), as this grade is of interest for the analysis of the report.
Denmark: Grade 10 is part of lower secondary education (ISCED 2); however, it is an optional school year.
Romania: Primary education (ISCED 1) includes a preparatory grade, followed by grades 1-4.
Hungary: There is no science teaching at ISCED 1/grades 1–2 (see also Figure 4.2). The information reflects the new National Core Curriculum in all grades for an overall picture, although it is being phased in gradually and changes were implemented just in grades 1 and 5 in the 2020/2021 school year.
Switzerland: The figure presents the situation in the 21 German-speaking and bilingual cantons (i.e. reflecting the most widespread approach). In the French-speaking cantons, science is a separate subject in most grades.

The end of primary education, which in many education systems coincides with the end of grade 6, often marks the end of integrated science teaching (as shown in Figure 4.1). After that, the curricula in most European education systems prescribe the teaching of science as separate subjects, which usually lasts for 2–4 years. In a few countries, separate-subject science teaching is prescribed for a longer duration. This is the case, for example, in Cyprus (9 years), Slovakia (7 years) and Sweden (6 years).

It should be noted that lower secondary students in Germany, Ireland, Latvia, Luxembourg, the Netherlands, Austria, Slovakia, Switzerland and Liechtenstein follow different tracks or pathways that have different curricula (see also Chapter 3, and European Commission / EACEA / Eurydice, 2020). An analysis of the organisation of science teaching in the different educational tracks within these education systems revealed only minimal differences from the general trend, in two systems: Germany and the Netherlands.

In some **German** *Länder*, science is taught as an integrated subject in grades 5 and 6 of secondary school (*Hauptschule*), instead of separate-subject science teaching, which is the approach in all other tracks.

In the **Netherlands**, vocational lower secondary education (*voorbereidend middelbaar beroepsonderwijs*) tracks offer science as separate subjects in grade 9, whereas in the pre-university education (*voorbereidend wetenschappelijk onderwijs*) and senior general secondary education (*hoger algemeen voortgezet onderwijs*) tracks, in addition to the first 2 years of lower secondary education, there is local/school autonomy.

In the other education systems with different tracks, there are no differences regarding the organisation of science teaching; however, the different tracks may set different performance levels for the separate science subjects.

4.2. Teachers of mathematics and science

In addition to the indications provided in curricula about the organisation of science teaching in schools, there are also guidelines as to who should be teaching science and mathematics. This section firstly presents these official requirements and secondly investigates the supply of fully qualified mathematics and sciences teachers across European education systems.

For mathematics and science teaching to be effective, teachers should be equipped with extensive theoretical and pedagogical knowledge of how these subjects are best taught and learned (Ardzejewska, McMaugh and Coutts, 2010; Junqueira and Nolan, 2016). This section therefore also presents information on current teachers' self-perceived need for professional development in teaching these subjects, according to international survey data.

4.2.1. Official guidelines regarding mathematics and science teachers

At the level of primary education, generalist teachers teach most school subjects. They are usually qualified to teach all, or almost all, subjects or subject areas prescribed in the curriculum. At lower secondary level, specialist teachers tend to be the ones to provide instruction. They are generally qualified to teach one or two specific subjects (EACEA/Eurydice, 2011a; EACEA/Eurydice, 2011b).

Figure 4.3 presents the results of the analysis of current curricula across European education systems regarding the types of teachers who should be teaching mathematics and science in schools. The first thing to note is that there are almost no differences between the subjects in terms of teacher types. In other words, whether generalist and/or specialist teachers should be teaching applies in most cases irrespective of the subject, except in Malta.

> In **Malta**, generalist teachers should teach mathematics until the end of primary education; however, both generalist and specialist teachers may teach science during the last 3 years of primary education, according to steering documents.

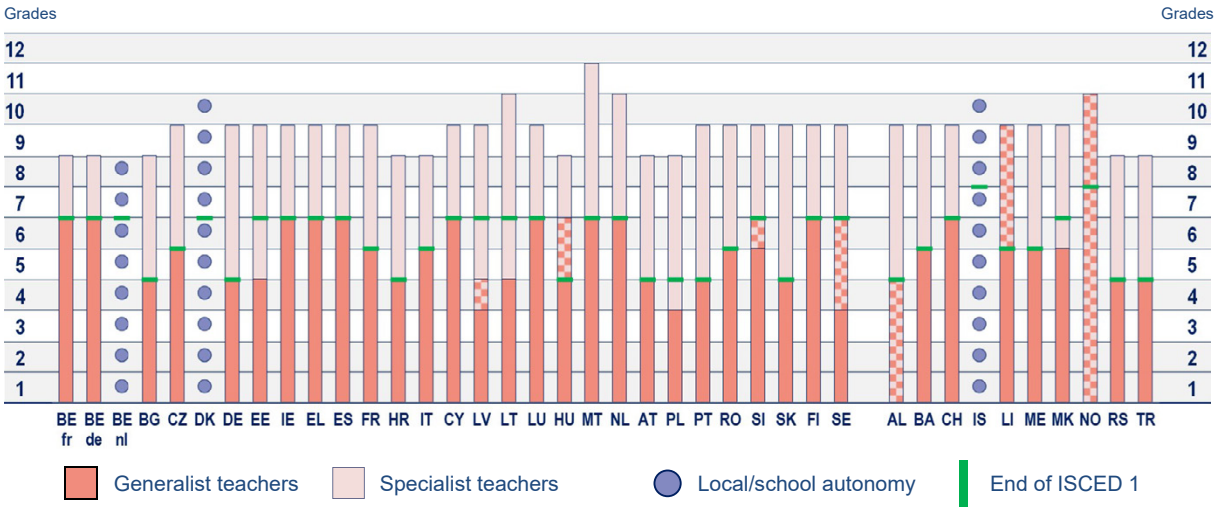
Overall, the analysis confirms the general picture presented above. The majority of European education systems require that generalist teachers provide instruction in mathematics and science at primary level (i.e. usually for a duration of around 4–6 years). In most cases, the end of instruction provided by generalist teachers coincides with the end of primary education.

After primary education, as mathematics teaching becomes more complex and science subjects begin to be taught separately (see Figures 4.1 and 4.2), most education systems advise that teachers who are specialists (i.e. specifically qualified in mathematics or science) should be the ones teaching these subjects. This specialist teaching can last from 2 years (e.g. in Belgium (French and German-speaking Communities)) to 6 years (in Lithuania).

Some exceptions to these overall trends can be noted. For example, in Albania and Norway, generalist and/or specialist teachers may be teaching mathematics and science in primary education (and in the case of Norway up until the end of lower secondary education) according to official steering documents. In Latvia, Hungary, Slovenia, Sweden and Liechtenstein, generalist teachers should teach both mathematics and science during the initial years of primary education. However, afterwards, generalist and/or specialist teachers may teach mathematics and science for several years or, in the case of Liechtenstein, until the end of compulsory education.

In Belgium (Flemish Community), Denmark and Iceland, local authorities / schools are autonomous when it comes to designating the type of teacher for mathematics and science in compulsory education. However, Belgium (Flemish Community) confirmed that the general picture presented above applies in practice (i.e. generalist teachers make up the majority of teachers in primary education, whereas in secondary education almost all subjects are taught by specialist teachers).

Figure 4.3: Teachers of mathematics and science according to curricula, ISCED 1-2, 2020/2021



Source: Eurydice.

Country-specific notes

Bulgaria: Grade 8 is included here, even though it is part of upper secondary education (ISCED 3), as this grade is relevant to the analysis in this report.
Denmark: Grade 10 is part of lower secondary education (ISCED 2); however, it is an optional school year.
Malta: The figure reflects the official guidance regarding mathematics teachers. In science, according to official guidance, both generalist and specialist teachers may be teaching pupils in the last 3 years of primary education.
Romania: Primary education (ISCED 1) includes a preparatory grade, followed by grades 1-4.

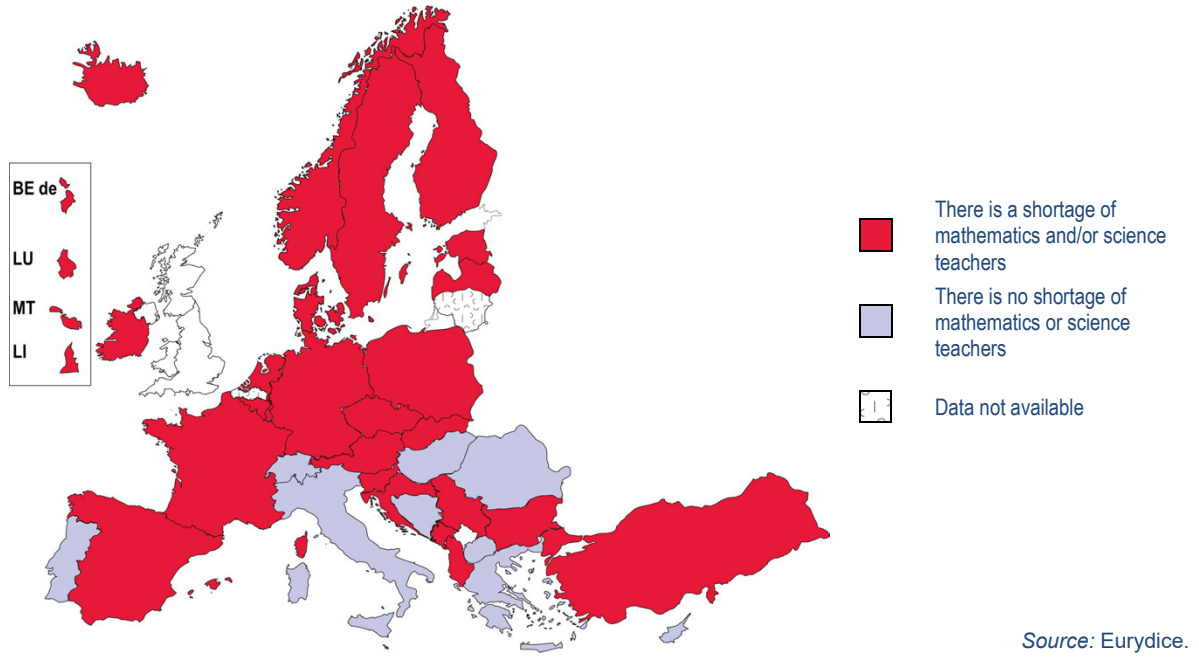
4.2.2. Supply of mathematics and science teachers

Despite official guidelines regarding the provision of mathematics and science instruction by generalist and/or specialist teachers, these teachers may not always be available in practice. It is known that many European education systems are suffering from shortages of teachers in general (European Commission / EACEA / Eurydice, 2021b). The present analysis thus investigated whether the shortages also concern mathematics and science teachers.

The findings confirm that, indeed, the great majority of education systems experience a shortage of mathematics and/or science teachers (see Figure 4.4). Only a few systems report no current shortage of mathematics and science teachers: Greece, Italy, Cyprus, Hungary, Portugal, Romania, Bosnia and Herzegovina, Switzerland and North Macedonia.

In the rest of the concerned countries, the reasons for shortages of mathematics and science teachers, as reported by top-level education authorities, include the large number of teachers retiring, the insufficient number of student teachers, and the attractiveness of the ICT and other sectors, which offer better job prospects. Consequently, teachers of mathematics and science often lack specialisation in these subjects, and in some cases subject specialists are teaching without the necessary pedagogical training.

Figure 4.4: Supply of mathematics and science teachers, 2020/2021



Source: Eurydice.

Country-specific note

Germany: Teacher supply differs according to the *Land*, school type and subject.

In order to increase the pool of mathematics and/or science teachers, education authorities are implementing various measures. Some countries, such as Czechia, Denmark, Estonia, Spain, Latvia, Austria, Poland and Norway, make it possible for teachers who are not specialised in mathematics or science to teach these subjects, while offering them training to obtain the necessary qualifications.

In **Czechia**, other specialist teachers (most often physics teachers) are entrusted with teaching mathematics since they usually have some knowledge of this area. These teachers are then often candidates for the CPD programmes leading to the extension of their qualifications if they are to teach mathematics in the long term.

In **Poland**, schools experiencing teacher shortages (often in mathematics and physics) usually increase the number of working hours of already employed staff, recruit retired teachers or recruit teachers without the required qualifications. Recruiting teachers without the required qualifications is possible only with the consent of the regional education authority, and under the condition that these teachers obtain the missing qualifications (e.g. pedagogical preparation) within a certain time frame.

In other countries, such as Estonia, Ireland, Malta, Austria and Finland, new courses or additional study places leading to a teaching qualification in mathematics or science are being offered.

In **Estonia**, additional funding was granted in 2021 to the two main Estonian teacher training universities to increase admission to mathematics and science teacher-training programmes at bachelor's and master's level, and to launch a new in-service training programme leading to the qualification required to be a basic school mathematics teacher.

In order to address shortages of teachers in mathematics and physics in **Ireland**, a postgraduate course has been introduced to upskill teachers in these subjects. Generalist teachers have been encouraged and supported to avail of this free course.

In **Malta**, the Directorate for Educational Services in the Ministry for Education is working with the University of Malta, the Institute for Education and the Malta College of Arts, Science and Technology to offer more courses leading to a teaching qualification in mathematics or science. The abovementioned institutions are offering part-time evening courses so that supply teachers (who are engaged when the usual teacher is absent or to replace a teacher who is on leave) can continue to work while obtaining a teaching qualification.

Several countries, including Croatia, Latvia, Slovenia, Norway and Serbia, offer scholarships for students who aim to become mathematics or science teachers.

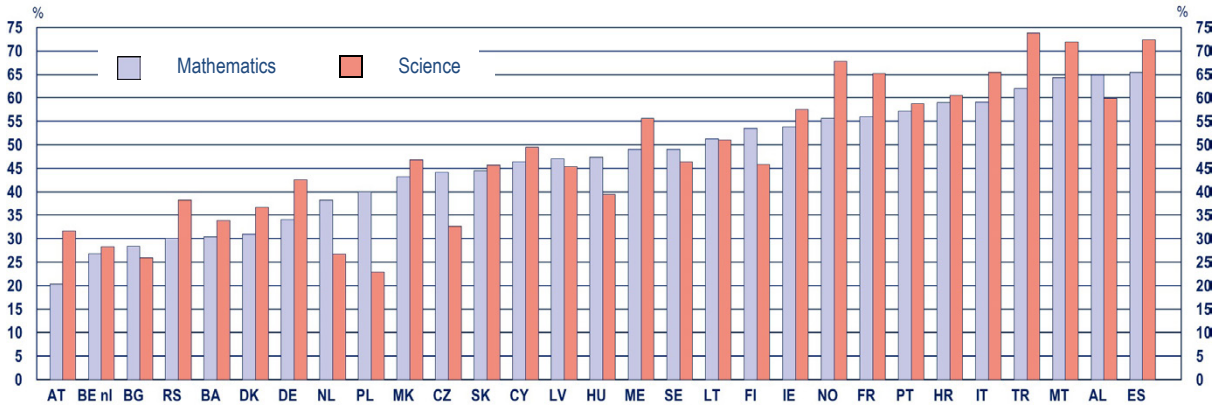
Finally, a number of education systems (e.g. Bulgaria, Czechia, Germany, Spain, France, Croatia, Luxembourg, Sweden and Liechtenstein) also report some general measures to address teacher shortages, such as communication campaigns and increased salaries or other incentives aiming to attract more people into the teaching profession.

4.2.3. Mathematics and science teachers' need for professional development

In view of the shortages of mathematics and science teachers across European education systems, the question arises of whether current teachers feel adequately prepared to teach these subjects or whether they think that they need further training. Figure 4.5 presents data from the Trends in International Mathematics and Science Study (TIMSS) 2019 survey on the percentage of fourth graders whose mathematics and science teachers indicated a need for future professional development in mathematics or science pedagogy/instruction.

The figure shows that there is a stronger need for professional development in science than in mathematics. In 19 out of the 29 education systems participating in the survey, the percentage of fourth grade students with science teachers expressing a need for training in science pedagogy/instruction was higher than the percentage of those with mathematics teachers expressing such a need.

Figure 4.5: Percentage of fourth graders whose mathematics or science teachers indicated a need for future professional development in mathematics or science pedagogy/instruction, 2019



	EU	AT	BE nl	BG	RS	BA	DK	DE	NL	PL	MK	CZ	SK	CY	LV
Mathematics	48.5	20.4	26.9	28.4	30.1	30.4	31.0	34.1	38.3	40.0	43.2	44.1	44.5	46.4	47.1
Science	50.8	31.6	28.3	26.0	38.2	33.8	36.6	42.6	26.8	23.0	46.8	32.6	45.7	49.5	45.4
	HU	ME	SE	LT	FI	IE	NO	FR	PT	HR	IT	TR	MT	AL	ES
Mathematics	47.3	49.0	49.1	51.3	53.5	53.8	55.7	56.0	57.2	58.9	59.1	62.0	64.3	64.9	65.5
Science	39.4	55.6	46.4	51.0	45.8	57.6	67.8	65.3	58.7	60.5	65.5	73.8	72.0	59.9	72.3

Source: Eurydice, based on IEA, TIMSS 2019 database.

Explanatory notes

Education systems are depicted in ascending order based on the mathematics percentage.

The percentages were calculated based on the variables ATBM09BB and ATBS08BB (linked to the question 'Do you need future professional development in any of the following? Mathematics pedagogy/instruction / Science pedagogy/instruction', with possible responses being (1) 'yes' or (2) 'no'). Percentages refer to the share of students whose teachers responded (1) 'yes'. Standard errors are available in Annex III.

'EU' comprises the 27 EU countries that participated in the TIMSS survey. It does not include participating education systems from the United Kingdom.

The difference is especially large (more than 10 percentage points) in Austria, Norway and Turkey. Conversely, the systems with a higher percentage (with 5 or more percentage points) of fourth graders with mathematics teachers expressing such a training need in their subject area are the Netherlands, Poland, Czechia, Hungary, Finland and Albania. However, overall, teachers of both subjects (teaching around half of the students in the EU-27) expressed a strong need for future professional development in the relevant pedagogy/instruction.

In science, more than 60% of fourth graders in Norway, France, Croatia, Italy, Turkey, Malta and Spain have teachers who expressed a need for future professional development in teaching the subject. The smallest percentages of students (i.e. less than 30%) with science teachers indicating this need can be found in Belgium (Flemish Community), Bulgaria, the Netherlands and Poland.

The situation is similar, albeit less pronounced, in mathematics. Over 60% of fourth graders in Turkey, Malta, Albania and Spain have teachers who indicated a need for future professional development in teaching the subject. The education systems with the smallest percentages (i.e. less than 30%) of students whose teachers expressed this need are those of Austria, Belgium (Flemish Community) and Bulgaria.

4.3. Student assessment in mathematics and science

Last but not least, another important element of mathematics and science teaching in schools is the assessment of students in these subjects. Generally, student assessment is an important tool for monitoring and improving the teaching and learning process. It can take a variety of forms. The analysis of this report focuses on the guidelines provided in the curricula of European education systems regarding two specific types of student assessment.

- Certified examinations. These are final examinations that result in the award of a qualification following completion of a particular stage or a full course of education, for instance at the end of primary or lower secondary education.
- National tests. These are examinations carried out under the responsibility of top-level education authorities. They can be used for various purposes: to evaluate the attainment of students, to monitor schools or to identify learning needs (see Section 4.3.2).

Large-scale assessments, such as national tests, have often been the subject of debate. Opponents of national tests believe, for example, that too much importance may be placed, and too much time and effort may be spent, on single tests that are likely to be limited in terms of curriculum coverage (Eveleigh, 2010). Moreover, studies have shown that when a test is perceived as very important, such as in the case of final examinations, students tend to experience higher levels of motivation but also test anxiety, the latter of which can be detrimental to their performance. Low achievers seem to be especially affected by test anxiety. School subjects also play a role, with mathematics being perceived as a relatively stressful subject in terms of assessments (Eklöf and Nyroos, 2013).

The results of national tests can, however, provide useful information related to the performance of students, schools and the education system as a whole; and they can guide the allocation of resources and decision-making for future school programmes (EACEA/Eurydice, 2009). Similar to some national tests, certified examinations summarise the educational attainment of students at a particular stage of education and have an important impact on their school career (EACEA/Eurydice, 2011b). Both types of assessment can therefore be considered an important element of the education system, including for the teaching and learning of mathematics and science. Chapter 7 will investigate this topic further by examining the relation between national tests/certified examinations in mathematics and students' achievement levels in this subject.

Before that, the following sections will present an overview of the certified examinations and national tests in mathematics and science that exist in European education systems (Section 4.3.1), the main purposes of these assessments (Section 4.3.2), and finally the changes in certified examinations and national tests during 2020/2021 due to the COVID-19 pandemic (Section 4.3.3).

4.3.1. Certified examinations and national tests

Certified examinations and national tests in mathematics and science take place during compulsory education in the great majority of European education systems; they are not carried out in Greece, Croatia, Switzerland, Liechtenstein and North Macedonia (see Figure 4.6). In all other systems, both types of assessments are common, particularly in lower secondary education.

Certified examinations are rare in primary education. In terms of mathematics and science, they take place in only Belgium (French Community), in mathematics and science as an integrated subject, and Bulgaria, in mathematics only. In other education systems, teachers/schools rely on other ways (e.g. continuous assessment) to evaluate and certify the achievements of students in primary education.

National tests, on the other hand, are carried out more widely at the primary level. The majority of education systems in Europe administer national tests in mathematics, and, in most cases, all students need to take them. National tests in mathematics based on a sample of students are being administered in only Belgium (French and Flemish Communities), Czechia, Estonia and Finland.

National tests in science as an integrated subject are carried out at primary level in less than one third of all education systems. In most of them, the tests are based on a sample of students. There are no national tests in separate science subjects at primary level, even in Greece, Cyprus, Luxembourg, Slovakia and Sweden, where separate science subjects are taught (see Figures 4.1 and 4.2).

Overall, it may thus be concluded that, across Europe, more emphasis is being placed on mathematics than on science as a subject for large-scale assessments in primary education. In contrast, at the level of secondary education, there is a greater balance between assessments in mathematics and science. As in the case of primary education, the most common type of assessments taking place at lower secondary level are national tests taken by all students in mathematics. The next most common assessments are certified examinations taken by all students in mathematics.

Science as an integrated subject is assessed in lower secondary education through certified examinations, particularly in those education systems in which science is still taught as an integrated subject at this education level (see also Figures 4.1 and 4.2), including in Belgium (French Community), Ireland, Italy, Malta and Norway. These examinations are taken either by all students or, where science as an integrated subject is optional or students are selected for examination (as is the case in Norway), by only some students. A few countries also carry out national tests in science as an integrated subject, and in most of these cases all students take these tests.

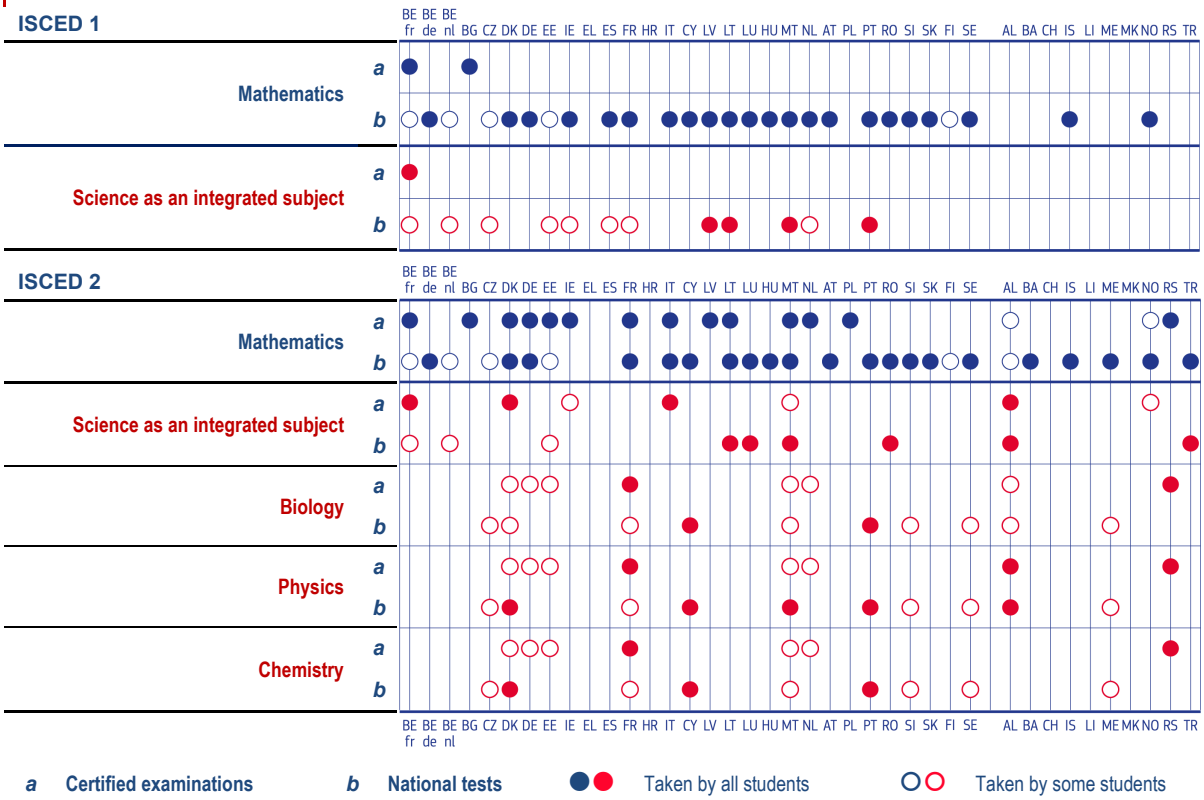
At secondary education level, more than one third of all education systems also carry out certified examinations and/or national tests in separate science subjects, such as biology, physics and chemistry. In addition to these subjects, other science subjects that are assessed in some education systems include geography, geology and technology.

In Cyprus, Portugal and Serbia, all students take part in all the certified examinations and/or national tests in the different science subjects. However, in other education systems with certified examinations and/or national tests in separate science subjects, only some students may take these assessments (i.e. they may be sample-based tests or students may take tests in only one of the science subjects).

In **Estonia**, all students in grade 9 must take a certified examination in Estonian, mathematics and an elective subject, which could be biology, geography, physics or chemistry.

Similarly, in **Sweden**, all students in grade 9 take a national test in biology, chemistry or physics. However, the students or schools cannot choose the subject; that decision is made by the Swedish National Agency for Education.

Figure 4.6: Certified examinations and national tests in mathematics and science, ISCED 1-2, 2020/2021



Source: Eurydice.

Explanatory notes

The figure presents certified examinations and national tests in mathematics and science. Information regarding the subjects/topics included in science as an integrated subject in the different education systems can be found in Annex I. The certified examinations and national tests presented here may also include other subjects; however, these are not indicated as this would go beyond the scope of the report. Changes in assessment procedures due to the COVID-19 pandemic are not taken into account (they are presented in Section 4.3.3).

Country-specific notes

Belgium (BE fr): There are certified examinations in mathematics and science that are taken by all students at ISCED 1 and 2. There are also national tests for identifying individual learning needs that are taken by all students at ISCED 1 (grades 3 and 5). However, these take place only every 3 years.
Denmark: Regarding national tests, this figure presents the compulsory tests for all students in mathematics and physics/chemistry. There are also voluntary national tests in mathematics in primary and lower secondary education, and in biology, physics/chemistry and geography in lower secondary education.
Spain: There are two national tests carried out at ISCED 1. The one in grade 3 tests all students in linguistic and mathematical competences (as indicated in the figure), whereas the one in grade 6 tests students in linguistic, mathematical and 'science and technology' competences in separate examinations.
France: In addition to the national tests in mathematics taken by all students at ISCED 1 and 2, there are also sample-based national tests at the end of both education levels (Cycle of Disciplinary Assessments Conducted on Samples (*Cycle des évaluations disciplinaires réalisées sur échantillons*), end of grades 5 and 9).
Sweden: All students in grade 9 take a national test in one of the science subjects (either biology, chemistry or physics).
Serbia: The certified examination comprises testing on the language of instruction and mathematics, and a combined test, which integrates natural and social sciences subjects (i.e. geography and history, in addition to subjects mentioned in the figure).

Finally, some countries are implementing changes to their certified examinations and/or national tests in mathematics and/or science.

In **Czechia**, a new national testing scheme came into force during the 2021/2022 school year. Each year, one of five literacies (reading, mathematics, foreign language, information/digital and science) is to be tested in various grades. In 2021/2022, it is science literacy. In addition, every 4 years, comprehensive national surveys/tests will be carried out in grades 5 and 9 (end of primary education and end of lower secondary education) in at least one of the two basic subjects (Czech language and literature; mathematics) and frequently in one other subject.

In **Denmark**, a new national testing scheme will come into force in 2022/2023. The tests in physics/chemistry will be voluntary, just as the current tests in biology and geography are.

In **Greece**, a pilot implementation of national diagnostic tests in Modern Greek language and mathematics for students in grade 6 of primary education and those in grade 3 of lower secondary education began in 2021/2022. The aim of these national tests is to monitor the progress made in the implementation of the curriculum and the achievement of expected learning outcomes.

In **Spain**, a new diagnostic national test in lower secondary education (grade 8) will be introduced in order to evaluate students' linguistic and mathematical competences. The autonomous communities will be able to add additional competences to be evaluated in the test. It will be implemented once the new grade 8 curriculum is applied (expected for the 2023/2024 school year).

In **Croatia**, the National Center for External Evaluation of Education will conduct national tests in mathematics and science, among other subjects, in a representative sample of 81 primary schools in the 2021/2022 and 2022/2023 school years, and implement a self-evaluation process in a subsample of 20 primary schools (out of the 81 primary schools that participated in the project) in the 2022/2023 school year.

In **Hungary**, a national test assessing science competences of all grade 6 and grade 8 students is being implemented from 2021/2022.

In **Poland**, it was planned that, from the 2021/2022 school year, students would have to choose one of four science subjects – biology, geography, chemistry and physics – as an additional subject to be included in the examinations they need to take at the end of compulsory education. In April 2021, it was decided by the Ministry of Education and Science to postpone (to 2024) the first examinations, which will include an elective science subject, due to the COVID-19 pandemic (see also Section 4.3.3) ([61]).

In **North Macedonia**, national tests in mathematics (and literacy) will be implemented for students in the third grade as of 2022/2023 and for students in the fifth grade as of 2024/2025.

4.3.2. Main purposes of certified examinations and national tests

Generally, certified examinations and national tests can be implemented for one or more of the following three purposes.

- They may summarise the attainment of students at a particular educational stage (e.g. at the end of primary or lower secondary education). The results are then used to award certificates and/or make important decisions about students' school careers, including 'streaming', progression from one year to the next or final grading. Tests used for this purpose are usually taken by all students.
- They may be used to monitor and evaluate schools and/or the education system as a whole. This objective is frequently, but not solely, attached to national tests, and such tests are sometimes taken by only a representative sample of students.
- They may serve to identify students' learning needs and thus to support learning processes and individualised follow-up (see also Chapter 6, Section 6.1.2). These tests may be taken by all or only some students.

Figure 4.7 shows the numbers of education systems using certified examinations and/or national tests in primary and lower secondary education to pursue each of the abovementioned purposes (see

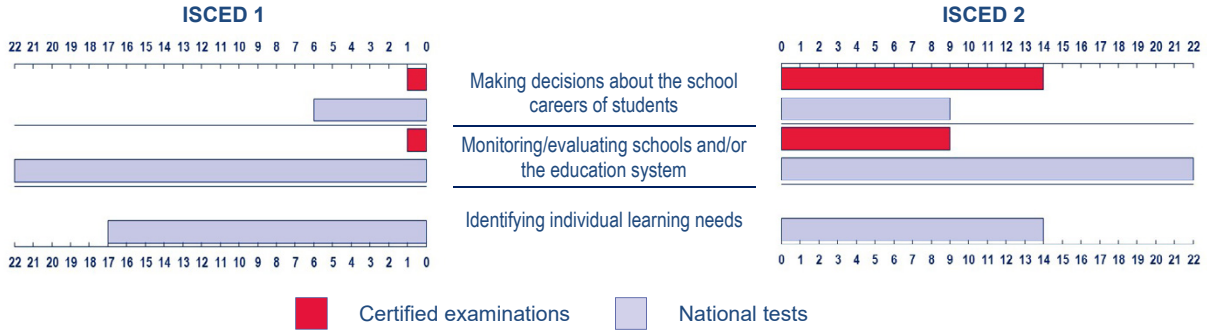
([61]) In the draft amendment to the Law on the Education System, submitted to the Parliament of the Republic of Poland in March 2022, there is a provision for the complete abandonment of this exam by the Ministry of Education and Science. See: https://www.gov.pl/web/premier/projekt-ustawy-o-zmianie-ustawy-o-systemie-oswiaty-oraz-niektorych-innych-ustaw

Annex II, Figure 4.7A for further information per country). It should be noted that these numbers exceed the number of certified examinations and national test that are being carried out in mathematics and science across Europe (see Figure 4.6), since many of these assessments are in fact used for several of the listed purposes at the same time.

Monitoring and evaluating schools and/or the education system as a whole is the most widely reported purpose of national tests at both primary level and lower secondary level. The second most frequently reported purpose of national tests at both education levels is identifying individual learning needs. National tests in mathematics and science are thus less frequently applied across Europe for individual high-stakes purposes (i.e. for making decisions about the school careers of students).

Certified examinations, on the other hand, mainly serve the purpose of informing decisions about the school careers of students at secondary level, followed by the objective of monitoring and evaluating schools and/or the education system. Identifying individual learning needs is not a purpose attached to certified examinations in any education system at any education level.

Figure 4.7: Main purposes of certified examinations and national tests in mathematics and science, ISCED 1-2, 2020/2021



Source: Eurydice.

Explanatory notes

The figure presents the number of European education systems (out of 39 in total) pursuing each of the three purposes with their certified examinations and/or national tests in primary and lower secondary education (for more information per country, see Annex II, Figure 4.7A). Many of these assessments are used for several of the listed purposes at the same time.

As mentioned above, certain assessments have combined purposes. For example, national tests can serve monitoring purposes as well as help to identify students' learning needs, as is the case in Ireland and France.

Primary schools in **Ireland** are required to analyse the outcomes of standardised testing in mathematics, both to determine whole-school performance and to identify learning needs for individual students or groups of students in the classroom setting. While it is hoped that schools that use standardised tests in science embark on a similar analysis of the outcomes of assessment, there is no requirement to do so.

In **France**, the national tests in mathematics (and French), which are taken by all students in grades 1 and 2 (ISCED level 1) and grade 6 (ISCED level 2), have the double objective of measuring the performance of the education system – feeding into educational policy and decision-making – and diagnosing students' difficulties in order to ensure remediation. For the purpose of the latter, the results of the tests are sent to every school without being published nationally, and aggregated results at national level are published.

Certified examinations and national tests that are used for making decisions about students' school careers may also serve monitoring purposes, as is the case in Poland, or help to identify students' learning needs, as is the case in Romania.

In **Poland**, the national examination in mathematics at the end of grade 8 has two main purposes. It assesses the extent to which students meet the requirements set in the core curriculum for primary education (for the three compulsory examination subjects),

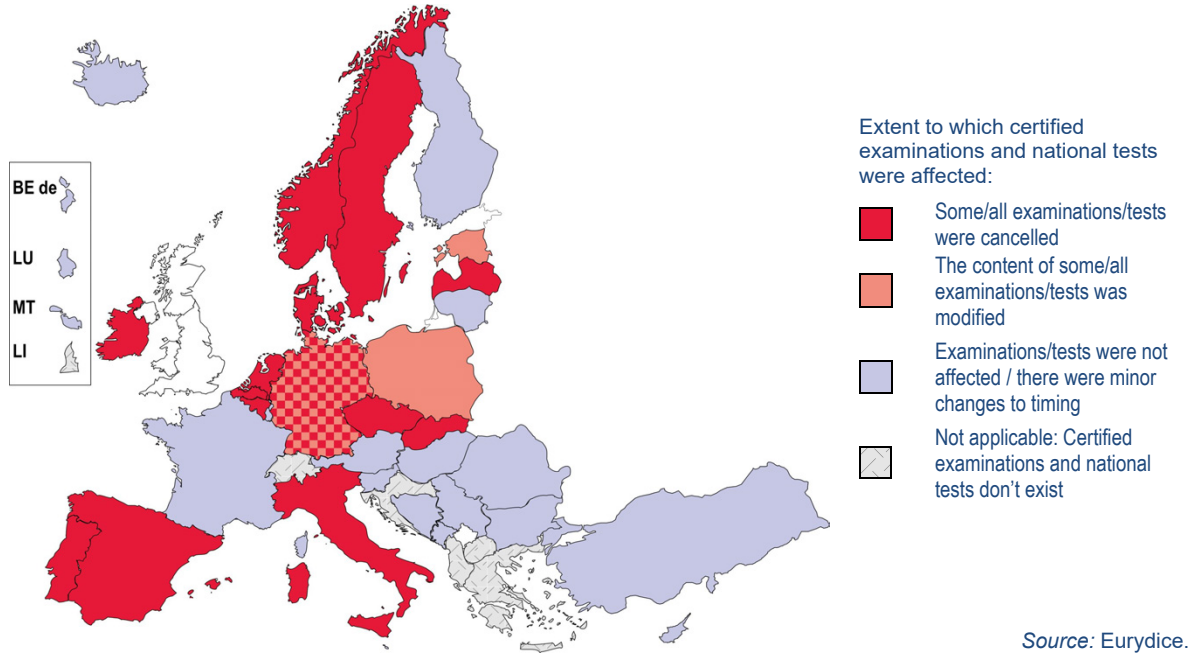
thereby providing feedback to students, parents, teachers and education authorities. It also replaces the secondary school entrance examination (results of the examination have no impact on the completion of primary school, but secondary schools use the results as one of the criteria in the student admission process).

In **Romania**, the national test for students in grade 8 is an external summative assessment of competences acquired throughout lower secondary education. It aims to provide guidance regarding the educational route to be taken in upper secondary education as well as to identify students' individual needs for support.

4.3.3. Changes in certified examinations and national tests due to the COVID-19 pandemic

The COVID-19 pandemic has had an important impact on all aspects of people's lives, including on the teaching, learning and assessment practices in schools (see also Chapter 2 and Chapter 6, Section 6.3.3). With regard to certified examinations and national tests, around half of European education systems report that the implementation of these assessments was affected during the 2020/2021 school year (see Figure 4.8).

Figure 4.8: Changes to certified examinations and national tests in mathematics and science due to the COVID-19 pandemic, ISCED 1-2, 2020/2021



Source: Eurydice.

Country-specific note

Germany: The *Länder* had a number of measures at their disposal, including the ones indicated here, that they could apply depending on the pandemic situation.

In many of these education systems – including in Belgium (French and Flemish Communities), Czechia, Denmark, Ireland, Spain, Italy, Latvia, the Netherlands, Portugal, Slovakia, Sweden and Norway – some or all certified examinations and/or national tests were cancelled. In some cases, alternative assessment measures were introduced.

In **Italy**, the written certified examinations in mathematics and science were cancelled in 2020/2021. Instead, one oral test was used, in which students had to present a paper. The topic of the paper was chosen in class; it was not necessarily on mathematics or science.

In **Slovakia**, national testing of all students in mathematics in secondary education was cancelled. However, a monitoring test took place, based on a representative sample of students. The aim of this test was to assess students' level of knowledge after the

pandemic and related distance-learning measures. The national test in mathematics (and languages) in primary education took place as usual.

The **Swedish** National Agency for Education decided to cancel most national tests in compulsory education (including those in mathematics and science) due to the pandemic. Only national tests in grade 3 took place as usual. To support schools with student assessment, the agency offered optional tests in the subjects that are normally tested in grades 6 and 9 (i.e. tests that were optional for schools to use, but not optional for the students).

The German *Länder* and the autonomous communities of Spain had some autonomy with regard to the implementation of certified examinations and national tests.

In **Germany**, the *Länder* had a number of measures at their disposal that they could apply, depending on the pandemic situation, without lowering the level of requirements specified by the Standing Conference of the Ministers of Education and Cultural Affairs. These measures were shifting examination dates to provide more study time, reducing the number of examinations/tests, selecting priority or elective topics and allowing schools to select centrally set examination items. Moreover, in April 2020, due to the COVID-19 pandemic, the standing conference gave the *Länder* the choice of whether to conduct the national tests VERA (*Vergleichsarbeiten*) 3 and 8.

In **Spain**, because of the COVID-19 pandemic, the diagnostic tests in grade 6 (and 10) were cancelled. However, the educational administrations of the autonomous communities had to estimate whether or not they would carry out the evaluation in grade 3 of primary education. In practice, most autonomous communities decided to cancel them during the 2020/2021 school year. However, the Ministry of Education, in its area of direct competence, decided to carry out the tests in Ceuta and Melilla due to their importance and guiding nature.

In Estonia and Poland, there were no cancellations of certified examinations or national tests; however, some other substantial changes in assessment practices took place due to the COVID-19 pandemic.

In **Estonia**, certified examinations in mathematics and science subjects took place at the usual times and followed the usual procedure. However, there were changes in the conditions for graduating from basic education due to the pandemic, in the sense that graduation did not depend on examination results. Moreover, two additional examination days were offered for those students who wanted to take examinations but could not attend on certain days due to the COVID-19 pandemic.

In **Poland**, the national examination in mathematics at the end of grade 8 was not based on all the requirements included in the core curriculum. A limited list of requirements for each examination subject was prepared by teams of educational experts and approved by the Ministry of Education and Science.

Finally, among the education systems reporting that their certified examinations and national tests were not substantially affected by the COVID-19 pandemic, there were some that made minor modifications to their assessment practices.

In **Malta**, no alterations as such took place due to the pandemic, except for certified examinations being held 2 months later than usual.

In **Romania**, national testing was not altered during the 2020/2021 school year. However, for students who had COVID-19 during the testing period, a special examination session was provided.

Summary

This chapter presented an overview of existing provisions in compulsory education curricula across Europe concerning the organisation of science teaching, the teachers in charge of mathematics and science instruction, and two specific types of student assessment – certified examinations and national tests – in both subject areas.

The analysis showed that science is taught as an integrated subject in almost all European education systems for at least some part of primary education. Curricula thus refer to ‘science education’, ‘natural sciences’, ‘environmental studies’, ‘learning about the world’ or ‘nature and society’ to describe

instruction that includes elements of biology, physics and chemistry, and, in some cases, topics related to geography, technology, history and geology.

In contrast, curricula for lower secondary education in most European education systems prescribe the teaching of separate science subjects (e.g. biology, physics, or chemistry). There has in fact been an increase in separate-subject science teaching across Europe compared with the situation 10 years ago (i.e. in 2010/2011; see EACEA/Eurydice, 2011b), with a number of countries giving up integrated science teaching in compulsory education.

Regarding the organisation of science teaching by school grades the chapter found that, in most education systems, curricula advise integrated science teaching for the first 4–6 years of compulsory education, which often coincides with the duration of primary education. After that (i.e. during lower secondary education in many education systems), curricula often prescribe 2–4 years of separate-subject science teaching.

An analysis of the organisation of science teaching in different educational tracks within European education systems revealed only minimal variations.

Curricula also provide guidelines regarding the types of teachers who should be teaching science and mathematics in schools. An analysis of European education systems showed that generalist teachers are required to provide instruction in both mathematics and science at primary level in almost all systems (i.e. usually for a duration of around 4–6 years, until the end of primary education). After that, specialist teachers usually take over mathematics and science instruction. However, some European countries deviate from this trend, either by stating in their curricula that generalist and/or specialist teachers may teach these subjects for several years or by relying on generalist teachers due to shortages of specialist teachers.

The findings of this report show that the great majority of European education systems are experiencing a shortage of mathematics and/or science teachers, resulting in differences between the types of teachers teaching science and mathematics in practice and those specified in official guidelines. Consequently, the teaching staff in charge of these subjects often lack the necessary specialisation, or they may be subject specialists who do not have the necessary pedagogical training. The measures implemented by countries to address this situation include offering professional training and additional qualifications to those teachers who require them, and introducing new courses or additional study places for those wishing to become mathematics or science teachers.

An analysis of data from the TIMSS 2019 survey on the percentage of fourth graders whose mathematics and science teachers indicated a need for future professional development in mathematics or science pedagogy/instruction supports the abovementioned findings. Current teachers of mathematics and science indicate a strong need for training; this need was even stronger for science than for mathematics. In 19 out of the 27 education systems participating in the survey, the percentage of fourth grade students with science teachers expressing a need for training in science pedagogy/instruction was higher than the percentage of those with mathematics teachers expressing such a need.

An analysis of certified examinations and national tests in mathematics and science in compulsory education showed that both types of assessment are more widely implemented at the level of lower secondary education than at primary level. Moreover, in primary education, more emphasis seems to be placed across Europe on mathematics than on science as a subject for such large-scale assessments: most education systems administer national tests in mathematics, which are taken by

all students; however, less than one third of all European education systems implement national tests in science as an integrated subject (usually sample based).

At the level of secondary education, there is greater balance between assessments in mathematics and those in science. Although the most common type of assessment taking place at lower secondary level remains national tests taken by all students in mathematics, followed by certified examinations taken by all students in mathematics, science as an integrated subject is assessed more frequently at this education level, through both certified examinations and national tests. More than one third of all education systems also carry out certified examinations and/or national tests in separate science subjects, such as biology, physics and chemistry.

The most widely reported main purpose of national tests in mathematics and science in compulsory education is to monitor and evaluate schools and/or the education system, followed by the purpose of identifying individual learning needs. The most widely reported purpose of certified examinations at lower secondary level is making decisions about the school careers of students, followed by the purpose of monitoring and evaluating schools and/or the education system. However, it should be noted that most of the reported assessments in compulsory education are in fact used for several of the aforementioned purposes at the same time.

The COVID-19 pandemic, in addition to having an important impact on many aspects of teaching and learning in schools, also affected certified examination and national test practices in around half of European education systems in 2020/2021. In many of them, some or all certified examinations and/or national tests were cancelled, or other substantial changes were made to the usual assessment practices, for example a reduction in the list of requirements for the different examination subjects or changes in the impact of the examination results on students' school careers.