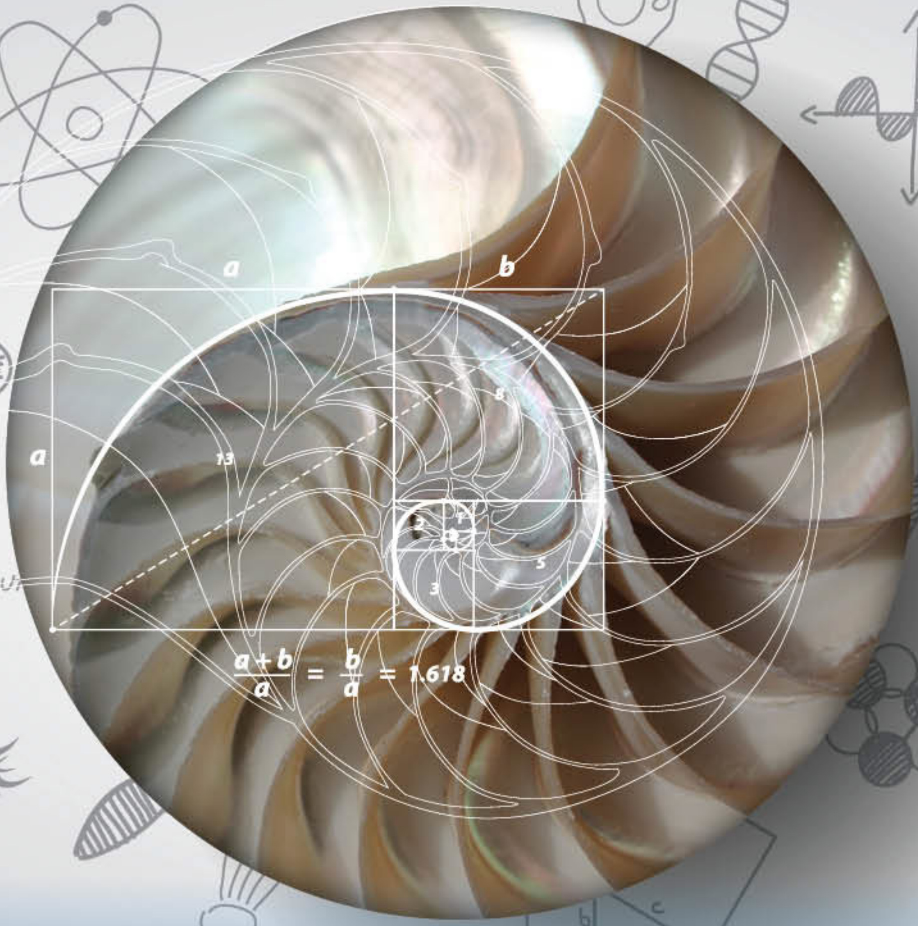
European Commission

Increasing achievement and motivation in mathematics and science learning in schools

Eurydice report



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FOREWORD

We have a duty towards the younger generations.

We bear responsibility for their education and training. We have to ensure that they are well equipped to face our societies' major challenges, to bring about sustainable development and global health or effectively fight the spread of misinformation and disinformation.

In our fast-changing world, mastering mathematics and science is key in these regards. Being able to analyse, to apply a scientific way of thinking, understanding the interconnectedness of nature and the human-built world, keeping a critical eye on the trustworthiness of information, these are all necessary competences for everybody in today's world.

Still, we know that not all pupils have the same chances of succeeding. The socio-economic background of students continues to influence achievement. For disadvantaged students, the risk of underperformance can be significant, which has been further exacerbated by the COVID-19 crisis.
Today, a considerable share of students in the European Union does not reach basic levels of numeracy and scientific literacy.

But we have a vision. Our goal is to build a European Education Area where all young people receive quality education, acquire an adequate level of knowledge, skills and competences, and have the opportunity to fully develop their potential.

This report provides new insights into what education authorities across Europe can do to strengthen student motivation, raise achievement, and help those falling behind, especially in mathematics and science learning. I am confident that this document will be of great support to education policy-makers and stakeholders across Europe.

Mariya Gabriel

Commissioner responsible for
Innovation, Research, Culture, Education and Youth

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CODES AND ABBREVIATIONS

Country codes

EU	European Union
BE	Belgium
BE fr	Belgium – French Community
BE de	Belgium – German-speaking Community
BE nl	Belgium – Flemish Community
BG	Bulgaria
CZ	Czechia
DK	Denmark
DE	Germany
EE	Estonia
IE	Ireland
EL	Greece
ES	Spain
FR	France
HR	Croatia
IT	Italy
CY	Cyprus
LV	Latvia
LT	Lithuania
LU	Luxembourg
HU	Hungary
MT	Malta
NL	Netherlands
AT	Austria
PL	Poland
PT	Portugal
RO	Romania
SI	Slovenia
SK	Slovakia
FI	Finland
SE	Sweden

	EEA and candidate countries
AL	Albania
BA	Bosnia and Herzegovina
CH	Switzerland
IS	Iceland
LI	Liechtenstein
ME	Montenegro
MK	North Macedonia
NO	Norway
RS	Serbia
TR	Turkey

Statistics

(:)	Data not available
(–)	Not applicable or zero

Abbreviations and acronyms

International conventions

IEA	International Association for the Evaluation of Educational Achievement
ISCED	International Standard Classification of Education (see the Glossary)
OECD	Organisation for Economic Co-operation and Development
PISA	Programme for International Student Assessment
TIMSS	Trends in International Mathematics and Science Study

EXECUTIVE SUMMARY

Education in mathematics and science plays a crucial role in equipping children and young people with the necessary skills, knowledge and viewpoints to be responsible and active citizens in our fast-changing and technology-driven societies. However, evidence from international student surveys such as that of the Programme for International Student Assessment (PISA) carried out by the Organisation for Economic Co-operation and Development (OECD) show that, in the EU-27, a considerable share of 15-year-olds – about 23% in 2018 – do not reach basic levels of skills in mathematics and science. In particular, students with socioeconomic disadvantages are over-represented among low achievers, which highlights important equity issues.

Against this background, this Eurydice report investigates how education system and curriculum structures, and teaching and learning objectives and practices, contribute to improving students' knowledge, skills and competences in mathematics and science. This report has a specific focus on support structures in place to help low achievers.

The report brings together qualitative information gathered by the Eurydice Network on top-level policies and measures in the area of mathematics and science education, and achievement data from two international assessment surveys (the 2019 Trends in International Mathematics and Science Study (TIMSS) administered by the International Association for the Evaluation of Educational Achievement (IEA), and the 2018 PISA survey carried out by the OECD).

The following summary highlights the key messages of the report, focusing on the characteristics of mathematics and science education common to education systems with lower levels of low achievers in mathematics and science.

The higher the share of underachieving students in primary education, the higher this rate in secondary education

- Percentages of low achievers tend to correlate across subject areas and education levels. Thus, within an education system, there are likely to be similar levels of low achievers in mathematics and science, and in primary and secondary education. This highlights the importance of providing comprehensive learning support for students who are falling behind in the early school grades.

- Education systems with relatively low percentages of underachieving students have higher average achievement scores and smaller differences between the high- and low-achieving students. In other words, education systems that manage to ensure basic numeracy and scientific literacy for more students also succeed in ensuring that the majority of students have similar – and comparatively high – levels of achievement.

- Students from low socioeconomic backgrounds are over-represented among low achievers in all European education systems. The impact of gender on student achievement is less straightforward. In most countries, gender differences among low achievers in mathematics and science are not significant.

Education systems providing learning support during the formal school day (as opposed to only after the formal school day) tend to have lower percentages of low-achieving students in both mathematics and science

- Whereas top-level authorities oblige schools to provide learning support for low-achieving students in the large majority of education systems, only about one quarter of them provide a detailed framework to be strictly implemented by schools. However, whether support should take place during or after the school day is specified by top-level authorities in the majority of education systems.
- The most common way of supporting students with learning difficulties is through additional one-to-one or small-group tutoring, either during the formal school day or outside it (or both). On average, education systems requiring schools to provide support during the school day have lower percentages of low-achieving students. This emphasises the effectiveness of the immediate and timely availability of one-to-one or small-group instruction during the day, when all students are present.
- Top-level learning support requirements or guidelines usually apply to learning difficulties in general, and are not related to particular subjects. Only a handful of education systems have specific provisions on supporting students in mathematics or numeracy. However, until 2020/2021, not a single European education system had issued specific top-level guidelines on how to provide support for students who lack basic scientific literacy.

Involving teachers with a specialisation in supporting low achievers can improve the effectiveness of learning support provision

- Education systems in which teachers with a specialisation in supporting low-achieving students ('remedial teachers') are involved in learning support provision have, on average, lower percentages of low achievement among fourth grade students in mathematics. The role of specialised teachers varies from coordinating learning support provision, developing individualised learning programmes and communicating with parents to actual teaching. Their role often depends on the availability of additional staff and the size of schools.
- Currently, only around one third of education systems employ teachers specialised in supporting low-achieving students in learning support provision. Learning support provision is most commonly the responsibility of classroom teachers.
- Involving remedial teachers to support students who are falling behind is less common in science subjects than in mathematics.

Countries implementing national tests in mathematics tend to have lower levels of students who lack basic numeracy competences

- Identifying students who lag behind is often the responsibility of schools. Thus, different schools and different teachers within the same school may use their own methods of evaluation, testing and grading.
- National tests can provide a standardised reference level and therefore can correct for teacher or school bias in grading. Education systems organising certified examinations or national tests in mathematics at primary level tend to have lower percentages of low achievers.

- Mathematics is more frequently the focus of national tests, especially in primary education. Moreover, national tests in science are usually sample-based, whereas national tests in mathematics are mostly taken by all students.
- National tests are often used for several purposes at the same time. The most widely reported purpose of national tests in mathematics and science in compulsory education is monitoring and evaluating schools and/or the education system. Compulsory top-level testing with the objective of identifying individual learning needs takes place in only one third of the education systems.

Increasing the time spent on learning mathematics or science in lower secondary education together with support measures provided to students with learning difficulties during the school day has the potential to lower underachievement rates

- More instruction time is dedicated to mathematics than to science. The number of hours dedicated to mathematics exceeds the number allocated to science in all the education systems in primary education, and in the majority of them at lower secondary level.
- Instruction time for mathematics is greater at primary level than at secondary level in most education systems. For science, the opposite trend is observed: in more than half of the education systems/tracks, the number of notional hours per year devoted to science in secondary education is at least double that of primary education.
- Instruction time alone does not explain differences in low achievement levels across European countries. However, when the pre-existing level of low achievement and the type of learning support students receive are controlled for, more instruction hours are associated with lower rates of 15-year-old students with poor numeracy and scientific literacy.

More countries are splitting science teaching into separate subjects in lower secondary education

- Almost all European education systems prescribe, in their primary education curricula, the teaching of science as an integrated subject for around 4–6 school years. Moreover, science is often taught together with other subject areas, such as social studies.
- At lower secondary level, most education systems prescribe the teaching of separate science subjects (e.g. biology, physics or chemistry), usually for 2–4 years. The number of education systems advising separate-subject science teaching has increased since 2010/2011.
- The statistical analysis did not reveal a clear relationship between how science subjects are taught and the percentage of low achievers.

Science curricula may benefit from the inclusion of socioscientific questions

- To increase interest and show students the usefulness of mathematics, real-life applications in various contexts are part of curricula in primary and lower secondary education in all European countries. History-of-science and especially socioscientific topics are not as common in curricula during these education levels.

- Education systems whose curricula refer to socioscientific issues have a higher proportion of 15-year-old students who achieve some basic scientific literacy. When students are invited to explore moral dilemmas in the field of biotechnology, explain their own opinions on animal testing or name risks to modern civilisation posed by technological progress, general levels of science achievement improve.

- Learning how to find scientific content by searching online and how to verify the credibility of information from various online sources is essential for facilitating meaningful reflections on socioscientific questions. It is therefore reassuring that digital literacy is integrated in science teaching and learning in lower secondary education in two thirds of the European education systems.

- Including certain factual aspects of history of science does not have a significant relationship with low achievement levels. Merely positioning scientific discoveries in time or learning some facts about the lives of scientists is not sufficient for developing scientific literacy. More research is needed to determine the extent to which the reflective aspects of history of science (e.g. the context of the scientific discoveries, an emphasis on science as a collective human endeavour) are included in European curricula and whether such themes improve achievement levels in science.

Topics related to the protection of nature or reducing pollution are addressed in curricula across Europe, but environmental sustainability is still not among the key educational principles in half of the European education systems

- Environmental sustainability themes are a common element of science subject curricula. In primary education, topics related to the need to take care of the environment, such as recycling, are studied in the integrated science subject or in the broader learning areas, such as ‘environmental studies’, ‘learning about the world’ or ‘nature and society’.

- In lower secondary education, learning about environmental sustainability takes place during biology, geography, physics and chemistry lessons. By grade 8, the curricula in most European countries state that students are expected to be able to discuss sustainable energy management, argue for solutions to preserve biodiversity or describe the greenhouse effect.

- However, more efforts are needed to include environmental sustainability as transversal and intrinsic in the content planning and pedagogies of every learning area. Environmental sustainability is a cross-curricular topic in fewer than half of the European countries.

There is a shortage of specialist teachers in mathematics and science, and a significant need for more continuing professional development in these fields

- Almost all education systems require generalist teachers to provide mathematics and science teaching at primary level (usually for 4–6 years). After that, specialist teachers should teach these subjects.
- In practice, the great majority of education systems are experiencing a shortage of mathematics and/or science teachers. To address this situation, education systems may offer the necessary professional training and additional qualifications to teachers who require them. Some countries have provided new courses, study places or scholarships for those wishing to become mathematics or science teachers.
- Data from the 2019 TIMSS survey shows that current teachers of mathematics and especially science indicate a strong need for training in the teaching of these subjects.

Despite the large impact of the COVID-19 pandemic on students' learning experiences, only half of the education systems have put additional learning support measures in place

- In 2020/2021, most schools in Europe had to switch to distance and/or blended learning for some time, more often in lower secondary education than in primary education. However, complete school closures were rather rare and of relatively short duration (usually immediately before or after school holidays).
- Almost all European education systems responded to the pandemic with new measures to upgrade digital resources and address gaps in digital competences. Several countries released additional funds for socioeconomically disadvantaged students to acquire computers or laptops. New digital learning materials and television and radio programmes in mathematics and science were created, but no specific COVID-19-related guidance in these subject areas was reported.
- Many certified examinations and/or national tests planned for 2020/2021 were cancelled, or had other substantial changes, for example a limited list of requirements for each examination subject or changes in the impact of the examination results.
- Despite the impact of the pandemic, only about half of the education systems put additional support measures or learning support programmes in place, or dedicated additional resources to learning support provision in mathematics and science.

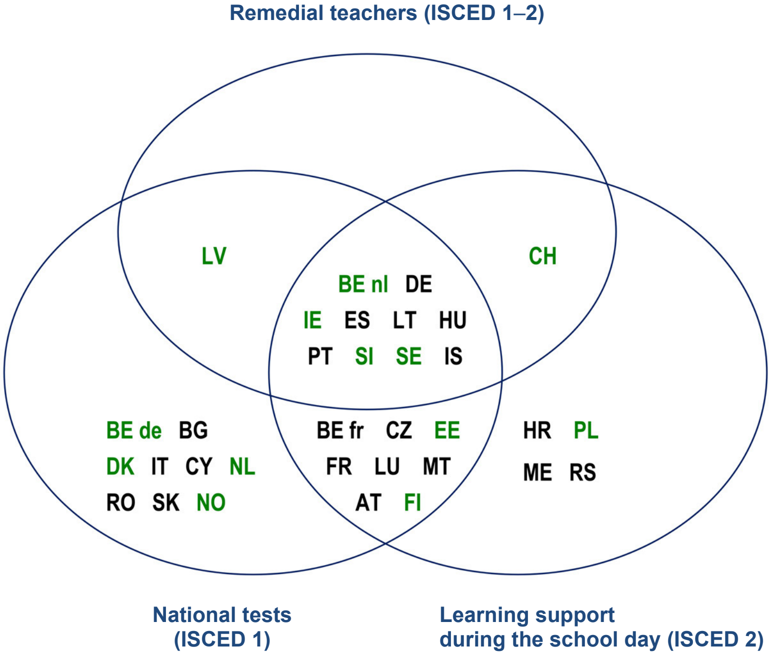
To reduce the percentage of low achievement, combinations of policy measures can be more effective than separate actions

- Certain policy measures and especially a combination of complementary factors may contribute to more students achieving basic numeracy and scientific literacy. The analysis in this report found a significant relationship between the following policy aspects and low-achievement rates:
    - learning support during the formal school day, organised or delivered by remedial teachers throughout primary and secondary education;
    - longer overall instruction time for mathematics and science, especially in lower secondary education;

  - systematic monitoring of student achievement (i.e. national testing administered already in primary education);
  - curriculum content that fosters reflection and relates to students' lives.

- Figure A illustrates one possible combination of three selected measures in relation to mathematics achievement among 15-year-olds. It shows that all of the education systems in which fewer than 20% of students do not have basic numeracy have at least one, but most often two, of the three following measures in place: (1) national tests in primary education, (2) learning support during the formal school day in lower secondary education and (3) involvement of teachers with a specialisation in supporting low-achieving students in primary and/or lower secondary education.

Figure A: Combinations of policy measures and low-achievement rates in mathematics, 2020/2021



None of these measures:
EL, AL, BA, MK, TR

Explanatory note

Education systems in which fewer than 20% of 15-year-olds are low achievers in mathematics are marked in green.

Source: Eurydice.

- In countries with none of these three measures, more than 35% of 15-year-olds lack basic numeracy.
- However, there are education systems with relatively few low achievers that implemented only one of the three measures, and some education systems have relatively high shares of low-achieving students despite having some of these measures in place. Such results reflect the complexity of education systems, which vary greatly in terms of the degree of school autonomy. They also highlight certain limitations of the country-level analysis. Top-level information is sometimes incomplete; therefore, the availability of more information on how learning support measures are organised in schools with a high degree of autonomy could further enrich such analysis. Nevertheless, this report puts forward some suggested policy improvements for those countries that need to boost levels of basic numeracy and scientific literacy.

INTRODUCTION

The importance of the quality and inclusiveness of education systems is indisputable. Particularly in the light of the growing challenges brought about by the COVID-19 pandemic, climate change and economic pressures, it is crucial to minimise any barriers to learning and skills development that may hinder citizens' full participation in and contribution to all aspects of society. Functional levels of numeracy and of scientific and technological knowledge are essential in this respect; it is difficult for anyone without basic skills in mathematics and science to lead a socially inclusive and productive life.

Evidence from international student surveys such as the Programme for International Student Assessment (PISA) carried out by the Organisation for Economic Co-operation and Development (OECD), which tests students' levels of achievement in reading, mathematics and science, is alarming. In the EU-27, an increasing share of 15-year-olds – about 23% in 2018 – do not reach basic levels of skills in mathematics and science (Education Commission, 2020). In other words, the EU-level target for basic skills (i.e. less than 15% of students not mastering basic skills (1)) is still out of reach. Furthermore, students with socioeconomic disadvantages are over-represented among low achievers, which highlights important equity issues.

The Council recommendation on key competences for lifelong learning urged Member States to pay special attention to raising the level of achievement of basic skills and fostering the acquisition of competences in science, technology, engineering and mathematics (2). It also provided a common European reference framework on key competences for policymakers, education and training providers, social partners and learners themselves. This framework identifies science, technology, engineering and mathematics competences as contributing to education in sustainable development, notably by motivating students to support 'environmental sustainability, in particular as regards scientific and technological progress in relation to oneself, family, community, and global issues' (3). It further acknowledges that a 'positive attitude in mathematics is based on the respect for truth and a willingness to look for reasons and to assess their validity' (4).

In the context of the goal to establish the European Education Area by 2025, the European Commission reiterated the importance of mastering basic skills as a prerequisite to thrive and to cope with life's challenges (5). Furthermore, the Commission announced the pathways to school success initiative, which will aim to help all students reach a baseline level of proficiency in basic skills. The initiative will also have a special focus on groups that are more at risk of underachievement and early school leaving.

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(1) The renewed strategic framework for European cooperation in education and training for 2021–2030 defines five EU-level targets to be reached by 2030, including one on low achievers of basic skills: the share of low-achieving 15-year-olds in reading, mathematics and science should be less than 15% by 2030. In this context, low achievers are defined as those who are below 'level 2' on the PISA scale (Council resolution on a strategic framework for European cooperation in education and training towards the European Education Area and beyond (2021–2030), OJ C 66, 26.2.2021).

(2) Council recommendation of 22 May 2018 on key competences for lifelong learning, OJ C 189, 4.6.2018.

(3) Council recommendation of 22 May 2018 on key competences for lifelong learning, OJ C 189, 4.6.2018.

(4) Council recommendation of 22 May 2018 on key competences for lifelong learning, OJ C 189, 4.6.2018.

(5) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on achieving the European Education Area by 2025.

Content of the report

Against this policy background, this report investigates how education system and curriculum structures, and teaching and learning objectives and practices, can contribute to improving students' knowledge, skills and competences in mathematics and science. There is a specific focus on the support structures in place to help low achievers.

The report has seven chapters.

Chapter 1 presents the main indicators of achievement levels in mathematics and science in European countries, focusing mainly on the percentage of low achievers in relation to the EU target.

Chapter 2 outlines the impact of the COVID-19 pandemic on the organisation of school education during the 2020/2021 school year, as well as the digital responses to the pandemic.

Chapter 3 investigates instruction time allocated in curricula / steering documents across Europe to the teaching of mathematics and science in schools.

Chapter 4 looks at the organisation of science education in compulsory education, mathematics and science teachers, and assessment using certified examinations and national tests in both subjects.

Chapter 5 explores the presence of various topics in the curricula that may increase students' interest in, as well as understanding of, mathematics and science. It also briefly discusses the ways in which certain environmental sustainability themes are included in science curricula. Approaches to digital technologies as facilitators of learning in mathematics and science are reviewed.

Chapter 6 is devoted to examining learning support systems and measures in mathematics and science education in Europe.

Chapter 7 examines the characteristics of education systems as presented in previous chapters and investigates which characteristics of curriculum organisation, assessment and support might be associated with lower percentages of low achievers in European education systems.

Annexes provide complementary information on various aspects discussed in the report.

Data sources and methodology

The report is mainly based on qualitative data, gathered by the Eurydice Network, on top-level policies and measures in the area of mathematics and science education. In addition, information from the 2020/2021 Eurydice instruction time data collection has also been used (European Commission / EACEA / Eurydice, 2021a). This report covers all the members of the Eurydice Network (the 27 EU Member States and Albania, Bosnia and Herzegovina, Switzerland, Iceland, Liechtenstein, Montenegro, North Macedonia, Norway, Serbia and Turkey).

The qualitative information in this report was collected through a questionnaire completed by national experts and/or the national representative of the Eurydice Network. The prime sources of this information are regulations/legislation, curricula and other types of official guidance issued by top-level education authorities. All contributors are acknowledged at the end of the report.

The Eurydice data used in this report focus on primary and lower secondary education (ISCED 1 and 2). In most cases, only public schools are included (except for Belgium, Ireland and the Netherlands, where government-dependent private schools are taken into account). The reference year of data is 2020/2021. During that school year, specific measures due to the COVID-19 pandemic influenced the organisation of schooling in many European countries. The report briefly addresses the challenges related to the pandemic in general, and how they influenced mathematics and science instruction in particular (see especially Chapter 2, but also Chapters 4 and 6). However, in most cases, the report considers the ‘normal’ circumstances when describing the ways in which students are learning.

The Eurydice data are complemented by quantitative data from two international assessment surveys: the 2019 Trends in International Mathematics and Science Study (TIMSS) carried out by the International Association for the Evaluation of Educational Achievement (IEA) and the 2018 PISA survey of the OECD. The surveys are primarily used to compute the percentages of low achievers in mathematics and science at two educational stages: in grade 4 and at the age of 15 years. Percentages of low achievers are in turn analysed, using a combination of qualitative and quantitative methods, as outcomes conditional on different characteristics of education systems. In addition, the report also presents some supplementary information drawn from international assessment surveys to provide a better understanding of students’ learning context.

CHAPTER 1: STUDENT ACHIEVEMENT IN MATHEMATICS AND SCIENCE

In our fast-changing and technology-driven societies, quality education and inclusion are essential to help establish a European Education Area by 2025 (6). The vision for quality in education includes the mastering of basic skills (in reading, mathematics and science), but also of transversal skills such as critical thinking, entrepreneurship, creativity and civic engagement. Mathematics and science education plays a crucial role in this regard, as these subject areas have great potential to equip young people with the necessary skills, knowledge and viewpoints to be responsible and active citizens who are able to think critically and creatively. As regards inclusive education, efforts should enable 'educational attainment and achievement to be decoupled from social, economic and cultural status' (7), thereby decreasing social inequalities, and should also challenge and dissolve gender stereotypes. An inclusive education system ensures 'a basic standard minimum education for all' (Field, Kuczera and Pont, 2007, p. 11).

There is a growing amount of evidence showing that the highest-performing education systems combine quality with equity (Checchi et al., 2014; European Commission, 2019; OECD, 2012; Parker et al., 2018). Consequently, 'education systems can pursue excellence and equity at the same time' (European Commission, 2019, p. 6). In order to reach this double goal of quality and inclusive education, the EU has set the following important objective: 'the share of low-achieving 15-year-olds in reading, mathematics and science should be less than 15%' (8). This objective is part of a set of targets the Commission proposes should be attained by 2030 within the framework of the European Education Area (9).

This chapter presents the main indicators of achievement levels in mathematics and science in European countries, focusing mainly on the percentage of low achievers according to the European Commission target. It builds on the extensive literature using the results of international assessment surveys such as the International Association for the Evaluation of Educational Achievement (IEA) Trends in International Mathematics and Science Study (TIMSS), and the Organisation for Economic Co-operation and Development (OECD) Programme for International Student Assessment (PISA).

After discussing the main data sources and their caveats, the chapter presents the percentage of low achievers among fourth graders – students in their fourth year of formal schooling – and among 15-year-old students. It then discusses quality and inclusion in European education systems, and the relationship between these education system characteristics and the percentage of low achievers. Finally, it examines some common determinants of success (or failure) in education, providing a snapshot of the percentage of low achievers by socioeconomic background and gender.

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(6) Commission communication – Achieving the European Education Area by 2025 (COM(2020) 625 final).

(7) Commission communication – Achieving the European Education Area by 2025 (COM(2020) 625 final), p. 7.

(8) Council Resolution on a strategic framework for European cooperation in education and training towards the European Education Area and beyond (2021–2030), OJ 2021/C 66/01.

(9) Commission communication – Achieving the European Education Area by 2025 (COM(2020) 625 final), p. 27.

1.1. Main data sources and caveats

Relying on international assessment surveys has its advantages and disadvantages. Certainly, international assessment surveys can grasp only a fraction of educational outcomes. However, comparing education systems based on surveys that are designed to be comparable in terms of sampling design and content is the most reliable option for researchers. Given that international assessment surveys are conducted at regular intervals, they allow comparisons to be made not only across many countries but also over time.

Nevertheless, some issues related to the cross-national comparability of results might remain even after careful survey design, especially if social, cultural and economic differences between education systems are considerable (Schnepf, 2018). This can be true even for the measurement of skills, as students might not have the same attitudes towards performing well on tests in general and low-stakes tests – tests with little or no impact on students' grades or official results – in particular. In addition, international assessment surveys sample only students who are in school, leaving out those who have left education early. This affects education systems differently depending on the proportion of out-of-school children in the population (Schnepf, 2018). Keeping these caveats in mind, international assessment surveys are still the best available tools for computing comparable indicators related to achievement levels in education.

Given the utmost importance of early learning experiences in children's educational opportunities and trajectories at later educational stages (OECD, 2012, 2018), it is essential to start the analysis at the earliest available level in order to understand quality and inclusion in education. Therefore, this chapter presents indicators based on two surveys covering two important time points in a student's education: the fourth grade, which is typically part of primary education (through TIMSS) (10), and the age of 15 years (through PISA), when students are in lower or upper secondary education (11). These methodological differences have to be kept in mind when comparing performance data across surveys.

The TIMSS survey evaluates the mathematics and science performance of the same cohort of students (12). It is conducted every 4 years, with the latest available data being from 2019. Data are available for 29 European education systems participating in this report (13).

PISA measures 15-year-olds' ability to use their reading, mathematics and science knowledge and skills to meet real-life challenges (14). PISA was launched in 2000 and has been conducted every 3 years since then. The latest available PISA survey is from 2018, with data available for almost all the education systems participating in this report (the exception is Liechtenstein).

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(10) TIMSS assesses students in participating countries in their fourth year of formal schooling, provided the mean age at the time of testing is at least 9.5 years. Because education systems vary in structure and in policies and practices with regard to age of starting school and promotion and retention, there are differences across countries in how the target grades are labelled and in the average age of students. In addition, some countries choose to administer TIMSS to a different grade than the fourth year of formal schooling: Norway chose to assess fifth grade students to obtain better comparisons with Sweden and Finland; Turkey also chose to assess students in the fifth grade (see more at: https://timss2019.org/reports/about/).

(11) The target population of the PISA surveys is an age-based population and not a grade-based population. This means that, depending on their structural features, education systems may differ in how 15-year-olds are distributed across different schools, pathways/tracks or grades. In participating countries, the majority of students may be enrolled at lower secondary level (ISCED level 2) or upper secondary level (ISCED level 3), or may be relatively evenly distributed across both levels (as in Czechia, Ireland, Luxembourg, Slovakia and Albania). See Table II.C.1 in OECD (2019b, pp. 365–366) for the list of dominant ISCED levels per country.

(12) See the website of the IEA for more details (https://www.iea.nl/).

(13) TIMSS 2019 data are not available for Belgium (French and German-speaking Communities), Estonia, Greece, Luxembourg, Romania, Slovenia, Switzerland, Iceland and Liechtenstein.

(14) See the OECD website dedicated to PISA for more details (https://www.oecd.org/pisa/). This report focuses on achievement in mathematics and science.

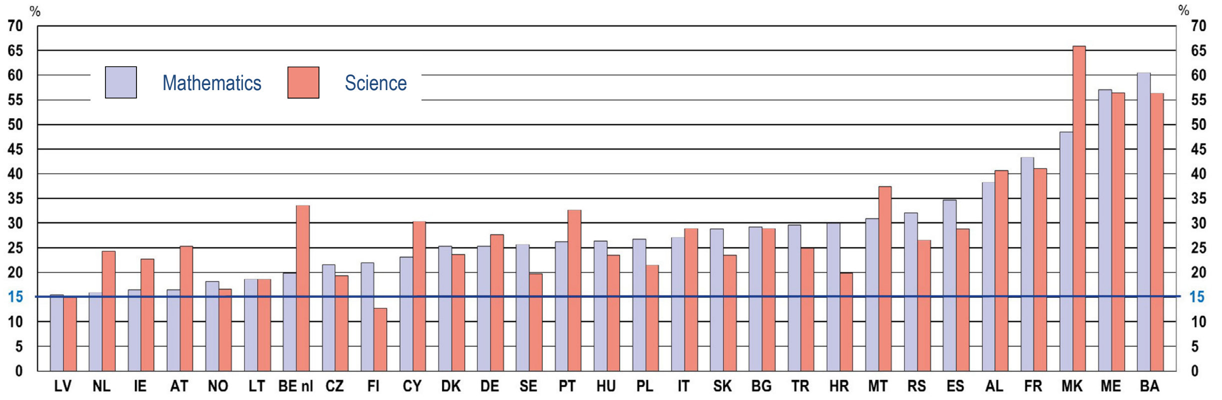
1.2. Percentage of low achievers

The European Commission target on low achievers provides a clear starting point for the discussion on quality and inclusive education in mathematics and science. As mentioned above, according to this target, the share of 15-year-olds who are low achievers in reading, mathematics and science should be less than 15%. In order to complete the picture on the percentage of low achievers among 15-year-olds in European countries, a similar share can be computed for fourth graders (i.e. primary school students) based on the TIMSS survey.

Low-achieving students in grade 4 are the ones who do not achieve the 'Intermediate International Benchmark'. In mathematics, this means that, although they might have some basic mathematical knowledge (15), they have difficulties applying their knowledge in simple situations or performing more complicated mathematical tasks such as computing with three- and four-digit whole numbers in a variety of situations, or reading, labelling and interpreting information in graphs and tables (Mullis et al., 2020, p. 36). In science, students who do not achieve the Intermediate International Benchmark show only a limited understanding of scientific concepts and have a limited knowledge of foundational science facts (Mullis et al., 2020, p. 107).

Figure 1.1 shows the percentage of low-achieving grade 4 students in mathematics and science in 29 European education systems. While the 15% European target concerns only 15-year-olds, this threshold is included in the figure for information (see blue line).

Figure 1.1: Percentage of low achievers in mathematics and science in the fourth grade, 2019



	LV	NL	IE	AT	NO	LT	BE nl	CZ	FI	CY	DK	DE	SE	PT	HU
Mathematics	15.5	15.9	16.4	16.5	18.1	18.6	19.9	21.6	22.0	23.1	25.3	25.4	25.6	26.2	26.4
Science	14.9	24.3	22.6	25.4	16.6	18.6	33.5	19.3	12.7	30.3	23.6	27.6	19.7	32.6	23.5
	PL	**IT**	**SK**	**BG**	**TR**	**HR**	**MT**	**RS**	**ES**	**AL**	**FR**	**MK**	**ME**	**BA**	
Mathematics	26.8	27.0	28.8	29.1	29.6	30.0	30.9	32.1	34.6	38.2	43.3	48.5	57.0	60.4	
Science	21.5	28.9	23.5	28.8	24.9	19.8	37.5	26.6	28.7	40.6	41.0	65.9	56.4	56.3	

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

Explanatory notes

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

The percentage of low-achieving students is defined as the percentage of students not achieving the Intermediate International Benchmark, which is set at a score of 475 points (for information on scoring, see the explanatory notes under Figure 1.3). Standard errors are available in Annex III.

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(15) 'They can add, subtract, multiply, and divide one- and two-digit whole numbers. They can solve simple word problems. They have some knowledge of simple fractions and common geometric shapes. Students can read and complete simple bar graphs and tables' (Mullis et al., 2020, p. 36).

As the figure depicts, in mathematics, the percentage of low achievers among fourth graders is above 15% in all education systems with available data. The percentages of low achievers are lowest in Latvia, the Netherlands, Ireland and Austria, followed by Norway, Lithuania and Belgium (Flemish Community). In these education systems, the percentage of students not achieving the Intermediate International Benchmark is below 20%. At the other end of the scale, the percentage of low achievers in mathematics is above 40% in France, North Macedonia, Montenegro, and Bosnia and Herzegovina. In Montenegro and Bosnia and Herzegovina, the majority of fourth graders (57% and over 60% respectively) are considered low achievers.

In science, the percentage of low achievers is below the 15% threshold only in Latvia (14.9%) and Finland (12.7%). Besides these two education systems, the percentage of low-achieving grade 4 students is below 20% in Norway, Lithuania, Czechia, Sweden and Croatia. The education systems registering the highest shares of low achievers are the same as in mathematics (France, North Macedonia, Montenegro, and Bosnia and Herzegovina), with the majority of students not achieving the Intermediate International Benchmark in North Macedonia, Montenegro, and Bosnia and Herzegovina (65.9%, 56.4% and 56.3% respectively).

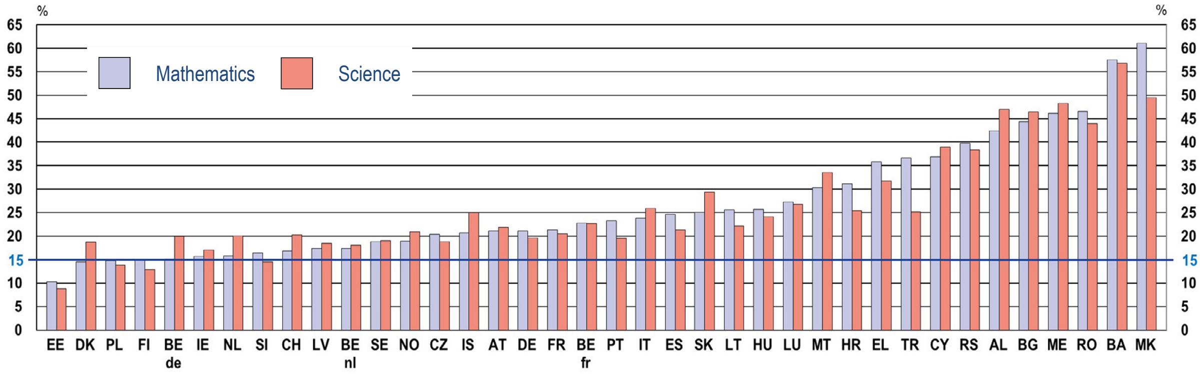
When it comes to 15-year-olds, the percentage of low achievers can be computed based on the PISA survey (Figure 1.2). The PISA survey examines ‘how well students can extrapolate from what they have learned and apply their knowledge in unfamiliar settings, both in and outside of school’ (OECD, 2019a, p. 26).

Low achievers with respect to the PISA survey are defined as students who do not reach ‘level 2’ proficiency. In mathematics, this means that these students can answer only those mathematics questions involving familiar contexts where all of the relevant information is present and the questions are clearly defined. They might be able to identify information and carry out routine procedures according to direct instructions, but can perform only those actions that are obvious and that immediately follow the given stimuli. However, interpreting and recognising situations poses problems for them, even if this requires no more than direct inference, extracting relevant information from a single source and making use of a single representational mode (such as a graph, table or equation) (OECD, 2019a, p. 105).

In science, students who do not achieve ‘level 2’ proficiency might be able to use basic or everyday content and procedural knowledge to recognise or identify explanations of simple scientific phenomena. However, they need support to undertake simple, structured scientific enquiries, and are able to identify only simple causal or correlational relationships and interpret only graphical and visual data that require a low level of cognitive demand (OECD, 2019a, p. 113).

In mathematics, as Figure 1.2 depicts, the percentage of low-achieving 15-year-olds is below the 15% target in only four education systems: those of Estonia (10.2%), Denmark (14.6%), Poland (14.7%) and Finland (15.0%). The percentages are lower than 20% in a further nine education systems. At the other end of the scale, the education systems with the highest percentages of low achievers (above 40%) are those of Albania, Bulgaria, Montenegro, Romania, Bosnia and Herzegovina, and North Macedonia. The majority of 15-year-old students are considered low achievers according to international standards in Bosnia and Herzegovina (57.6%) and North Macedonia (61.0%).

Figure 1.2: Percentage of low achievers among 15-year-old students in mathematics and science, 2018



	EE	DK	PL	FI	BE de	IE	NL	SI	CH	LV	BE nl	SE	NO	CZ	IS	AT	DE	FR	BE fr
Mathematics	10.2	14.6	14.7	15.0	15.1	15.7	15.8	16.4	16.8	17.3	17.3	18.8	18.9	20.4	20.7	21.1	21.1	21.3	22.8
Science	8.8	18.7	13.8	12.9	20.0	17.0	20.0	14.6	20.2	18.5	18.0	19.0	20.8	18.8	25.0	21.9	19.6	20.5	22.6
	PT	**IT**	**ES**	**SK**	**LT**	**HU**	**LU**	**MT**	**HR**	**EL**	**TR**	**CY**	**RS**	**AL**	**BG**	**ME**	**RO**	**BA**	**MK**
Mathematics	23.3	23.8	24.7	25.1	25.6	25.6	27.2	30.2	31.2	35.8	36.7	36.9	39.7	42.4	44.4	46.2	46.6	57.6	61.0
Science	19.6	25.9	21.3	29.3	22.2	24.1	26.8	33.5	25.4	31.7	25.2	39.0	38.3	47.0	46.5	48.2	43.9	56.8	49.5

Source: Eurydice, based on OECD, PISA 2018 database.

Explanatory notes

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

The percentage of low-achieving students is defined as the percentage of students who score below the baseline level of proficiency (level 2) on the PISA mathematics and/or science scales. This corresponds to not achieving 420.07 points in mathematics, and 409.54 points in science (for information on scoring, see the explanatory notes under Figure 1.4). Standard errors are available in Annex III.

Similarly to mathematics, in science the percentage of low achievers among 15-year-olds is below 15% in four education systems: those of Estonia (8.8%), Finland (12.9%), Poland (13.8%) and Slovenia (14.6%). Estonia, Poland and Finland have therefore reached the European target in both subject areas. In nine education systems, the percentage of low achievers in science is between 15% and 20%. The education systems with a percentage of low achievers higher than 40% in science are the same as in the case of mathematics: those of Albania, Bulgaria, Montenegro, Romania, Bosnia and Herzegovina, and North Macedonia. The share in Bosnia and Herzegovina is above 50%.

As these comparisons illustrate, percentages of low achievers tend to correlate across subject areas (16). In other words, if an education system has a relatively high/low percentage of low achievers in one subject area, it tends to also have relatively high/low percentages of low achievers in other areas. Most education systems also tend to perform similarly across education levels (i.e. in primary and secondary education) (17). This suggests that certain education systems can tackle low achievement in general – across subjects and educational levels – better than others. So the question arises: what are the characteristics of education systems that have lower shares of low achievers? The next section starts this analysis by addressing quality and inclusion in education.

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(16) The Spearman correlation coefficient between percentages of low achievers in mathematics and science is 0.67 in TIMSS 2019 and 0.93 in PISA 2018, both significant at the 5% level.

(17) The Spearman correlation coefficient between percentages of low achievers in primary and secondary education is 0.73 in mathematics and 0.61 in science, both significant at the 5% level.

1.3. Quality and inclusive education

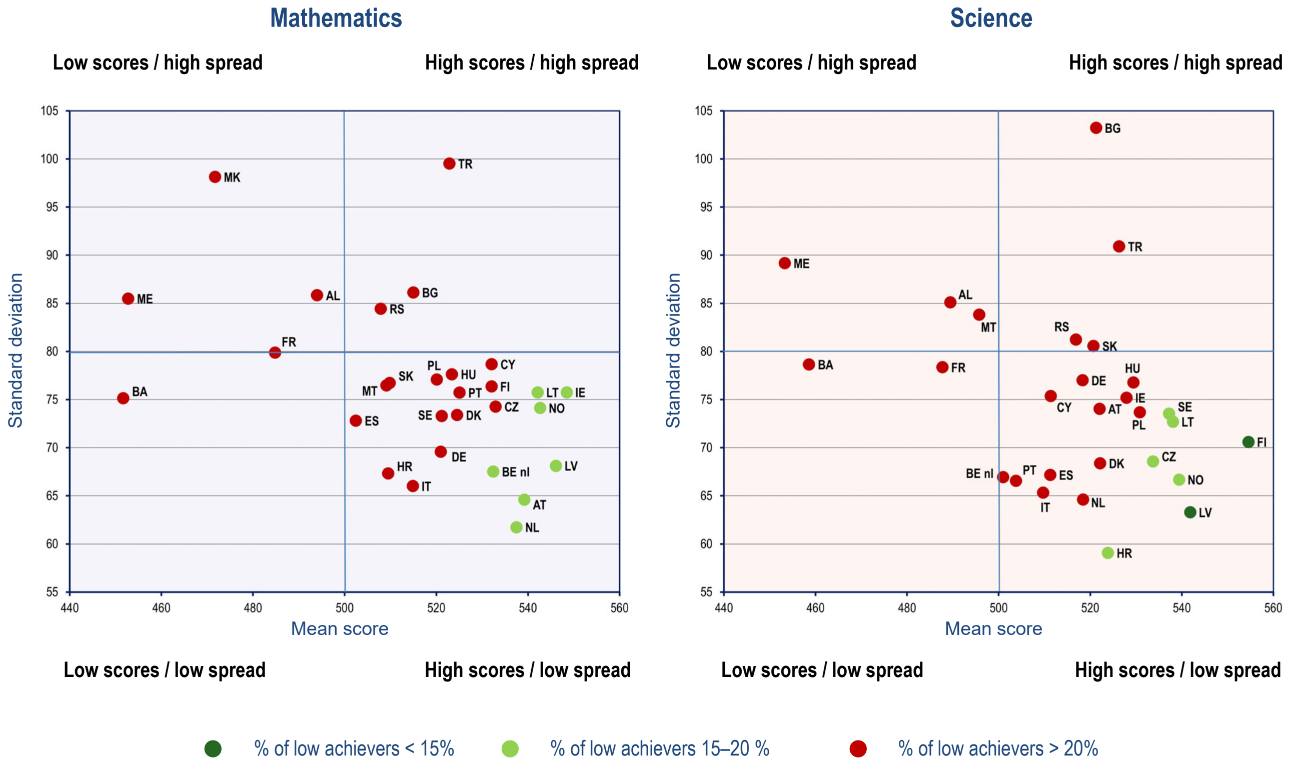
Assessing quality and inclusion in education systems is a complex task. Nevertheless, international student assessment surveys allow indicators to be defined and computed that enable international comparisons along given dimensions.

When it comes to quality, average achievement within education systems is the most commonly used indicator. Average achievement refers to the weighted mean score of all students participating in a given survey within an education system.

Inclusive education means, on the one hand, that most students can reach a minimum basic achievement level (i.e. the share of underachieving students is as small as possible), and, on the other hand, that differences between students' achievement levels are not too wide. Therefore, this chapter relies on the standard deviation of achievement scores within education systems as the main indicator for inclusion. Nevertheless, several other indicators can also capture such differences between students, including the achievement gap between the lowest percentile or quartile and the highest percentile or quartile of students (see, for example, European Commission / EACEA / Eurydice, 2020).

Figure 1.3 shows education systems along the quality and inclusion dimensions in both mathematics and science based on the TIMSS 2019 survey, while Figure 1.4 does the same based on the PISA 2018 survey. As the figures illustrate, education systems with similar levels of average performance can have different ranges of student scores and vice versa.

Figure 1.3: Mean score and standard deviation in mathematics and science for fourth grade students, 2019



		BE nl	BG	CZ	DK	DE	IE	ES	FR	HR	IT	CY	LV	LT	HU	MT
Mathematics	Mean score	532	515	533	525	521	549	503	485	510	515	532	546	542	523	509
	Standard deviation	67.5	86.1	74.3	73.4	69.6	75.8	72.8	79.9	67.3	66.0	78.7	68.1	75.7	77.6	76.5
Science	Mean score	501	521	534	522	518	528	511	488	524	510	511	542	538	529	496
	Standard deviation	66.9	103.2	68.6	68.4	77.0	75.2	67.2	78.3	59.1	65.3	75.4	63.3	72.7	76.8	83.8
		NL	**AT**	**PL**	**PT**	**SK**	**FI**	**SE**		**AL**	**BA**	**ME**	**MK**	**NO**	**RS**	**TR**
Mathematics	Mean score	538	539	520	525	510	532	521		494	452	453	472	543	508	523
	Standard deviation	61.7	64.6	77.1	75.7	76.7	76.3	73.3		85.8	75.1	85.5	98.1	74.1	84.4	99.5
Science	Mean score	519	522	531	504	521	555	537		490	459	453	426	539	517	526
	Standard deviation	64.6	74.0	73.7	66.5	80.6	70.6	73.5		85.1	78.6	89.2	102.8	66.7	81.2	90.9

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

Explanatory notes

The TIMSS achievement scale was established in TIMSS 1995 based on the achievement of all participating countries, treating each country equally. The TIMSS scales have a typical range of achievement between 300 and 700 in both mathematics and science. A centre point of 500 points was set to correspond to the mean of overall achievement at the first data collection, with 100 points set to correspond to the standard deviation. Achievement data from each subsequent TIMSS assessment have been reported on these scales, so that increases or decreases in achievement may be monitored across assessments. TIMSS uses the scale centre point as a point of reference that remains constant from assessment to assessment.

TIMSS describes achievement at four points along the scale as international benchmarks: Advanced International Benchmark (625), High International Benchmark (550), Intermediate International Benchmark (475) and Low International Benchmark (400). The score gaps between the benchmarks correspond to 75 points on the achievement scale.

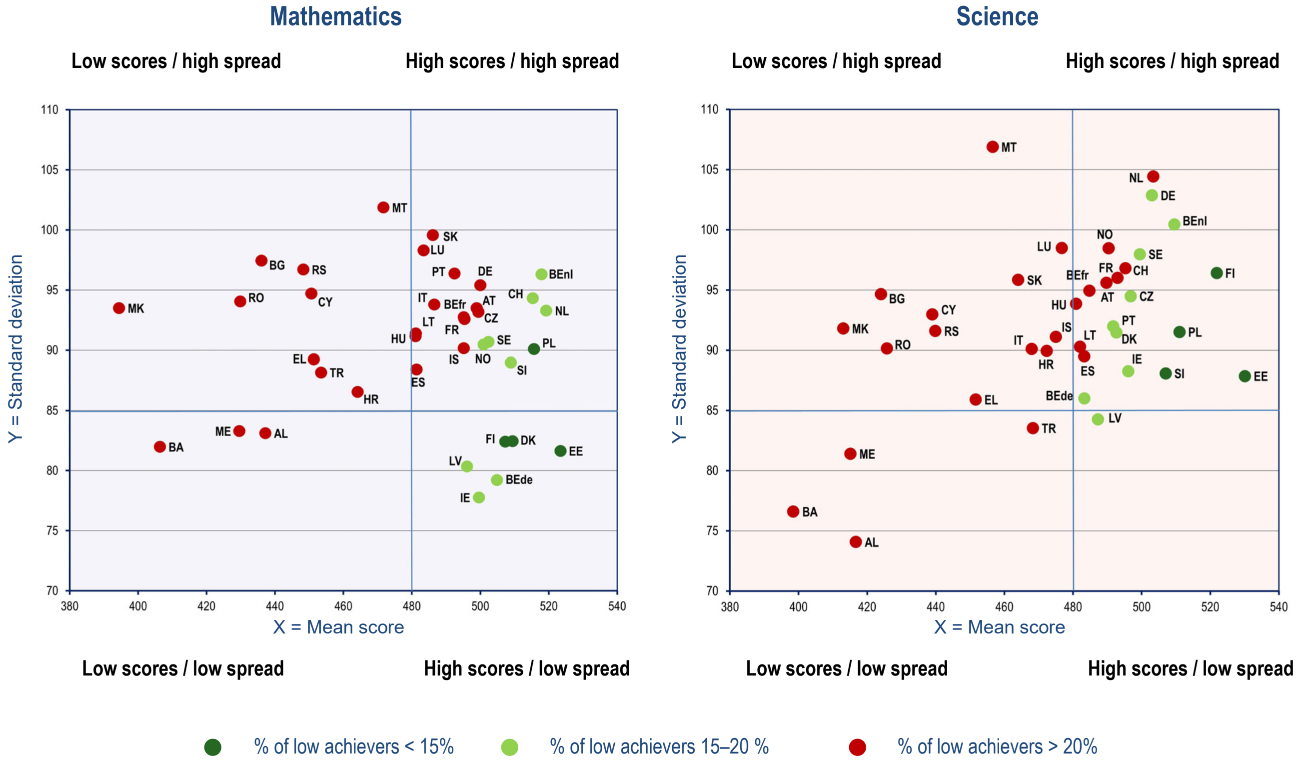
Standard errors are available in Annex III.

In primary education, differences between countries are relatively small. Most countries crowd relatively close to the bottom right corner in Figure 1.3 in both mathematics and science. This means that, in grade 4, most education systems are relatively close to the desired combination of high quality (mean scores higher than 500) and a high level of inclusion (measured as low spread, e.g. standard deviation below 80).

In Figure 1.3, education systems with the lowest shares of underachieving students (see Figure 1.1) are marked in dark green (below 15%) and light green (above 15% but below 20%). As is clearly visible in the figures, these are the education systems closest to the bottom right corner, with the highest mean scores (over 520 points) and lowest standard deviations (around or below 75 points). Given that score gaps between adjacent benchmarks correspond to 75 points in the TIMSS survey – for example, the difference between the low and intermediate benchmarks as defined by the TIMSS survey is 75 points – having a standard deviation around or below 75 points means that differences between low- and high-achieving students do not exceed one benchmark. In other words, education systems with low percentages of low achievers in primary education are visibly characterised by high levels of both quality and inclusion according to the TIMSS survey.

The picture changes slightly when examining quality and inclusion in secondary education, through the achievement levels of 15-year-old students (Figure 1.4). In the PISA 2018 survey, mean scores of European countries are situated between 390 and 530 points. Although the majority of education systems have mean scores higher than 480 points, 12 countries have lower averages in mathematics, and an even greater number of countries, 16, have lower averages in science. Differences between high- and low-achieving students are also more pronounced, with the overwhelming majority of countries having ranges above 80 points. In the PISA survey, a difference of 80 points is interpreted as the difference in described skills and knowledge between successive proficiency levels (i.e. between proficiency levels 1 and 2, between levels 2 and 3, etc.). Thus, education systems are more spread out along both the quality dimension and the inclusion dimension. This means that differences both within and between countries are bigger in secondary education than in primary education.

Figure 1.4: Mean score and standard deviation in mathematics and science for 15 year-old students, 2018



		BE fr	BE de	BE nl	BG	CZ	DK	DE	EE	IE	EL	ES	FR	HR	IT	CY	LV	LT	LU	HU
Mathematics	Mean score	495	505	518	436	500	510	500	523	500	451	481	495	464	487	451	496	481	483	481
	Standard deviation	92.7	79.2	96.3	97.4	93.2	82.4	95.4	81.6	77.8	89.2	88.4	92.6	86.5	93.8	94.7	80.3	91.4	98.3	91.1
Science	Mean score	485	483	510	424	497	493	503	530	496	452	483	493	472	468	439	487	482	477	481
	Standard deviation	94.9	86.0	100.5	94.6	94.5	91.5	102.9	87.8	88.3	85.9	89.5	96.0	89.9	90.1	93.0	84.3	90.3	98.5	93.9

		MT	NL	AT	PL	PT	RO	SI	SK	FI	SE	AL	BA	CH	IS	ME	MK	NO	RS	TR
Mathematics	Mean score	472	519	499	516	493	430	509	486	507	502	437	406	515	495	430	394	501	448	454
	Standard deviation	101.9	93.3	93.5	90.1	96.4	94.0	89.0	99.6	82.4	90.7	83.1	82.0	94.3	90.2	83.3	93.5	90.5	96.7	88.2
Science	Mean score	457	503	490	511	492	426	507	464	522	499	417	399	495	475	415	413	490	440	468
	Standard deviation	106.9	104.4	95.6	91.5	92.0	90.1	88.1	95.8	96.4	98.0	74.1	76.6	96.8	91.1	81.4	91.8	98.4	91.6	83.5

Source: Eurydice, based on OECD, PISA 2018 database.

Explanatory notes

PISA scores are set in relation to the variation in results observed across all test participants. There is theoretically no minimum or maximum score in PISA; rather, the results are scaled to fit approximately normal distributions, with means around 500 points and standard deviations around 100 points. PISA scales are divided into proficiency levels (1–6) corresponding to increasingly difficult tasks. For each proficiency level identified, descriptions were generated to define the kinds of knowledge and skills needed to complete those tasks successfully. Each proficiency level corresponds to a range of about 80 points. Hence, differences in scores of 80 points can be interpreted as the difference in described skills and knowledge between successive proficiency levels.

Because the PISA sample is defined by a particular age group, rather than a particular grade, in many countries, students who participate in the PISA assessment are distributed across two or more grades. Based on this variation, past reports have estimated the average difference in scores across adjacent grades for countries in which a sizeable number of 15-year-olds are enrolled in at least two different grades. These estimates take into account some socioeconomic and demographic differences that are also observed across grades. On average across countries, the difference between adjacent grades is about 40 points (see more in OECD, 2019a).

Standard errors are available in Annex III.

Similarly to primary education, systems with the lowest percentages of underachieving students (marked in dark green (below 15%) and light green (above 15% but below 20%); see Figure 1.2) have relatively high mean scores. However, patterns are different between mathematics and science for 15-year-old students. In mathematics, similarly to what Figure 1.3 showed in primary education, a group of six education systems with low percentages of low achievers (those of Belgium (German-speaking Community), Denmark, Estonia, Ireland, Latvia and Finland) are situated in the bottom right corner in Figure 1.4, with high mean scores and low standard deviations. These are the systems where the survey points towards quality meeting equity in education. However, these education systems are not the only ones with a share of underachievers below 15% or 20%. Another group of countries with high mean scores can be distinguished: those with a standard deviation of scores above 85 (Belgium (Flemish Community), the Netherlands, Poland, Slovenia, Sweden, Switzerland and Norway). These education systems achieve similar quality levels to the first group, but have lower levels of inclusion.

In science, however, even education systems with low shares of underachieving students have a standard deviation of scores larger than 85 points, and in some cases even around or exceeding 100 points. Moreover, the relationship between the mean and the spread of scores seems much stronger – and goes in the opposite direction – than in mathematics and in both fields in primary education: the higher the mean scores, the larger the differences between students (18). As a result, the bottom right corner of the figure for achievement in science is left largely unpopulated.

These differences between mathematics and science are linked to the fact that the range of scores tends to be narrower in science than in mathematics in education systems with a high percentage of low achievers, while tending to be wider in systems with a relatively low share of underachieving students. In other words, in countries with large shares of low achievers, differences between students tend to be bigger in mathematics than in science. Conversely, countries with lower percentages of low achievers have a relatively narrow achievement gap in mathematics, but less so in science. Education systems that achieve the EU target despite a wider spread of scores (most notably those of Estonia and Finland) can do so because, in these cases, the differences lie not in the achievement levels of low achievers but in those of high achievers: high-achieving students achieve higher scores in science than in mathematics (19). In Belgium (German-speaking Community), Denmark, Ireland and Latvia, on the other hand, low-achieving students in science have lower scores than low-achieving students in mathematics (20).

Following this general discussion on achievement levels and differences, in light of the European Commission's definition of inclusive education (21), the final section of this chapter looks into how achievement might be linked to the socioeconomic background or gender of students.

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(18) The Spearman correlation coefficient between the mean scores and the standard deviations in science is 0.37, significant at the 5% level.

(19) See the P90 values in Annex III, Table 1.4.

(20) See the P10 values in Annex III, Table 1.4.

(21) Commission communication – Achieving the European Education Area by 2025, COM(2020) 625 final, p. 7.

1.4. Determinants of student achievement

Equity in education implies that personal and social circumstances should not be an obstacle to educational success. It is commonly measured by analysing the school achievement differences between, for example, those students who are born in rich and poor households, boys and girls, those who have highly educated parents and those who do not, and those who speak the main national language at home and those who do not. This section is devoted to examining the common determinants of success (or failure) in education, providing a snapshot of the percentage of low achievers by socioeconomic background and gender in order to gain an initial insight into the extent of differences between students from various backgrounds.

Socioeconomic status

Socioeconomic background is the most common individual characteristic determining achievement in education. Students from families of low socioeconomic status are more likely to have lower levels of literacy and numeracy, to leave school early or to have negative attitudes towards school (Considine and Zappala, 2002a). Research confirms that socioeconomic background variables such as parental education, ethnicity, the number of books at home and housing type are among the strongest predictors of academic performance (Considine and Zappala, 2002b; European Commission / EACEA / Eurydice, 2020; Jerrim et al., 2019; OECD, 2012). Nevertheless, socioeconomic background does not have the same impact on achievement in all education systems. As the Eurydice report *Equity in School Education in Europe* demonstrated, the correlation between socioeconomic background and student achievement largely depends on how education systems are structured and organised (European Commission / EACEA / Eurydice, 2020).

A common proxy used for socioeconomic status is the number of books at home, as reported by students. Researchers argue that the number of books at home provides a good theoretical proxy for the educational, cultural and economic background of families (see, for example, Schütz, Ursprung and Wößmann, 2008; Wößmann, 2003, 2004). Empirically, the number of books at home is found to be a more important predictor of student performance than parental education (Schütz, Ursprung and Wößmann, 2008) (22). In addition, this variable is available in both surveys analysed. This section examines differences in the percentages of low achievers among students from lower (maximum of 25 books at home) and higher (26 books or more at home) socioeconomic backgrounds.

Figure 1.5 shows these differences based on the TIMSS survey (i.e. between different groups of students in the fourth grade of primary education). In all European education systems, children from households with a maximum of 25 books tend to have lower results in mathematics and science than those with 26 or more books at home. As the charts and tables in Figure 1.5 show, gaps between shares of low achievers among students from lower and higher socioeconomic backgrounds are between 10 and 31 percentage points in mathematics, and between 10 and 34 percentage points in science. The smallest differences, of around 10–12 percentage points, can be found in Latvia in both subject areas, in the Netherlands in mathematics and in Croatia in science, while the differences are largest (above 30 percentage points) in Bulgaria, France and Slovakia in both subject areas.

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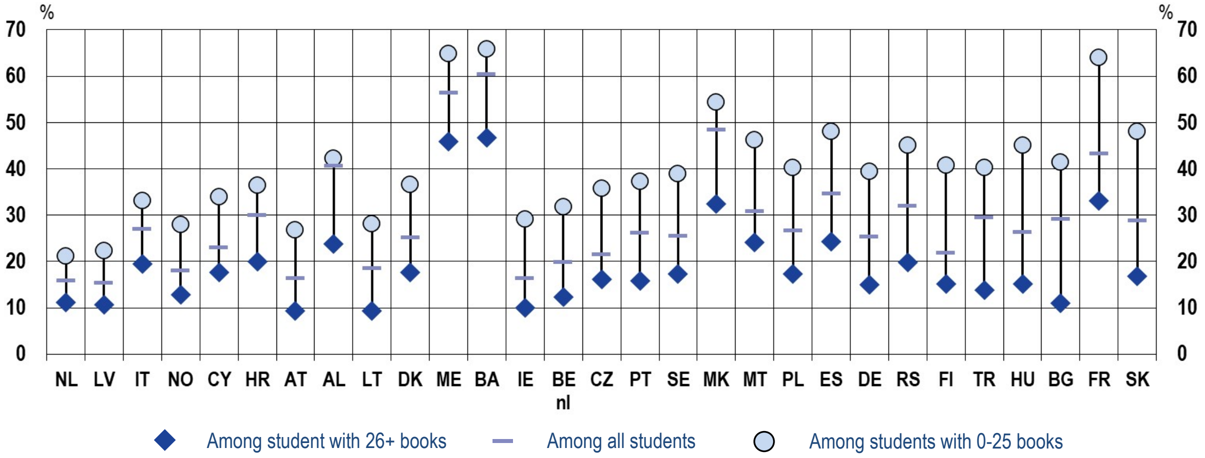
(22) Certainly, having books at home can have different cultural connotations in different education systems (i.e. having many books may signal high educational, social and cultural status in some education systems more than in others), which might limit the comparability of results to some extent.

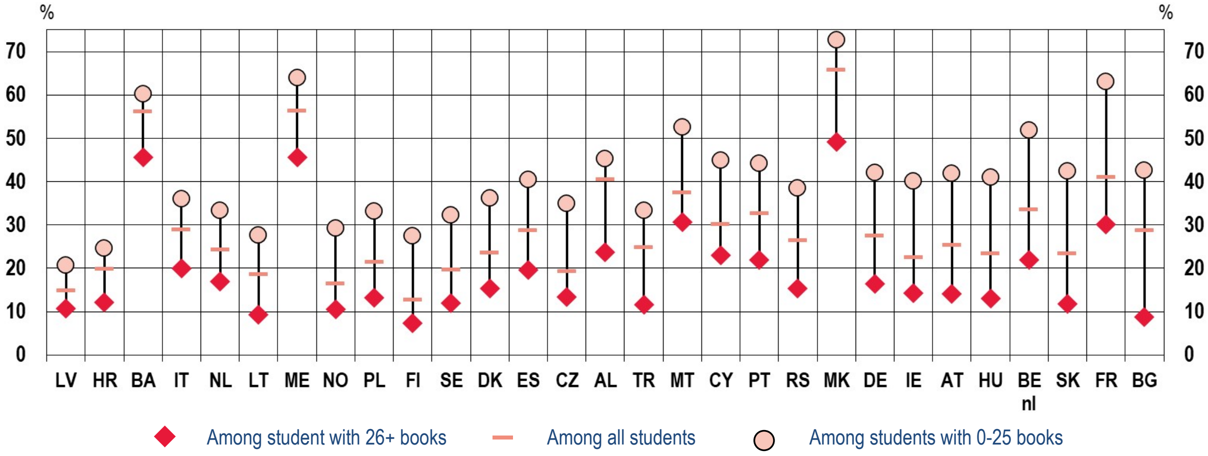
Figure 1.5: Percentage of low achievers in mathematics and science in the fourth grade, by the number of books at home, 2019

Mathematics



		NL	LV	IT	NO	CY	HR	AT	AL	LT	DK	ME	BA	IE	BE nl	CZ
Mathematics	26+ books	11.2	10.7	19.4	12.8	17.7	20.0	9.3	23.8	9.3	17.7	46.0	46.7	10.0	12.3	16.2
	0-25 books	21.2	22.2	33.1	27.9	33.9	36.5	26.8	42.3	28.1	36.5	64.9	65.9	29.2	31.9	35.8
	Percentage point difference	9.9	11.5	13.7	15.1	16.2	16.5	17.5	18.6	18.8	18.8	19.0	19.2	19.2	19.6	19.6
		PT	SE	MK	MT	PL	ES	DE	RS	FI	TR	HU	BG	FR	SK	
	26+ books	15.9	17.3	32.4	24.1	17.4	24.3	14.9	19.8	15.2	13.9	15.2	11.0	33.1	16.9	
	0-25 books	37.2	38.9	54.3	46.3	40.3	48.0	39.4	45.1	40.7	40.2	45.0	41.5	63.9	48.1	
	Percentage point difference	21.4	21.6	21.9	22.1	22.9	23.8	24.5	25.3	25.6	26.3	29.8	30.4	30.8	31.2	

Science



		LV	HR	BA	IT	NL	LT	ME	NO	PL	FI	SE	DK	ES	CZ	AL
Science	26+ books	10.7	12.1	45.7	20.0	16.9	9.4	45.6	10.6	13.2	7.3	11.9	15.4	19.6	13.4	23.7
	0-25 books	20.8	24.5	60.2	36.1	33.4	27.7	64.0	29.2	33.2	27.5	32.3	36.1	40.5	34.9	45.3
	Percentage point difference	10.1	12.4	14.5	16.0	16.5	18.3	18.4	18.5	20.0	20.3	20.4	20.7	20.9	21.6	18.4
		TR	MT	CY	PT	RS	MK	DE	IE	AT	HU	BE nl	SK	FR	BG	
	26+ books	11.5	30.8	23.0	21.9	15.4	49.1	16.5	14.3	14.2	13.1	22.0	11.8	30.2	8.7	
	0-25 books	33.4	52.6	44.9	44.3	38.4	72.7	42.1	40.1	42.0	41.0	51.8	42.4	63.0	42.6	
	Percentage point difference	21.8	21.9	21.9	22.3	23.0	23.6	25.6	25.8	27.8	27.9	29.7	30.5	32.8	33.8	

Source: Eurydice based on IEA, TIMSS 2019 database.

Explanatory notes

Education systems are depicted in ascending order based on the percentage point differences between low achievement rates among students with 0–25 and 26+ books in mathematics/science.

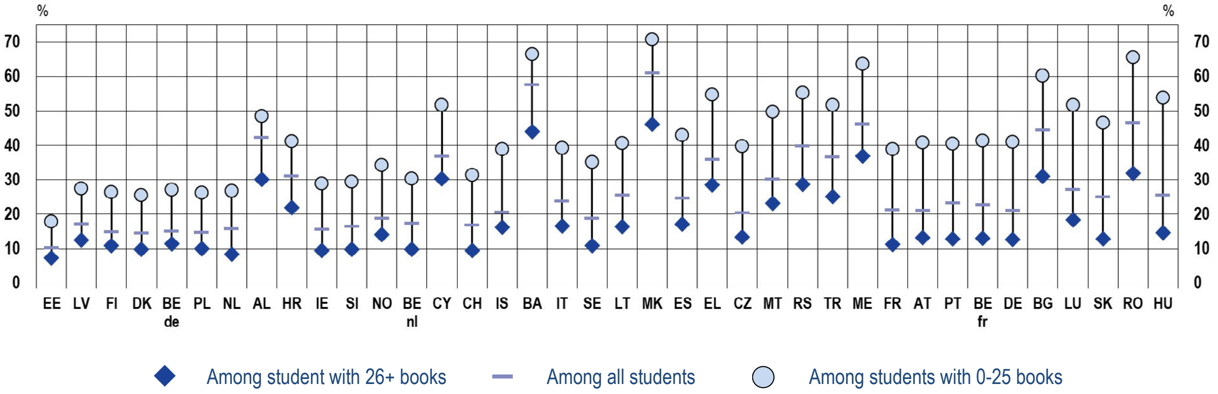
The original categories of the number of books at home variable (ASBG04) were transformed so that there were two values only: (1) 0–25 books and (2) 26+ books. Please consult Annex III, Table 1.5 for the relative size of the two subgroups and for the standard errors.

Differences in the percentages of low achievers between the two subgroups of students are statistically significant ($p < 0.05$) in all education systems. Percentage point differences were calculated before rounding.

Similar differences can be computed for 15-year-old students based on the PISA survey. Figure 1.6 shows the percentage of low achievers among 15-year-olds, by the number of books at home (0–25 books or 26 or more books). Differences between the percentages of low achievers among students from lower and higher socioeconomic backgrounds in the PISA survey lie between 10 and 39 percentage points in mathematics, and between 9 and 38 percentage points in science.

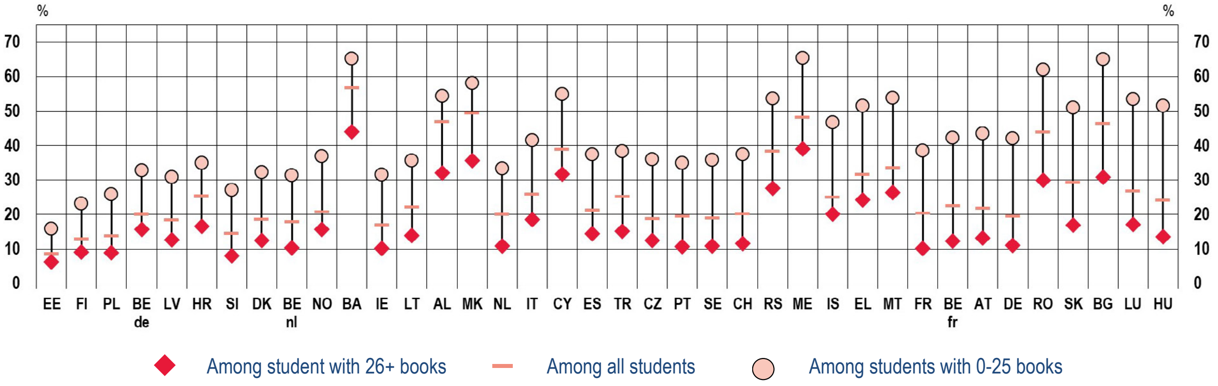
Figure 1.6: Percentage of low achievers in mathematics and science among 15-year-olds, by the number of books at home, 2018

Mathematics



		EE	LV	FI	DK	BE de	PL	NL	AL	HR	IE	SI	NO	BE nl	CY	CH	IS	BA	IT	SE
Mathematics	26+ books	7.4	12.4	11.0	9.9	11.4	10.0	8.4	30.1	22.0	9.5	9.8	14.2	9.9	30.2	9.6	16.3	44.0	16.5	11.0
	0-25 books	17.8	27.5	26.4	25.4	27.0	26.1	26.7	48.4	41.3	28.9	29.4	34.3	30.3	51.7	31.4	38.8	66.5	39.2	35.1
	Percentage point difference	10.4	15.0	15.4	15.6	15.7	16.1	18.3	18.3	19.3	19.4	19.7	20.1	20.3	21.5	21.8	22.5	22.5	22.7	24.1
		LT	MK	ES	EL	CZ	MT	RS	TR	ME	FR	AT	PT	BE fr	DE	BG	LU	SK	RO	HU
	26+ books	16.4	46.2	17.1	28.6	13.5	23.3	28.8	25.2	36.9	11.2	13.3	12.8	13.0	12.7	31.1	18.4	12.9	31.9	14.7
	0-25 books	40.7	70.8	42.9	54.7	39.7	49.7	55.3	51.8	63.5	38.8	40.9	40.5	41.3	41.1	60.2	51.8	46.5	65.6	53.8
	Percentage point difference	24.2	24.5	25.8	26.1	26.2	26.4	26.5	26.5	26.7	27.6	27.6	27.7	28.3	28.4	29.1	33.3	33.5	33.7	39.1

Science



Source: Eurydice based on OECD, PISA 2018 database.

Data (Figure 1.6)

		EE	FI	PL	BE de	LV	HR	SI	DK	BE nl	NO	BA	IE	LT	AL	MK	NL	IT	CY	ES
Science	26+ books	6.2	9.2	8.9	15.7	12.7	16.6	8.1	12.5	10.3	15.7	44.0	10.2	14.0	32.0	35.7	10.9	18.6	31.8	14.5
	0-25 books	15.9	23.2	25.9	32.8	30.9	34.9	27.0	32.3	31.4	36.9	65.2	31.6	35.6	54.3	58.1	33.4	41.6	54.8	37.5
	Percentage point difference	9.6	14.0	17.0	17.0	18.2	18.3	19.0	19.8	21.0	21.2	21.2	21.3	21.6	22.3	22.4	22.5	23.0	23.0	23.1
		TR	CZ	PT	SE	CH	RS	ME	IS	EL	MT	FR	BE fr	AT	DE	RO	SK	BG	LU	HU
	26+ books	15.2	12.5	10.7	10.9	11.6	27.6	39.1	20.1	24.2	26.4	10.1	12.4	13.2	11.0	29.9	17.0	30.8	17.2	13.6
	0-25 books	38.3	36.0	34.9	35.9	37.5	53.6	65.5	46.7	51.4	53.7	38.4	42.3	43.5	42.0	62.0	50.9	65.1	53.5	51.5
	Percentage point difference	23.1	23.5	24.1	25.0	25.9	26.0	26.4	26.5	27.2	27.3	28.3	30.0	30.2	31.0	32.1	33.9	34.3	36.3	37.9

Source: Eurydice based on OECD, PISA 2018 database.

Explanatory notes

Education systems are depicted in ascending order based on the percentage point differences between low achievement rates among students with 0–25 and 26+ books in mathematics/science.

The original categories of the number of books at home variable (ST013Q01TA) were transformed so that there were two values only: (1) 0–25 books and (2) 26+ books. Please consult Annex III, Table 1.6 for the relative size of the two subgroups and for the standard errors.

Differences in the percentages of low achievers between the two subgroups of students are statistically significant ($p < 0.05$) in all education systems. Percentage point differences were calculated before rounding.

In both subject areas, differences between the two groups of students are smallest in Estonia, at around 10 percentage points, followed by Latvia, Finland, Denmark, Belgium (German-speaking Community) and Poland in mathematics, and Finland, Poland and Belgium (German-speaking Community) in science. Similarly to the findings based on the TIMSS survey, the education systems in Bulgaria and Slovakia are among those with the largest differences between students by socioeconomic background in both subject areas, together with Romania, Luxembourg, and Hungary. The biggest differences in the shares of low achievers by socioeconomic background can be found in Hungary, reaching more than 39 percentage points in mathematics, and almost 38 percentage points in science.

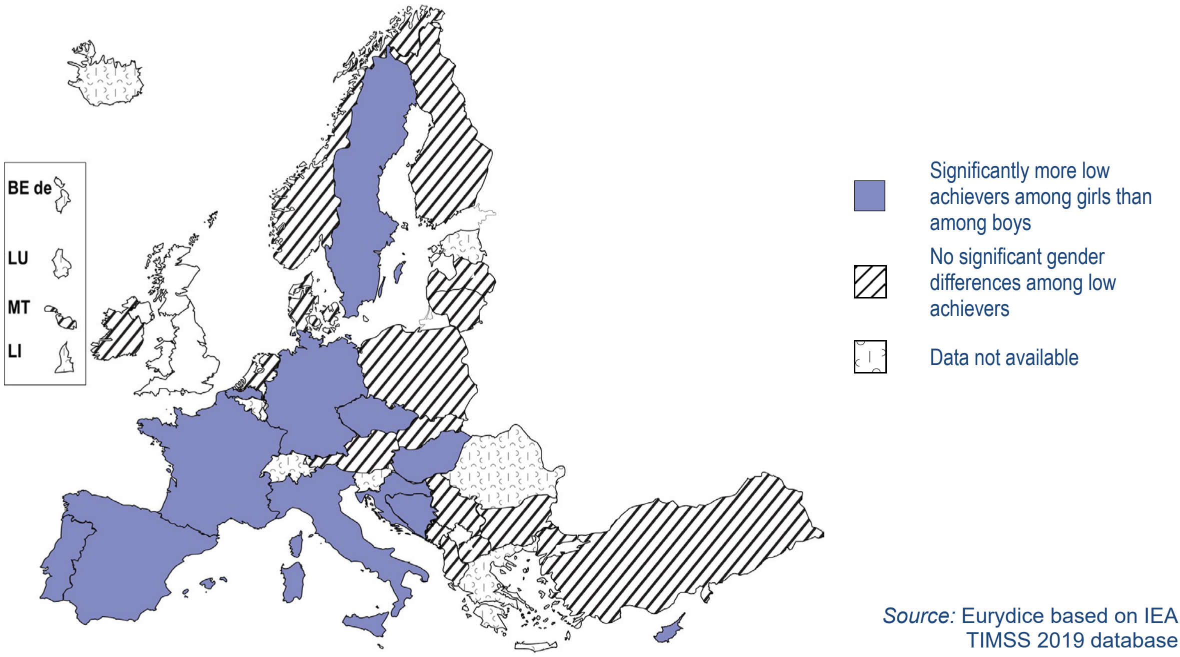
Thus, socioeconomic background influences the chances of becoming a low achiever across all education systems and subject areas. Nevertheless, differences between countries suggest that achievement gaps between students can be reduced by developing appropriate policies that decrease socioeconomic inequalities.

Gender

When it comes to mathematics and science education, gender differences are often highlighted, drawing attention to existing gender stereotypes related to science, technology, engineering and mathematics (STEM) subjects. However, the impact of gender on student achievement is less straightforward than that of socioeconomic status. While students from low socioeconomic backgrounds are clearly over-represented among low achievers in all education systems, there is no such overarching pattern in relation to the gender of students. Firstly, in most countries, gender differences in low achievement are not significant at all, especially in primary education. Secondly, gender patterns differ across educational levels. In primary education, girls struggle with basic mathematics more than boys, at least in some European countries with available data. Among 15-year-olds, boys do not grasp elementary science in more than half of European countries, and in a few countries this is also the case in mathematics.

Looking first at low achievers in primary education, data show virtually no gender differences in science achievement. The only education system with significant gender differences in this subject area is that of North Macedonia, where the percentage of low achievers is higher among boys than among girls in science (23). In contrast, in mathematics, as Figure 1.7 shows, achievement differences between boys and girls might require targeted policies in some European countries.

Figure 1.7: Gender differences in the percentage of low achievers among fourth grade students in mathematics, 2019



Source: Eurydice based on IEA, TIMSS 2019 database.

% of low achievers	BE nl	BG	CZ	DK	DE	IE	ES	FR	HR	IT	CY	LV	LT	HU	MT
Girls	22.0	29.4	23.5	25.6	26.5	17.2	37.4	45.8	32.6	29.4	26.3	16.0	19.3	28.3	32.0
Boys	17.6	28.9	19.8	24.5	21.6	15.6	31.9	40.7	27.3	24.7	19.6	14.9	18.1	24.5	29.9
Percentage point difference	4.3 (*)	0.5	3.8 (*)	1.1	4.8 (*)	1.6	5.5 (*)	5.2 (*)	5.3 (*)	4.8 (*)	6.7 (*)	1.1	1.2	3.8 (*)	2.0

	NL	AT	PL	PT	SK	FI	SE		AL	BA	ME	MK	NO	RS	TR
Girls	16.9	16.8	27.5	29.4	30.7	22.1	27.3		39.5	63.5	58.2	46.9	17.4	31.0	29.6
Boys	14.7	16.1	26.2	23.1	27.0	21.7	23.6		37.1	57.4	55.7	49.7	17.6	33.0	29.4
Percentage point difference	2.2	0.7	1.3	6.3 (*)	3.7	0.4	3.7 (*)		2.3	6.1 (*)	2.8	-2.7	-0.1	-2.0	0.3

Explanatory note

Statistically significant differences ($p < 0.05$) are marked with a (*). Percentage point differences were calculated before rounding. Standard errors are available in Annex III.

As the figure reveals, gender differences are not significant in the majority of education systems with available data. However, in 12 education systems (24), these differences are significant and they point in the same direction: there is a higher share of low achievers among girls than among boys, with differences of between 3 and 7 percentage points. This might suggest that girls can have a slight disadvantage in mathematics in primary education (25). Interestingly, when looking back at Figure 1.1, it becomes clear that almost all education systems with significant gender differences also have

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(23) In North Macedonia, the percentage of low achievers is 62.2% among girls and 69.1% among boys. For data on other education systems, please consult the statistical annex (Annex III, Table 1.7).

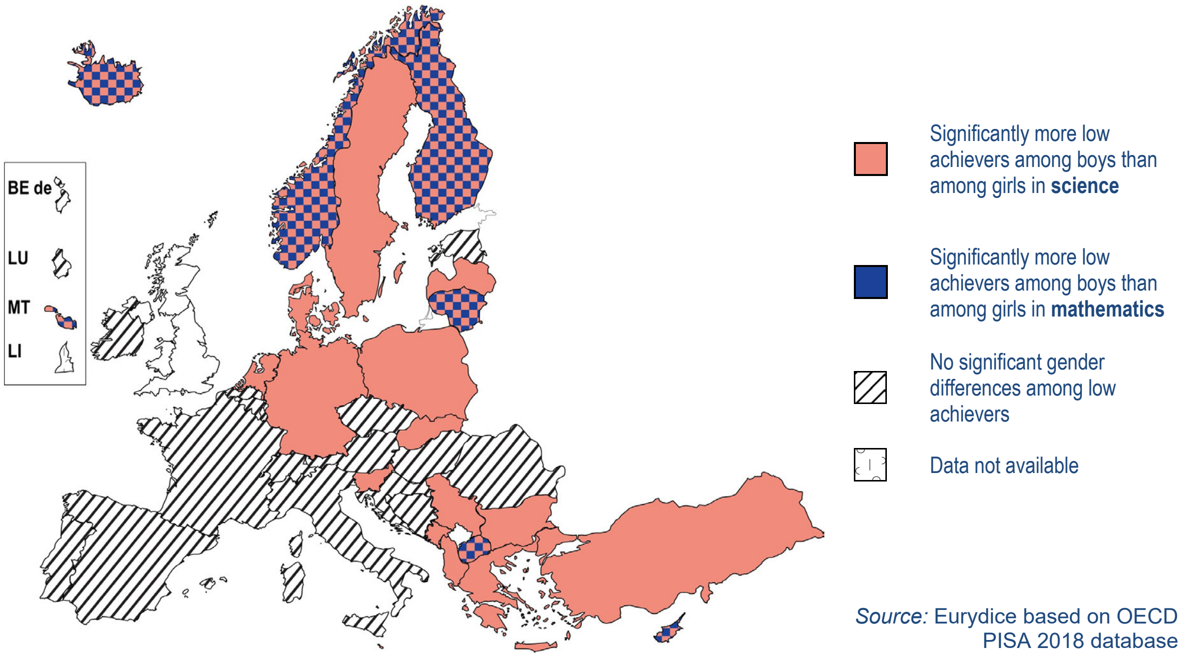
(24) These are Belgium (Flemish Community), Czechia, Germany, Spain, France, Croatia, Italy, Cyprus, Hungary, Portugal, Sweden, and Bosnia and Herzegovina.

(25) While this report does not address the issue of high achievement, the share of high achievers is smaller among girls than among boys in the majority of countries with available data (source: IEA, TIMSS 2019 database).

relatively high overall levels of low achievement, above 20% (the only exception is Belgium (Flemish Community)).

However, this slight female disadvantage concerning low achievement in mathematics completely disappears in secondary education. As Figure 1.8 illustrates, among 15-year-olds, percentages of low achievers in mathematics are largely similar among girls and boys, with significant differences between the genders in only seven education systems: those of Cyprus, Lithuania, Malta, Finland, Iceland, North Macedonia and Norway. Moreover, in these seven systems, the percentage of low achievers is higher among boys than among girls, with differences of between 3 and 8 percentage points.

Figure 1.8: Gender differences in the percentage of low achievers among 15-year-old students in mathematics and science, 2018



Source: Eurydice based on OECD, PISA 2018 database.

		BE fr	BE de	BE nl	BG	CZ	DK	DE	EE	IE	EL	ES	FR	HR	IT	CY	LV	LT	LU	HU
Maths	Girls	23.8	15.6	19.0	43.6	20.0	14.3	21.0	10.3	15.7	34.6	24.8	21.3	31.9	25.1	33.8	17.4	23.8	28.2	26.5
	Boys	21.8	14.6	15.7	45.2	20.8	14.9	21.2	10.1	15.7	37.0	24.6	21.2	30.4	22.6	39.8	17.3	27.4	26.3	24.8
	Difference	2.0	1.0	3.2	-1.6	-0.9	-0.6	-0.2	0.2	0.0	-2.4	0.3	0.1	1.4	2.4	-6.0 (*)	0.1	-3.6 (*)	1.9	1.7
Science	Girls	22.6	18.3	18.3	42.4	18.1	17.1	18.2	8.0	16.0	28.5	20.8	19.4	24.0	25.9	33.5	16.0	19.7	25.7	24.6
	Boys	22.6	21.8	17.8	50.2	19.4	20.2	20.8	9.5	18.1	34.9	21.8	21.6	26.8	25.8	44.2	21.1	24.6	27.8	23.6
	Difference	0.1	-3.5	0.6	-7.8 (*)	-1.2	-3.1 (*)	-2.6 (*)	-1.5	-2.1	-6.3 (*)	-1.0	-2.1	-2.8	0.1	-10.7 (*)	-5.1 (*)	-5.0 (*)	-2.2	1.0
		MT	**NL**	**AT**	**PL**	**PT**	**RO**	**SI**	**SK**	**FI**	**SE**	**AL**	**BA**	**CH**	**IS**	**ME**	**MK**	**NO**	**RS**	**TR**
Maths	Girls	26.0	15.1	21.7	14.1	23.2	47.1	15.8	24.8	13.1	18.1	40.6	57.4	17.5	18.0	47.9	59.2	16.6	39.3	37.6
	Boys	34.2	16.4	20.5	15.4	23.3	46.0	17.0	25.4	16.8	19.5	44.1	57.7	16.3	23.4	44.6	62.7	21.1	40.2	35.7
	Difference	-8.8 (*)	-1.3	1.2	-1.3	-0.1	1.1	-1.2	-0.6	-3.8 (*)	-1.4	-3.5	-0.3	1.2	-5.4 (*)	3.3	-3.6 (*)	-4.5 (*)	-0.9	1.9
Science	Girls	28.2	18.5	20.6	12.7	19.0	43.1	12.3	27.5	8.9	17.3	41.6	56.1	19.2	22.2	46.6	45.0	17.9	36.5	22.9
	Boys	38.4	21.6	23.1	15.0	20.1	44.8	16.7	31.1	16.7	20.8	52.2	57.4	21.1	27.8	49.7	53.5	23.7	40.1	27.4
	Difference	-10.2 (*)	-3.2 (*)	-2.5	-2.2 (*)	-1.0	-1.7	-4.4 (*)	-3.5 (*)	-7.7 (*)	-3.5 (*)	-10.7 (*)	-1.3	-1.9	-5.6 (*)	-3.0 (*)	-8.6 (*)	-5.8 (*)	-3.7 (*)	-4.6 (*)

Explanatory note

The table includes only countries with available data (in protocol order). Statistically significant differences ($p < 0.05$) are marked with a (*). Percentage point differences were calculated before rounding. Standard errors are available in Annex III.

This female advantage is even stronger in science, where gender differences in the shares of low achievers are significant in the majority of education systems covered in this report. The share of low achievers in science among 15-year-old boys is 2–11 percentage points higher than among 15-year-old girls in 21 education systems, with differences of over 10 percentage points in Cyprus, Malta and Albania (26).

Interestingly – although certainly not without exceptions – education systems with a slight female disadvantage in mathematics in primary education tend to have non-significant gender differences in secondary education, while the gender disparity with a male disadvantage tends to appear in education systems with no significant gender differences in primary education. Nevertheless, as the report will show, education systems do not act upon this male disadvantage when designing targeted policies for low achievers in mathematics or science.

Summary

This chapter analysed the percentage of low achievers in mathematics and science in European education systems, linking such percentages to quality and inclusion in education. As the chapter showed, only a handful of European countries have managed to reach the European target of having no more than 15% of 15-year-old students underachieving in the different subject areas representing basic skills. Most European education systems still need to find ways to lower the proportion of students who are not able to solve more complex mathematical or scientific problems.

Percentages of low achievers tend to correlate across subject areas and education levels. Thus, within an education system, they are likely to be at similar levels in mathematics and science, as well as in primary and secondary education. The analysis has shown that education systems with relatively low percentages of underachieving students tend to combine quality and inclusion in education: they have higher average scores and smaller differences between the high- and low-achieving students.

At the same time, there are consistent differences in the likelihood of becoming a low achiever between students from more or less affluent families in all education systems. Differences between the percentages of low achievers among students from higher and lower socioeconomic backgrounds are significant everywhere, with students from low socioeconomic backgrounds being over-represented among low achievers. Nevertheless, the gaps between the two groups differ across education systems, which demonstrates that the impact of socioeconomic background on achievement can potentially be reduced if appropriate policies and structures are put in place.

The impact of gender on student achievement is less straightforward than that of socioeconomic status. In most countries, gender differences in low achievement are not significant at all, especially in primary education. Furthermore, gender patterns differ across educational levels. In primary education, girls struggle with basic mathematics more than boys, at least in some of the European countries with available data. Among 15-year-olds, boys are more likely to become low achievers in science in the majority of education systems, and in a few countries this is also the case in mathematics.

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(26) Although this report does not address the issue of high achievement, it has to be noted that, while boys are the majority of low achievers in the PISA survey, they form the majority of high achievers as well. In mathematics and to a lesser extent in science, the percentage of high achievers – students scoring higher than level 5 in PISA – is larger among boys than among girls in the majority of education systems (source: OECD, PISA 2018 database).

CHAPTER 2: TEACHING AND LEARNING IN THE CONTEXT OF THE COVID-19 PANDEMIC

The daily reality of schools across Europe was strongly affected in 2020 and 2021 by the COVID-19 pandemic, which led to school closures in many countries and periods of distance or blended learning (combining online and classroom-based learning) for many students. Many schools were ill-prepared for this unprecedented situation. They did not know which technologies and methodologies were the most appropriate for teaching, in terms of effectiveness, security and accessibility (Cachia et al., 2021). Teachers had to rapidly adapt to new modes of delivery of teaching, in which they had not necessarily been trained; and students had to rely initially on their own resources to continue learning remotely using textbooks, the internet, television, etc. (Schleicher, 2020).

Some students who had a supportive home environment, characterised by, for example, a high level of support from parents, a quiet space to study and the necessary digital devices, reported learning gains in some areas, such as in the use of technologies and in transversal skills such as creativity, problem-solving and communication (Cachia et al., 2021). However, a number of reports and studies point to the lack of effective formal teaching during this time and the resulting learning losses (Cerna, Rutigliano and Mezzanotte, 2020; Di Pietro, Biagi and Costa, 2020; Hanushek and Wößmann, 2020; Wößmann et al., 2020). For example, a study on schools in the Flemish Community of Belgium over a period of 6 years (2015–2020) found a significant learning loss for students in the 2020 cohort. The study suggests that school closures led to a decrease in average scores in mathematics and Dutch compared with the previous cohort (Maldonado and De Witte, 2022).

Moreover, the pandemic was found to have exacerbated existing educational inequalities. Students with low educational attainment, those from disadvantaged backgrounds, those who did not have access to digital learning resources and those with learning difficulties or lacking the resilience to learn on their own, faced substantially more obstacles in the context of distance learning (Cachia et al., 2021). Studies have highlighted the detrimental effect that school closures and distance learning have had on these students, including in mathematics (Engzell, Frey and Verhagen, 2021; Grewenig, Lergetporer, Werner, et al., 2021; Hanushek and Wößmann, 2020).

This evidence of negative effects prompted the European Commission to table a proposal for a Council Recommendation on blended learning for high-quality and inclusive primary and secondary education, adopted by the Council in November 2021 (27). The Council Recommendation forms part of the response to lessons learned from the COVID-19 pandemic, which highlighted many pre-existing challenges and inequalities. It recommends short-term measures to address the most pressing gaps observed so far and outlines a way forward in terms of blending learning environments and tools that can help build more resilient primary and secondary education and training systems.

This chapter highlights some general aspects related to the impact of the COVID-19 pandemic on schools during the 2020/2021 school year (the reference year of this report), before the next chapter returns to the analysis of mathematics and science education. The first section presents the organisation of school education during this school year (i.e. it looks at when schools were open, closed or provided distance and/or blended learning). It then outlines the variation in the digital preparedness of schools before the pandemic in Europe. Finally, the main actions taken by top-level education authorities to support the digital capacities of schools and teachers are described. These actions include providing recommendations/guidelines on digital education, supporting continuing

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(27) Council Recommendation of 29 November 2021 on blended learning approaches for high-quality and inclusive primary and secondary education 2021/C 504/03. OJ C 504, 14.12.2021, p. 21–29.

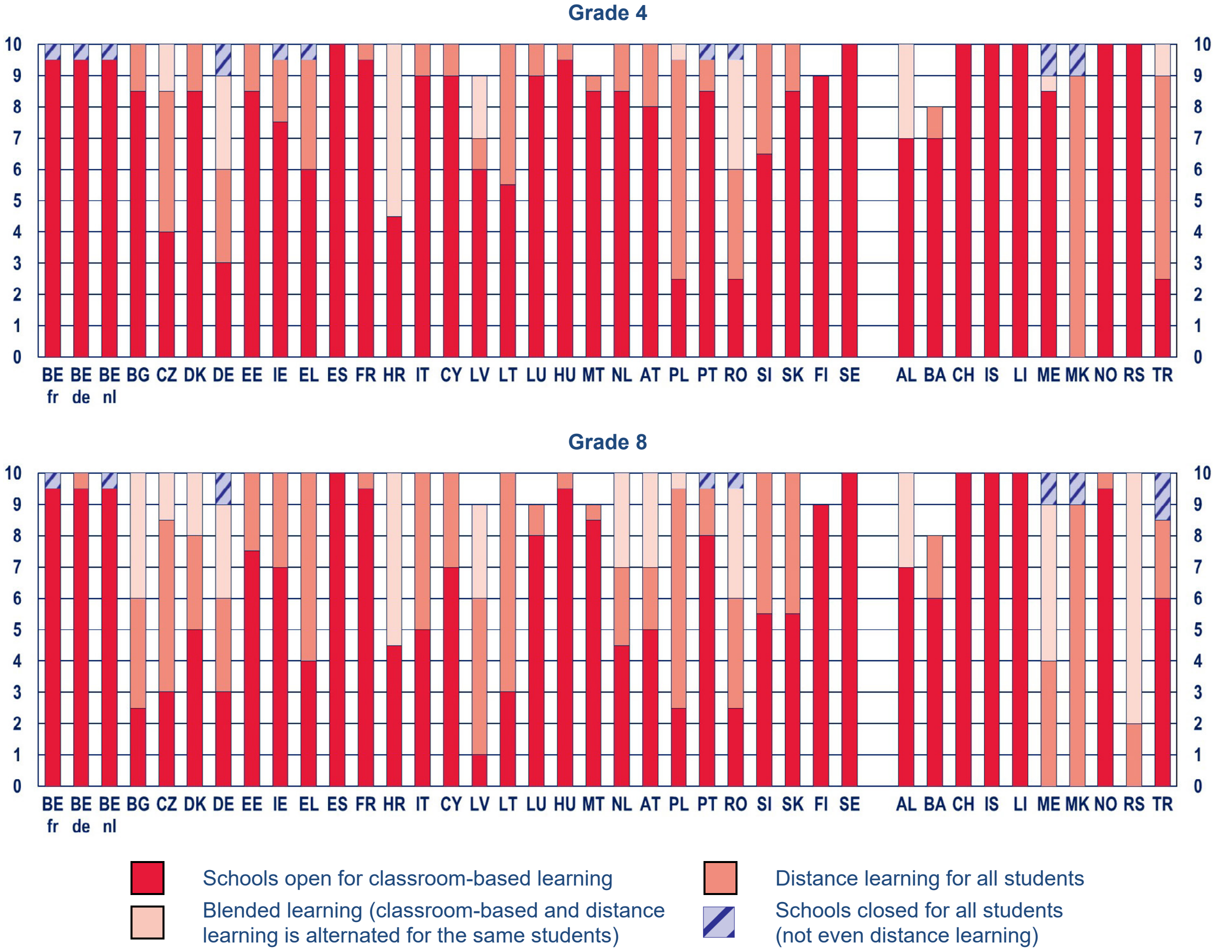
professional development (CPD) for teachers and providing additional funding where digital infrastructure, connectivity or devices were lacking.

In addition to these general aspects, the pandemic had effects on some specific elements of school education that relate to mathematics and science teaching, which will be discussed in the following chapters. Chapter 4 discusses the changes to certified examinations and national tests in mathematics and science in 2020/2021. Adjustments to the provision of learning support in mathematics and science are presented in Chapter 6.

2.1. The organisation of school education during 2020/2021

In order to understand the extent of school closures and their potential impact on teaching and learning in schools, including in mathematics and science, this section investigates the organisation of schooling during 2020/2021. Figure 2.1 presents the number of months – between September 2020 and June 2021 (i.e. 10 calendar months) – during which European education systems kept schools open or closed – with or without the possibility of distance learning – or offered the option of blended learning (see Annex II, Figure 2.1A, for further information per country). Distance learning means that teaching and learning occur entirely remotely (from home), whereas blended learning combines online learning opportunities with traditional classroom-based methods.

Figure 2.1: Duration in months of different forms of school organisation in the context of the COVID-19 pandemic, grades 4 and 8, 2020/2021



Source: Eurydice.

Explanatory notes

The figure presents the number of months during which European education systems applied the indicated forms of school organisation during the 2020/2021 school year (except July and August, i.e. the main summer holiday months). See Annex II, Figure 2.1A, for a breakdown by calendar month and for further country-specific information.

The figure shows that, in Europe, schools remained largely open during the 2020/2021 school year. However, only Spain, Finland, Switzerland, Iceland and Liechtenstein kept schools open for classroom-based learning for all grade 4 and grade 8 students throughout the entire year. In Sweden, schools were as well kept open, but school organisers were given permission to switch to blended or distance learning in some cases. In most other education systems, schools had to adapt their usual teaching and learning practices by switching to distance learning and/or blended learning for some of the school year. Complete school closures due to the pandemic were rather rare and of relatively short duration. Variations between countries in the total duration of the school year are mainly due to longer school holidays during the school year or the summer holidays starting already in June.

Distance learning was the second most common form of school organisation. It was used in grade 4 and/or grade 8 for a duration of less than a month in France, Hungary and Malta, and for 5 months or more in Czechia, Greece, Italy, Lithuania, Poland, North Macedonia and Turkey. This mode of learning from home was used in slightly more education systems and for slightly longer for grade 8 students than for grade 4 students. This raises concerns about the older students' school careers, social development, and mental health and well-being (Viner, Russel, Saulle, et al., 2022).

Around one third of the education systems opted for blended learning as the dominant form of school provision, either instead of or in addition to a period of distance learning for all students. This applied in grade 4 and/or grade 8 for less than a month in Poland and Montenegro, and for more than 5 months in Croatia and Serbia. Overall, like distance learning, blended learning was implemented in more European education systems and for longer periods in grade 8 than in grade 4.

Finally, schools were rarely entirely closed (i.e. without the provision of even distance learning). Complete closure occurred only in Belgium, Germany, Ireland, Greece, Portugal, Romania, Montenegro, North Macedonia and Turkey. However, the closures generally lasted for a short period (1–2 weeks), and they mainly took place immediately before or after school holidays.

2.2. Digital preparedness of primary schools before the COVID-19 pandemic

Numerous European policy initiatives have been encouraging schools and teachers to take advantage of digital technologies for school management as well as for teaching practices (28). The Trends in International Mathematics and Science Study (TIMSS) administered by the International Association for the Evaluation of Educational Achievement (IEA) provides some information on school digitalisation levels just before the COVID-19 pandemic (in 2019). Two aspects are worth highlighting: firstly, the extent to which schools were already implementing online learning management systems and, secondly, the availability of computers for student use in schools. Although both reflect levels of school digitalisation, the use of online learning systems relates more to teacher familiarity with or acceptance of technology (Dindar et al., 2021), whereas the student–computer ratio may indicate the extent of the digital infrastructure available to students.

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(28) See, for example, Recommendation of the European Parliament and of the Council of 18 December 2006 on key competences for lifelong learning, OJ L 394, 30.12.2006, p. 10; Council Recommendation of 22 May 2018 on key competences for lifelong learning, OJ C 189, 4.6.2018, p. 1; and Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the digital education action plan, COM(2018) 22 final.

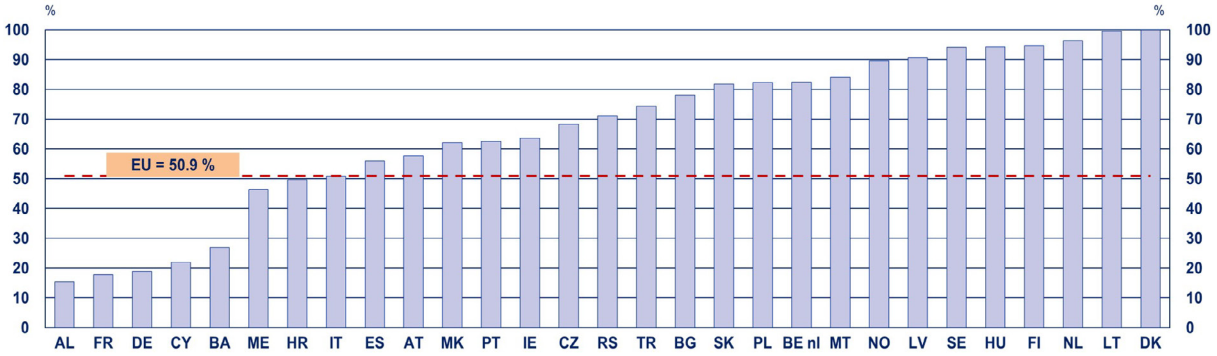
TIMSS data reveal that, in 2019, approximately half of grade 4 students in participating European countries attended schools that used an online learning management system to support learning (see Figure 2.2). The availability of such systems in schools does not necessarily imply that teachers and students were engaging in distance education before the pandemic. It is more likely that the systems were used for the digital management of grades, student access to course materials, teacher–student communication, etc. The availability of an online learning management system can serve as an indication of school digital competence (Pettersson, 2018). Such competence facilitates acceptance of digital technologies and their integration into school processes (Blau and Shamir-Inbal, 2017; Dindar et al., 2021).

At least 90% of students attended schools with an online learning management system in Latvia, Sweden, Hungary, Finland, the Netherlands, Lithuania and Denmark. In these countries, schools may have been better prepared for the sudden switch to distance teaching and learning. For example,

> According to evaluations (29), schools in **Finland** were able to use the digital infrastructure that existed before the COVID-19 pandemic, as well as digital tools and learning environments, reasonably well. Two factors proved particularly important. Firstly, since 2016, the government had been funding a network of tutor teachers, which proved essential for teachers' preparedness for distance teaching during the pandemic. Secondly, since 2015, national authorities have been supporting the 'computers for everyone' initiative, which collects donated used computers and supplies them to schoolchildren and students (30).

In contrast, the proportions of students attending schools with an online learning management system were considerably lower in Albania, France, Germany, Cyprus, and Bosnia and Herzegovina. In these countries, before the COVID-19 pandemic, only 15–30% of grade 4 students were enrolled in schools that used an online management system to support learning.

Figure 2.2: Percentage of fourth graders whose school used an online learning management system to support learning before the COVID-19 pandemic, 2019



EU	AL	FR	DE	CY	BA	ME	HR	IT	ES	AT	MK	PT	IE	CZ
50.9	15.3	17.7	18.9	21.9	26.9	46.4	49.6	50.7	56.0	57.6	62.1	62.5	63.6	68.3
RS	**TR**	**BG**	**SK**	**PL**	**BE nl**	**MT**	**NO**	**LV**	**SE**	**HU**	**FI**	**NL**	**LT**	**DK**
71.1	74.4	78.1	81.8	82.3	82.4	84.0	89.6	90.8	94.2	94.3	94.6	96.4	99.5	100.0

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

Explanatory notes

Education systems are depicted in ascending order.

The proportion is calculated based on school principals answering 'yes' to question 9 (ACBG09) of the TIMSS survey 'Does your school use an online learning management system to support learning (e.g., teacher-student communication, management of grades, student access to course materials)?' 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.

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(29) Pennanen et al. (2021); Vuorio et al. (2021) (English abstract on p. 9). See also a factsheet from the Finnish Board of Education and a case study by the Association of Finnish Municipalities.

(30) https://www.kaikillekone.fi/

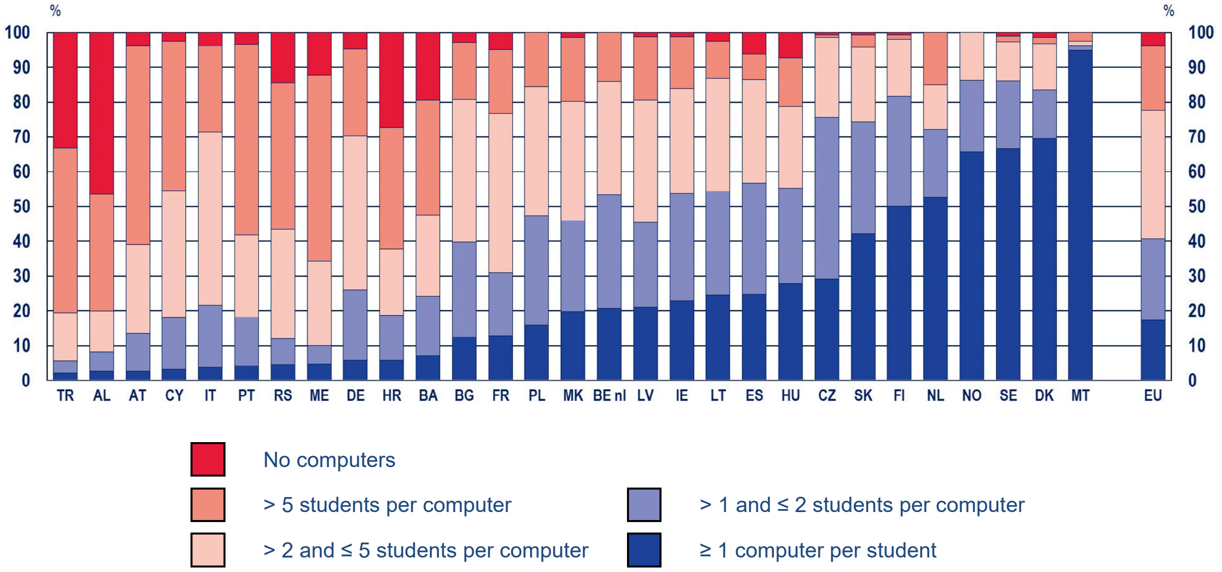
The availability of digital devices such as computers and tablets in schools provides some insight into student familiarity with digital learning environments. Figure 2.3 shows the distribution of fourth graders per computer in schools before the COVID-19 pandemic.

Before the pandemic, most schools in Europe had a certain number of digital devices available for use by fourth grade students. The most common situation, applying to 36.9% of students in the EU, was one computer being shared by more than two but fewer than five students. Moreover, 23.4% of students attended schools with one digital device available per more than one but fewer than two students. Such schools may have had some dedicated computer classrooms that were used by different classes for teaching certain subject areas. It is rather difficult to determine individual students' levels of familiarity with digital learning environments, but it is likely that many of them had some exposure to computers and the internet at school.

The survey data indicate that there was at least one digital device for every student for 17.3% of fourth grade students in the EU in 2019. These students may have had access to a computer or a laptop during any lesson, including in their own classroom. The best digitally equipped education system is in Malta, where at least one computer or tablet was available for 94.8% of students. In Denmark, Sweden and Norway, this was the case for 65–70% of fourth graders.

By contrast, very few students (fewer than 5%) had individual access to computers at school in Turkey, Albania, Austria, Cyprus, Italy, Portugal, Serbia and Montenegro. High proportions of students did not have any access to digital devices at school in Albania (46.5%), Turkey (33.3%) and Croatia (27.4%). Students and teachers in these schools may have experienced considerable challenges when the COVID-19 pandemic interrupted classroom-based learning.

Figure 2.3: Distribution of fourth graders per computer in schools before the COVID-19 pandemic, 2019



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

Data (Figure 2.3)

Ratio (students per computer)	EU	TR	AL	AT	CY	IT	PT	RS	ME	DE	HR	BA	BG	FR	PL
≤ 1	17.3	2.1	2.6	2.7	3.2	3.6	4.2	4.6	4.7	5.7	5.7	7.2	12.5	12.8	15.9
> 1 and ≤ 2	23.4	3.5	5.6	10.8	14.9	18.1	13.9	7.4	5.3	20.2	13.0	17.0	27.3	18.1	31.3
> 2 and ≤ 5	36.9	13.8	11.6	25.5	36.5	49.7	23.7	31.5	24.2	44.2	19.1	23.3	40.9	45.9	37.2
> 5	18.5	47.3	33.7	57.2	42.8	24.7	54.7	42.0	53.4	25.0	34.8	33.0	16.4	18.2	15.6
No computers	3.8	33.3	46.5	3.8	2.6	3.9	3.5	14.5	12.4	4.9	27.4	19.5	2.9	5.1	0.0
	MK	**BE nl**	**LV**	**IE**	**LT**	**ES**	**HU**	**CZ**	**SK**	**FI**	**NL**	**NO**	**SE**	**DK**	**MT**
≤ 1	19.7	20.6	21.1	22.8	24.6	24.7	27.9	29.0	42.0	50.0	52.5	65.7	66.5	69.5	94.8
> 1 and ≤ 2	26.3	32.7	24.3	30.8	29.7	31.9	27.3	46.5	32.3	31.6	19.5	20.5	19.5	13.9	1.5
> 2 and ≤ 5	34.3	32.5	35.2	30.1	32.4	29.8	23.5	22.9	21.3	16.4	12.8	13.8	11.2	13.4	1.1
> 5	18.2	14.2	18.2	14.9	10.8	7.4	13.9	1.0	3.6	1.3	15.2	0.0	1.6	1.7	2.6
No computers	1.6	0.0	1.3	1.4	2.5	6.2	7.5	0.6	0.7	0.8	0.0	0.0	1.2	1.5	0.0

Explanatory notes

Education systems are depicted in ascending order based on percentage of students who have at least one computer available at school.

The calculations are based on two questions from the TIMSS school questionnaire. The response to question 2 (ACBG02) – ‘What is the total enrolment of fourth grade students in your school?’ – was divided by the response to question 7 (ACBG07) – ‘How many computers (including tablets) does your school have for use by fourth grade students?’ When question 7 indicated 0 (‘no computers’), the ratio was not calculated. In such cases the table shows the proportion of grade 4 students attending schools with no computers. 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.

2.3. Top-level digital responses to the COVID-19 pandemic

As per the previous section, and according to a number of research reports (Cachia et al., 2021; Graaf et al., 2021; Zancajo, Verger and Bolea, 2022), there was considerable variation in digital skills, equipment and learning resources among schools in European countries at the start of the COVID-19 pandemic. In many places, the sudden shift to distance learning served as an important push towards digital acceleration in education. Some countries took the opportunity to advance already planned reforms, and others started to revise curricula and teaching plans in order to strengthen the digital aspects of the syllabus.

> In **Belgium (Flemish Community)**, the *digisprong* plan builds on the immediate response to the COVID-19 crisis. A relaunch fund of EUR 375 million was awarded for ICT support for schools in 2021 (compared with annual ICT investment of EUR 32 million in 2019). The plan aims to create a future-oriented and secure ICT infrastructure for all compulsory education schools; a strongly supportive and effective ICT school policy; ICT-competent teachers and teacher trainers; and adapted digital learning resources. Investments are being made in the necessary framework for schools, including strengthening the role of ICT coordinators, developing digital services, and establishing a knowledge and advice centre for schools. The plan also includes various actions to provide high-quality digital teaching materials, with attention paid to cybersecurity and tackling cyberbullying (31).

Figure 2.4 reveals that education systems across Europe tackled the challenges presented by the COVID-19 pandemic with new guidance, teacher training and allocation of additional funding. Numerous training courses and guidance materials regarding how to organise distance teaching and learning were provided. Many additional resources were directed at schools, teachers and students to ensure the necessary digital infrastructure, connectivity and digital devices existed, as well as to enhance teachers’ digital skills and competences. Only six European education systems have seen no changes to top-level recommendations, continuing professional development (CPD) or funding concerning digital resources in primary or lower secondary schools since the start of the COVID-19 pandemic.

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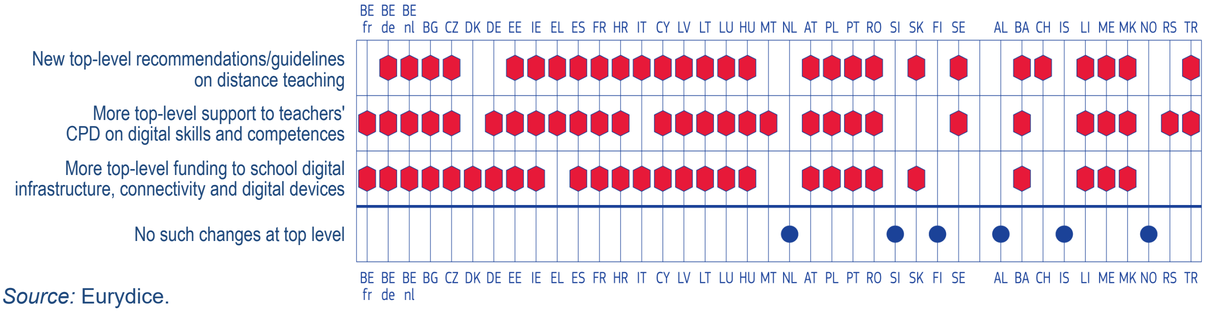
(31) https://onderwijs.vlaanderen.be/nl/directies-en-administraties/organisatie-en-beheer/ict/digisprong

Figure 2.4: Top-level changes in recommendations, continuing professional development (CPD) and funding concerning distance teaching and learning since the start of the COVID-19 pandemic, ISCED 1-2, 2020/2021



	BE fr	BE de	BE nl	BG	CZ	DK	DE	EE	IE	EL	ES	FR	HR	IT	CY	LV	LT	LU	HU
New top-level recommendations/guidelines on distance teaching		⬢	⬢	⬢	⬢			⬢	⬢	⬢	⬢	⬢	⬢	⬢	⬢	⬢	⬢	⬢	⬢
More top-level support to teachers' CPD on digital skills and competences	⬢	⬢	⬢	⬢	⬢		⬢	⬢	⬢	⬢	⬢	⬢	⬢		⬢	⬢	⬢	⬢	⬢
More top-level funding to school digital infrastructure, connectivity and digital devices	⬢	⬢	⬢	⬢	⬢	⬢	⬢	⬢	⬢		⬢	⬢	⬢	⬢	⬢	⬢	⬢	⬢	⬢
No such changes at top level																			

	MT	NL	AT	PL	PT	RO	SI	SK	FI	SE	AL	BA	CH	IS	LI	ME	MK	NO	RS	TR
New top-level recommendations/guidelines on distance teaching			⬢	⬢	⬢	⬢		⬢		⬢		⬢	⬢		⬢	⬢	⬢			⬢
More top-level support to teachers' CPD on digital skills and competences	⬢		⬢	⬢	⬢	⬢				⬢		⬢			⬢	⬢	⬢		⬢	⬢
More top-level funding to school digital infrastructure, connectivity and digital devices			⬢	⬢	⬢	⬢		⬢				⬢			⬢	⬢	⬢			
No such changes at top level		●					●		●		●			●				●		

Source: Eurydice.

New guidelines or recommendations on how to organise distance teaching and learning were issued in 29 of the 39 education systems analysed. In most of these cases, the country's ministry of education launched a dedicated website for all information related to COVID-19 measures in schools, provided recommendations on delivering education remotely and provided numerous digital learning resources. A few countries (e.g. Portugal and Montenegro) also sent printed recommendations on the implementation of distance teaching to all schools.

> In **Czechia**, several new methodological recommendations for different school types and education levels have been issued: 'methodical recommendations for distance learning' (32), 'recommendations for distance learning and mental health' (33), and pedagogical recommendations for the return of pupils to schools' (34). These recommendations focus predominantly on the procedures for adapting teaching to the needs of pupils, methods to help pupils who did not participate in distance learning and rules for evaluation.
>
> The **Lithuanian** National Agency for Education issued a detailed 'distance learning and teaching manual', which summarises recommendations and methodological suggestions to prepare schools for possible new outbreaks of COVID-19, application of blended/distance learning in the future, as well as new teaching methods and their proper implementation (35).
>
> The website of the **Hungarian** Educational Authority published recommendations on a number of digital teaching methods (36).
>
> The **Austrian** Federal Ministry of Education, Science and Research created a dedicated platform 'distance learning – all information for teachers, students and parents' and the 'digital school' portal to simplify communication between teachers, learners and parents (37).
>
> In March 2020, the **Polish** Ministry of Education and Science launched an education portal that contains various digital teaching materials and tools, a guide for schools on how to secure personal data during distance learning and a guidebook for headteachers and teachers on how to act in the context of temporary limitations on the operation of education system units (38).
>
> **Portugal** created the 'support to schools' website in 2020. It provides a comprehensive set of resources to support learning and school management, in order to enrich and enhance the teaching and learning process during this challenging time. It includes guiding principles for the implementation of distance learning in schools; guidelines on the use of technologies to support distance learning; guidelines on the work of ICT resource centres (focusing on the evaluation and prescription process); and guiding principles on pedagogical assessment in distance learning (39).
>
> The **Romanian** Ministry of National Education launched an information portal (40) that includes methodological guidelines for all levels of education.

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(32) https://www.edu.cz/wp-content/...
(33) https://www.edu.cz/methodology/...
(34) https://www.edu.cz/methodology/...
(35) https://www.emokykla.lt/...
(36) https://tudasbazis.ekreta.hu/...; https://moodle.up2u.kifu.hu/; https://www.oktatas.hu/kozneveles/...; https://www.oktatas.hu/pub_bin/...
(37) https://www.bmbwf.gv.at/Themen/schule/beratung/corona/corona_fl.html
(38) https://www.gov.pl/web/zdalnelekcje; https://www.gov.pl/web/edukacja-i-nauka/zdalne-nauczanie-uodo; https://www.gov.pl/web/edukacja-i-nauka/informator-dla-dyrektorow-szkol-i-nauczycieli
(39) https://apoioescolas.dge.mec.pt/
(40) https://educatiacontinua.edu.ro/

Digital competences were already part of the initial education and CPD of teachers in many European countries (European Commission / EACEA / Eurydice, 2019). However, the need for training in the use of an online learning environment, distance teaching tools, digital learning materials and remote assessment methods increased when schools were not able to provide classroom-based learning due to the COVID-19 pandemic. The majority of European education systems systems (29 out of 39) reported allocating more top-level support to address the deficit in teachers' digital skills and competences.

In **Czechia**, several webinars, newsletters, websites and videos on how to use digital learning resources were provided for teachers (41).

In **Estonia**, thematic online seminars were organised for teachers (42).

In **Spain**, in the call for network training courses for teachers for 2020/2021, specific courses related to distance teaching were included, for example distance teaching, design of learning experiences for distance education, evaluation of learning in distance education mode and the online tutor (43).

In **Poland**, a number of training courses aiming to improve teachers' distance teaching skills were continued or launched (44).

Top-level authorities in 27 European countries provided additional funding to acquire the lacking digital infrastructure, connectivity and digital devices for schools, teachers and students. This funding was to be used for connectivity, computers, tablets, accessories (docking stations, microphones, cameras, etc.), software, platforms and other related equipment or services. Several countries released additional funds for vulnerable students.

The **Greek** Ministry of Education provided a voucher worth EUR 200 per pupil/student from families that fulfilled certain financial criteria for the purchase of an electronic device for the pupils/students (tablet, laptop or desktop computer). This applied to 560 000 people aged 4–24 years.

Since the first quarter of the 2020/2021 school year, schools in **Spain** have lent up to 500 000 electronic devices with internet connection to the most vulnerable students to enable distance learning. This was financed by the central government through a EUR 16 000 million COVID-19 fund for the autonomous communities (45).

In **Italy**, urgent measures linked to the COVID-19 pandemic included additional financing of EUR 85 million aimed at the 'purchase of devices and individual digital tools for the use of integrated digital teaching activities, to be granted to less well-off students, also in compliance with the criteria of accessibility for people with disabilities, as well as for the use of digital platforms for distance learning and for the necessary network connectivity' (46).

To ensure that all students have the digital infrastructure necessary for distance learning, the Federal Ministry of Education, Science and Research in **Austria** procures notebook computers and tablets to be loaned, for a limited period, to secondary school students on the basis of need. The initiative is being implemented in ongoing close coordination with and with the support of the education directorates and school authorities (47).

In **Poland**, in April 2020, the Ministry of Education and Science launched a call for local governments to purchase ICT equipment needed by schools, teachers and students for the purpose of distance education. The remote school co-financing programme released PLN 150 million (approximately EUR 33 million) from the European Regional Development Fund under the digital Poland operational programme for 2014–2020. 90% of local governments applied for and received individual grants, ranging from PLN 35 000 to PLN 100 000 (approximately EUR 7 000 to EUR 22 000). The procedure was shortened and simplified, so that schools could quickly acquire the necessary equipment (48).

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(41) https://koronavirus.edu.cz
(42) https://www.harno.ee/oppetoo-kriisi-ajal#veebiseminarid
(43) https://www.boe.es/diario_boe/txt.php?id=BOE-B-2021-5947
(44) https://lekcjaenter.pl/; http://www.doskonaleniewsieci.pl.
(45) https://www.lamoncloa.gob.es/consejodeministros/resumenes/Paginas/2020/160620-cministros.aspx
(46) Art. 21 of Decree-Law 137/2020.
(47) https://www.bmbwf.gv.at/Themen/schule/beratung/corona/corona_fl/endgeraete.html
(48) https://www.gov.pl/web/cyfryzacja/zdalna-szkola–rekordowe-tempo; https://ose.gov.pl/aktualnosci/...

The analysis of digital responses to the COVID-19 pandemic indicates that most measures were general and not subject specific. New digital learning materials and television and radio programmes in mathematics and science were created, but no specific COVID-19-related guidance in these subject areas was reported.

Summary

This chapter provided a brief insight into the impact of the COVID-19 pandemic on the organisation of school education and some of the consequent policies and measures implemented by European education systems to strengthen digital teaching and learning.

Schools across Europe remained largely open during the 2020/2021 school year, although almost all education systems had to switch to distance learning and/or blended learning for some of the school year. Complete school closures were rather rare and of relatively short duration (generally immediately before or after school holidays). Both distance learning and blended learning were used more in grade 8 than in grade 4, leading to concerns about the older students' school careers and overall well-being.

Overall, the rapid shift to distance or blended learning revealed large differences in the levels of digitalisation between countries as well as between schools, teachers and learners. Survey data reveal that in 2019, most schools in Europe had a certain number of digital devices available. However, in the EU, 18.5% of grade 4 students were enrolled in schools where at least five students had to share one computer. In addition, 3.8% of students had no access to computers at school whatsoever. Before the pandemic, an online learning management system was used in approximately half of schools.

Top-level authorities in almost all European education systems responded with new measures to upgrade digital resources and address competence gaps. Guidelines for schools and teachers concerning distance teaching and learning were drafted and published on the websites of ministries of education or on dedicated information portals. Additional top-level support was allocated to address teacher-training deficits. Moreover, top-level authorities provided considerable public resources to strengthen the digital education infrastructure and schools' technological resourcing. Several countries reported targeted funding to provide digital devices to disadvantaged students.

It should be noted, however, that the changes presented here were not the only ones. In addition to these and other general adjustments made in response to the COVID-19 pandemic, many education systems decided to adapt certain aspects of teaching and learning that are directly related to mathematics and science teaching. Changes were made, for example, to certified examinations and national tests in these subjects and to the provision of learning support. These aspects will be addressed in later chapters of this report (Chapters 4 and 6 respectively).

CHAPTER 3: INSTRUCTION TIME

Learning requires time. Time is an essential aspect of the ‘Carroll model’ of school achievement (see Carroll, 1989), in which three of the five explanatory variables can be expressed in terms of time: (1) the time a student needs to accomplish a task or learning unit (aptitude), (2) the time that is provided for learning, by the school curriculum for instance (opportunity), and (3) the time a student is willing to spend on a task or learning unit (perseverance).

This chapter focuses on the time allocated by education authorities to teach mathematics and science. In other words, it concerns the ‘opportunity to learn’ – to use Carroll’s term – provided by education authorities. More precisely, it examines how much time schools are required to devote to teaching mathematics and science, as set by law (Phelps et al., 2012).

Although there is no doubt that time is important for learning, there is very little evidence on the optimal instruction time to be allocated to curriculum subjects in general and to mathematics and science in particular (Prendergast and O’Meara, 2016). Nonetheless, a few empirical studies have looked into the effect of instruction time for mathematics or science on students’ academic achievement. These studies can be categorised into three groups (Meyer and Klaveren, 2013).

The first group of studies relate instruction time differences to variations in student achievement. Lavy (2015), for example, using Programme for International Student Assessment (PISA) 2006 data, shows that instruction time has a positive and significant relationship with students’ academic achievement. The same study also reveals that the effect of instruction time is larger for girls, students with a migrant background and students from a low socioeconomic background. Further analyses indicate that the productivity of instruction time is higher in schools operating under accountability measures and in schools with autonomy in budgetary decisions and the recruitment/dismissal of teachers (Lavy, 2015).

The second group comprises studies that take advantage of policy changes to conduct comparative analysis. Jensen’s (2013) empirical research carried out in Denmark analyses the effect of increased instruction time in reading and mathematics on student achievement in these subjects following a policy reform in 2003. The findings show that the increase in instruction time had a positive effect on student achievement in mathematics, but not in reading. To explain this result, Jensen suggests that, as opposed to reading, educational exercises in mathematics mostly take place in school, which makes students’ academic achievement in this subject more sensitive to variations in instruction time (Jensen, 2013).

The last empirical research group contains studies that evaluate the effect of specific education programmes that increase instruction time (e.g. extended-day or extended-year programmes). The study by Battistin and Meroni (2016) investigates the short-term effects of a large-scale intervention, which provided additional instruction time in mathematics and Italian language to non-randomly selected classes in particularly low-achieving lower secondary schools in southern Italy. The study came to similar conclusions to Jensen’s (2013): this intervention had positive effects on average test scores in mathematics, but not in reading literacy. The findings suggest that additional instruction time helps students increase their basic knowledge, which they can use more successfully in normal teaching hours.

Conversely, Meyer and Klaveren (2013) found that an extended-day programme applied in seven Dutch elementary schools for 3 months had no significant effect on student achievement in either mathematics or reading. They hypothesise that the short duration of the programme could partly explain its ineffectiveness. They also stress the importance of appropriate educational practices for the success of such educational interventions. However, before drawing any definite conclusions, Mayer and Klaveren (2013) suggest that such extended-day / extended-year programmes should be implemented in different educational contexts and carefully evaluated.

Overall, research evidence seems to point to the positive effect of increased instruction time, particularly in mathematics. However, the significance of such an outcome must be carefully weighed against the limited number of research studies, especially those investigating science. Furthermore, instruction time alone cannot account for students' academic achievement. As highlighted by Carroll (1989, p. 27), quoting Gage (1978), 'time is, in a sense, a psychologically empty concept'. What matters is what happens during the lessons. Scholars investigating the relationships between instruction time and students' academic achievement emphasise the quality of teaching as a key factor in students' successful learning (Lavy, 2015; Meyer and Klaveren, 2013; Phelps et al., 2012). In other words, as stated by Prendergast and O'Meara (2016, p. 15), 'adding hours to the school day or days to the school year could have limited return if the time is not used efficiently'.

The quality of teaching depends on a wide range of factors, including appropriate teaching methods and material, an adequate curriculum, and well-trained teachers and school leaders. Some of these aspects are reviewed in other parts of this report. The significance of the time factor, which is addressed in this chapter, is particularly interesting in relation to teaching. If learning takes time, teaching does too, especially when adopting particular teaching approaches. For example, teaching methods such as student-centred approaches placing students at the centre of the teaching process, as opposed to the more traditional frontal and teacher-centred approach, require more time (Leong and Chick, 2011). The same applies to teaching methods focusing on learning processes rather than learning outputs (Prendergast and O'Meara, 2016).

This chapter investigates the instruction time allocated to the teaching of mathematics and science in schools in the different European education systems. The data relate to the intended instruction time, i.e. instruction time determined by top-level education authorities in official documents such as the national curriculum or other similar steering documents for primary and lower secondary education (49). In order to fully comprehend the data, this chapter also briefly touches upon issues relating to curriculum organisation (i.e. whether mathematics and/or science are taught as subjects on their own or part of broader knowledge areas; see also Chapter 4, Section 4.1) and how top-level education authorities and schools share the responsibility for designing the curriculum (50).

The chapter will present instruction time as it was originally planned by education authorities for the 2020/2021 school year. The effect of school closures due to the COVID-19 pandemic is only included in the figures if the change in instruction time was incorporated in legislation already before the start of the school year (see Chapter 2 for more details on school closures and distance learning). This is the

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(49) The data are collected jointly by Eurydice and the Organisation for Economic Co-operation and Development (OECD) Network for the Collection and Adjudication of System-Level Descriptive Information on Educational Structures, Policies and Practices (NESLI) on a biennial basis. The data presented in this report come from the 2020/2021 data collection. In addition, data for Luxembourg (*enseignement secondaire général*), Slovakia (*8-ročné gymnázium*) and Switzerland were collected by Eurydice for the purpose of this report.

The data for Spain are based on national and regional regulations on the curriculum and school calendars. Statistics on the number of students per grade and autonomous community are used to calculate the weighted averages, as reported by the statistics office of the Ministry of Education and Vocational Training (2018/2019 reference year).

The data for Germany are based on a weighted average and are calculated by the Secretariat of the Standing Conference of the Ministers of Education and Cultural Affairs of the *Länder*. The *Länder* provide data on the compulsory core curriculum. The averages are weighted by the number of students across each type of school. Data from Lower Saxony and North Rhine-Westphalia (only for primary education) are missing in the calculation.

(50) For additional information on instruction time in schools in Europe, please consult the biennial Eurydice report on this topic (European Commission / EACEA / Eurydice, 2021a).

case of three countries: Malta, Portugal and North Macedonia, where the school year started later than usual (European Commission / EACEA / Eurydice, 2021a, p. 15). For other systems with some periods of complete school closure (see Figure 2.1), changes in instruction time are not included in the figures.

3.1. School autonomy in allocating instruction time

The instruction time allocated to subjects is an important feature of the school curriculum. In all European countries, top-level education authorities define the minimum total instruction time for all curriculum subjects; they also stipulate that mathematics (51) and science (52) are compulsory subjects in primary and lower secondary education (53). Before analysing instruction time allocated to mathematics and science in more detail, this section discusses some aspects of school autonomy and curriculum organisation that allow better interpretation of the data.

Top-level education authorities are in fact not the sole decision-makers in allocating instruction time to curriculum subjects. In a substantial number of countries, schools / local authorities enjoy some autonomy in deciding how instruction time should be allocated through the grades (vertical flexibility) and across curriculum subjects (horizontal flexibility), and which subjects should be part of the compulsory curriculum (subject flexibility).

Vertical flexibility refers to cases where top-level education authorities determine the total number of hours for a specific subject to be taught across more than one grade, without specifying how these hours should be distributed (European Commission / EACEA / Eurydice, 2021a). This concerns seven countries (Czechia, Estonia, Lithuania, Finland, Sweden, Iceland and Norway). In Estonia, for example, the Ministry of Education and Research determines instruction time for each subject in each of the three education stages structuring compulsory education, and schools are free to allocate this amount of instruction time to each grade.

Horizontal flexibility concerns cases where top-level education authorities set a total number of teaching hours for a range of compulsory subjects within the same grade. Schools / local authorities decide how much time to allocate to each subject (European Commission / EACEA / Eurydice, 2021a). This type of school autonomy exists to varying degrees in six countries (Belgium, Denmark, Italy, the Netherlands, Poland and Portugal). In Belgium (Flemish Community), for instance, it concerns the full range of compulsory subjects in primary and lower secondary education, whereas in Poland it applies to only the first three grades of primary education. The horizontal flexibility in Italy applies to almost all compulsory subjects in primary education. Therefore, in these education systems, instruction time for mathematics and science can vary across schools.

Besides vertical and horizontal flexibility, schools / local authorities in some countries also enjoy some subject flexibility (i.e. schools / local authorities choose some of the subjects that are part of students' compulsory curriculum). This concerns 14 education systems (54) in primary and lower secondary

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(51) The common Eurydice–OECD data collection on instruction time defines mathematics as a subject category covering all numeracy skills and subjects such as arithmetic, algebra, geometry and statistics (European Commission / EACEA / Eurydice, 2021a); this chapter uses this definition.

(52) The common Eurydice–OECD data collection on instruction time defines science as a subject category including subjects such as science, physics, chemistry, biology, environmental sciences and ecology (European Commission / EACEA / Eurydice, 2021a); this chapter uses this definition. However, science as a broad subject category might include slightly different subjects according to national curricula, such as geography. Please see Annex I of this report.

(53) Some grades in Ireland (lower secondary schools enjoy great autonomy in defining the school curriculum – see at the end of this section) and Hungary (science is not taught in grade 1) make exception to that rule.

(54) Belgium (French and Flemish Communities), Czechia, Estonia, Ireland, Greece, Spain, Latvia, Hungary, Portugal, Slovakia, Finland, Albania and Montenegro.

education. In all of them, subject flexibility applies to less than 20% of total instruction time except in Ireland (62%) and Spain (24%) in lower secondary education. Typically, schools / local authorities use this flexible instruction time to offer subjects that are not part of the curriculum defined by top-level education authorities but respond to the particular needs and circumstances of the local school community. These subjects might be an additional foreign language or an advanced course in mathematics. The particularly high percentage in Ireland is due to the large degree of school autonomy granted to schools following the 2014 curriculum reform (European Commission / EACEA / Eurydice, 2021a).

3.2. Instruction time for mathematics and science in relation to other knowledge areas

The curriculum, especially at primary level, is not always (fully) built on common disciplines such as science, mathematics, social studies and ICT. Instead, it is organised around broader knowledge areas including several traditional disciplines. Specific instruction time arrangements suggest that such curriculum organisation exists in some countries.

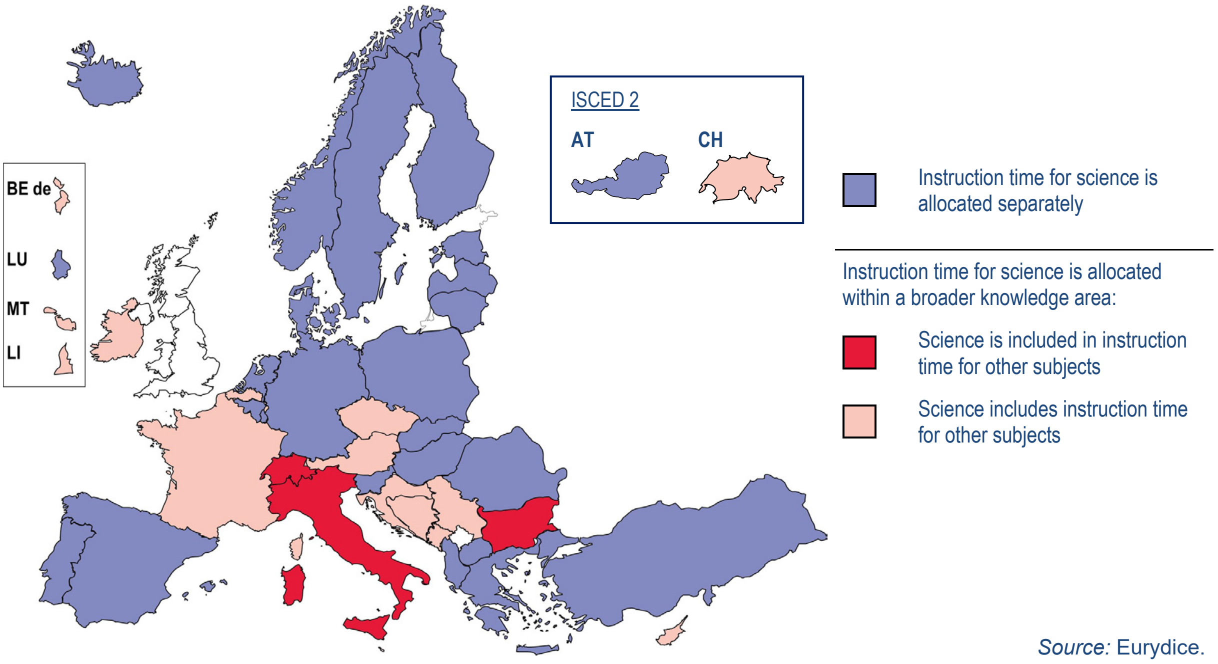
As Figure 3.1 indicates, in most education systems, top-level education authorities define instruction time for science separately. In other words, instruction time for science neither is included in nor includes instruction time for other subjects or knowledge areas.

However, in 16 education systems, top-level education authorities allocate instruction time for science together with other curriculum subjects in one or more grades in primary or lower secondary education. In nearly all of these systems, instruction time for science, as defined by top-level education authorities, includes instruction time for social studies (Czechia, France, Croatia, Austria, Bosnia and Herzegovina, Liechtenstein, Montenegro and Serbia) and/or technology (Belgium (German-speaking and Flemish Communities), Ireland, France, Cyprus, Malta, Austria and Montenegro). In France, in addition to the two previously cited subjects, instruction time for science comprises learning time for ICT. In all these cases, the focus of these broad knowledge areas is somewhat placed on science.

The reverse is found in Bulgaria and Italy, where broad knowledge areas including science focus on social studies (Bulgaria) and mathematics (Italy). Finally, Switzerland shows a mixed picture: in primary education, a broad knowledge area focusing on social studies includes instruction time for science and technology, while in lower secondary education instruction time for science includes taught time for technology.

In about half of the aforementioned cases, this particular instruction time arrangement for teaching science concerns all grades of primary education. In Bulgaria, Cyprus, Bosnia and Herzegovina, and Montenegro, it applies only to some grades at primary level, whereas in Belgium (German-speaking Community), Switzerland and Liechtenstein it concerns both primary and lower secondary education. In France, the number of grades in which it applies varies depending on the subject concerned (social studies, ICT and technology). Finally, top-level education authorities in Italy do not define instruction time for science as a separate subject, but define it for a broader knowledge area comprising mathematics and science.

Figure 3.1: Allocation of instruction time for science, ISCED 1-2, 2020/2021



Source: Eurydice.

Explanatory notes

The main purpose of the map is to show whether instruction time for science is allocated separately or it integrates (or is integrated in) instruction time for other subjects.

This map aims to provide an overall representation of primary and lower secondary education together. The picture provided for education systems where science integrates (or is integrated in) other subjects might concern only some grades in primary or lower secondary education.

Country-specific notes

Belgium (BE de, BE nl): Top-level education authorities do not determine instruction time for individual subjects (horizontal flexibility), but indicate that technology should be taught with sciences in primary education (Belgium (Flemish Community)) or in both primary and lower secondary education (Belgium (German-speaking Community)).
Poland: For ISCED 1, top-level education authorities do not determine instruction time for individual subjects (horizontal flexibility) in the first three grades, so this categorisation applies only to the last grade of primary education (grade 4).
Switzerland: The map shows the situation in the 21 German-speaking and bilingual cantons, which constitute most of Switzerland. In the French-speaking cantons, science is a standalone subject in most grades.

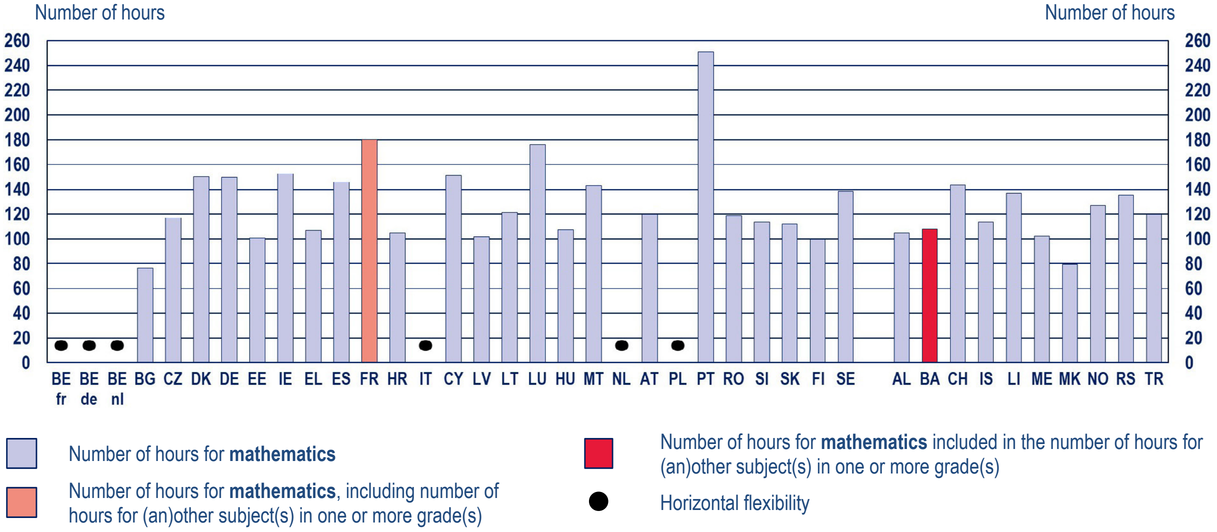
In contrast to taught time for science, instruction time for mathematics is allocated to the teaching of only mathematics in all countries except France, Italy, and Bosnia and Herzegovina. In France, it comprises the time allocated to teach ICT (a cross-curricular subject) in the last two grades of primary education; in Italy, it includes instruction time for science, as mentioned above. Finally, in Bosnia and Herzegovina, top-level education authorities define a certain amount of instruction time to teach both reading / writing / literature and mathematics in the first grade of primary education.

3.3. Instruction time for mathematics

This section discusses the instruction time allocated to teach mathematics in primary and lower secondary education. It also examines the relationship between the number of hours allocated to mathematics on the one hand and instruction time for mathematics as a proportion of total instruction time on the other hand. All indicators present the minimum amount of instruction time per notional year (i.e. the total teaching load for mathematics for a given education level divided by the number of years of that education level). This calculation removes variations resulting from the differences in the number of grades in each education level across Europe.

At primary level, instruction time for mathematics per notional year ranges from 100 to 120 hours in around half of the education systems for which there are data (see Figure 3.2); in the other half, it is greater than 120 hours, with Portugal having the highest number of taught hours (251 hours) (55). Bulgaria and North Macedonia are the only countries where the amount of instruction time stands below 100 hours per notional year (76 and 80 hours respectively).

Figure 3.2: Instruction time for mathematics per notional year, ISCED 1, 2020/2021



BE fr	BE de	BE nl	BG	CZ	DK	DE	EE	IE	EL	ES	FR	HR	IT	CY	LV	LT	LU	HU	MT
●	●	●	76	117	150	150	101	153	107	146	180	105	●	151	102	122	176	107	143
NL	**AT**	**PL**	**PT**	**RO**	**SI**	**SK**	**FI**	**SE**		**AL**	**BA**	**CH**	**IS**	**LI**	**ME**	**MK**	**NO**	**RS**	**TR**
●	120	●	251	119	114	112	100	138		105	108	143	113	137	102	80	127	135	120

Source: Eurydice.

Explanatory notes

Instruction time per notional year in primary education: This corresponds to the total taught time in primary education divided by the number of years in primary education.

Horizontal flexibility: Top-level education authorities determine the total instruction time for a group of subjects within a specific grade. Schools / local authorities are then free to decide how much time to allocate to individual subjects.

When horizontal flexibility applies to some of the grades in primary level, those grades are excluded from the calculation of notional years.

Country-specific notes

Denmark: Data correspond to the taught time for the last six grades of primary education (accommodating 7-13-year olds), which comprises seven grades, so taught time is divided by 6. Horizontal flexibility applies in the first grade (accommodating 6-year olds).
France: Data include instruction time for ICT in the last two grades of primary education.
Poland: In the first three grades of primary education, which comprises four grades, horizontal flexibility applies. Instruction time is defined for mathematics only in the last grade of primary education.
Portugal: Data correspond to the taught time for the first four grades of primary education, which comprises six grades, so taught time is divided by 4. Horizontal flexibility applies in the last two grades.
Bosnia and Herzegovina: Data do not include instruction time for mathematics in the first grade.
Switzerland: Data show the situation of the 21 German-speaking and bilingual cantons, which constitute most of Switzerland.
North Macedonia: Owing to the COVID-19 pandemic, the number of instruction days was reduced from 180 to 159. Moreover, the length of lessons was shortened by 10 minutes (distance learning), further reducing the total instruction time. The 2020/2021 teaching programme was realised.

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(55) It should be noted that Portugal's data are calculated based on the first four grades of primary education, which comprises six grades.

In addition to Portugal, a few countries provide 150 hours or more for the teaching of mathematics per notional year: Denmark, Germany, Ireland, France, Cyprus and Luxembourg. In France, instruction time for mathematics includes instruction time for ICT (a cross-curricular subject) in the last two grades of primary education. Conversely, in Bosnia and Herzegovina, instruction time for mathematics in grade 1 is part of the teaching load for reading, writing and literature.

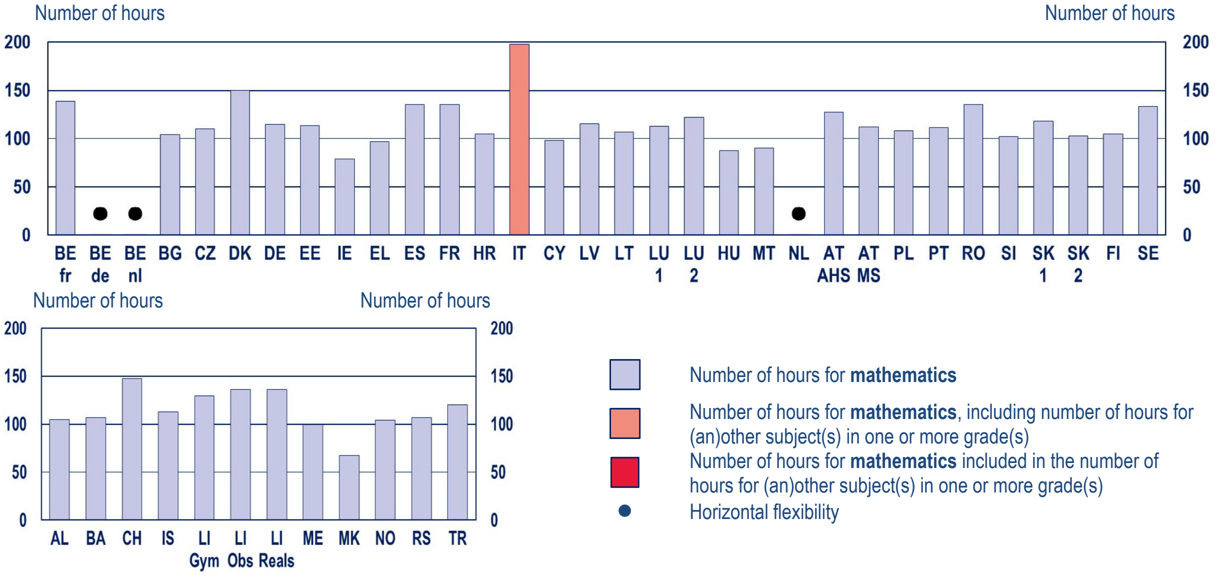
As explained above, in Belgium, Italy, the Netherlands and Poland, schools decide how to allocate the total instruction time across curriculum subjects for all or most grades of primary education (horizontal flexibility). In Poland, this horizontal flexibility concerns 3 out of 4 years in primary education. In Denmark and Portugal, schools have this autonomy in some years at primary level (the first grade (out of seven) accommodating 6-year olds in Denmark and the last two (out of six) in Portugal).

In lower secondary education, the minimum instruction time per notional year for mathematics ranges from 100 to 120 hours in around 21 education systems/tracks (see Figure 3.3). It stands below 100 hours in six countries: Ireland, Greece, Cyprus, Hungary, Malta, and North Macedonia. At the other end of the range, 12 education systems/tracks provide more than 120 hours per notional year for teaching mathematics, with Denmark offering the largest number of hours (i.e. 150 hours). Italy stands out, as instruction time for mathematics also includes taught hours for science.

Most education systems provide less instruction time to mathematics at lower secondary level than in primary education. This decrease is particularly significant (i.e. more than 50%) in Ireland and Portugal. In Germany, France, Cyprus, Luxembourg, Malta and Serbia, the decrease is around 20%. It has to be noted that these countries have a comparatively large number of taught hours in primary education. France needs to be singled out: despite an important drop (25%), it is still among the countries with a comparatively high amount of instruction time for mathematics in lower secondary education.

Some countries at the lower end of the range of taught hours in lower secondary education also have a relatively low amount of instruction time for mathematics in primary education. This is particularly the case in North Macedonia, and also to some extent in Bulgaria, Croatia, Finland, Albania and Montenegro, where around 100 hours per notional year are dedicated to the teaching of mathematics in both primary education and lower secondary education.

Figure 3.3: Instruction time for mathematics per notional year, ISCED 2, 2020/2021



BE fr	BE de	BE nl	BG	CZ	DK	DE	EE	IE	EL	ES	FR	HR	IT	CY	LV	LT	LU 1	LU 2	HU	MT	NL
139	●	●	104	110	150	115	114	79	97	135	135	105	198	98	116	106	113	122	87	90	●
AT AHS	**AT MS**	**PL**	**PT**	**RO**	**SI**	**SK 1**	**SK 2**	**FI**	**SE**	**AL**	**BA**	**CH**	**IS**	**LI Gym**	**LI Obs**	**LI Reals**	**ME**	**MK**	**NO**	**RS**	**TR**
128	113	108	111	135	102	118	103	105	133	105	107	148	113	130	137	137	100	68	104	107	120

Source: Eurydice.

Explanatory notes

Instruction time per notional year in lower secondary education: This corresponds to the total taught time in lower secondary education divided by the number of years in lower secondary education.

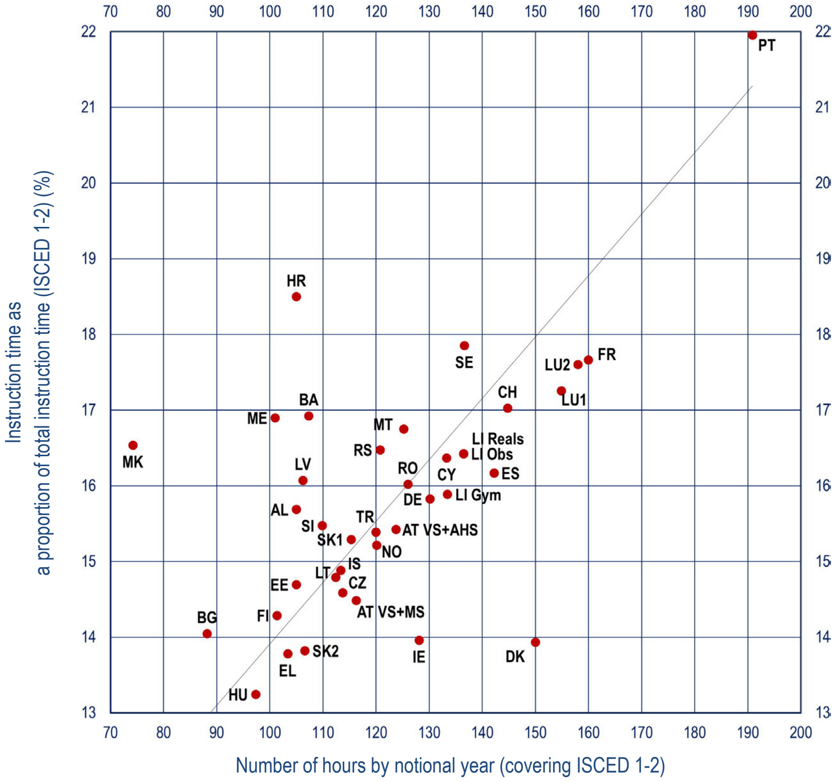
Horizontal flexibility: Top-level education authorities determine the total instruction time for a group of subjects within a specific grade. Schools / local authorities are then free to decide how much time to allocate to individual subjects.

Country-specific notes

Italy: Data include instruction time for science in the three grades of lower secondary education.
Luxembourg: LU1 corresponds to *enseignement secondaire classique* (classical secondary education); LU2 corresponds to *enseignement secondaire général* (general secondary education).
Austria: AHS corresponds to *Allgemeinbildende höhere Schule* (academic secondary school – grades 5–8) and MS corresponds to *Mittelschule* (compulsory secondary school – grades 5–8).
Slovakia: SK1 corresponds to the grades of lower secondary education (grades 5–9) in *Základná škola* (basic school); SK2 corresponds to grade 5 in *Základná škola* and the first four grades of *8-ročné gymnázium* (8-year grammar school). Calculations of instruction time for *8-ročné gymnázium* include data for the first year of ISCED 3.
Switzerland: Data show the situation of the 21 German-speaking and bilingual cantons, which constitute most of Switzerland.
Liechtenstein: LI Gym corresponds to *Gymnasium* (school type with advanced requirements); LI Obs corresponds to *Oberschule* (school type with basic requirements); LI Reals corresponds to *Realschule* (school type with intermediate requirements).
North Macedonia: Owing to the COVID-19 pandemic, the number of instruction days was reduced from 180 to 159. Moreover, the length of lessons was shortened by 10 minutes (distance learning), further reducing the total instruction time. The 2020/2021 teaching programme was realised.

A large number of taught hours dedicated to mathematics does not necessarily imply that the curriculum places a lot of emphasis on mathematics. Figure 3.4 intends to show whether a significant amount of instruction time corresponds to a comparatively significant weight of mathematics within the curriculum. More specifically, this figure presents the relationship between the aggregated number of hours in primary and secondary education for mathematics by notional year (x-axis) and instruction time for mathematics as a proportion of total instruction time in primary and lower secondary education (y-axis).

Figure 3.4: Instruction time for mathematics per notional year and as a proportion of total instruction time, ISCED 1-2, 2020/2021



Explanatory notes

Instruction time per notional year in primary and lower secondary education: This corresponds to the total taught time in hours in primary and lower secondary education divided by the number of years in primary and lower secondary education.

Horizontal flexibility: Top-level education authorities determine the total instruction time for a group of subjects within a specific grade. Schools / local authorities are then free to decide how much time to allocate to individual subjects.

The figure does not show education systems/tracks with horizontal flexibility in all or most grades of primary level and/or lower secondary level (i.e. Belgium, Italy, the Netherlands and Poland).

Source: Eurydice.

Country-specific notes

See Figures 3.2 and 3.3.

Austria: VS + AHS stands for *Volkschule* (primary school – grades 1–4) + *Allgemeinbildende höhere Schule* (AHS; academic secondary school – grades 5-8); VS + MS stands for *Volkschule* (primary school – grades 1–4) + *Mittelschule* (compulsory secondary school – grades 5–8).

As expected, the scatter plot shows a strong and positive relationship between the two sets of data. Most education systems are situated along the trend line going from Hungary (few notional hours and low percentage) to Portugal (large number of hours and high percentage) ([56]).

Considering this trend and the number of hours allocated to mathematics, education systems furthest from the trend line, namely those of Croatia, Bosnia and Herzegovina ([57]), Montenegro and North Macedonia, have a high percentage of instruction time dedicated to mathematics relative to the number of notional hours. In other words, despite a relatively lower number of taught hours (in comparison with other countries), their curriculums put relatively more emphasis on mathematics (in comparison with countries with a similar number of taught hours). The same observation can also be made about Latvia, Malta, Sweden, Albania and Serbia, although to a lesser extent.

The opposite seems much less frequent. In other words, only a couple of countries – Denmark and Ireland ([58]) – show a relatively low percentage of instruction time dedicated to mathematics in relation to the number of notional hours, compared with other countries.

([56]) The data for Portugal are calculated based on some of the grades in primary education (see Figure 3.2 and country-specific notes).

([57]) In Bosnia and Herzegovina, data do not include instruction time for mathematics in the first grade, which may partly explain the low amount of taught time.

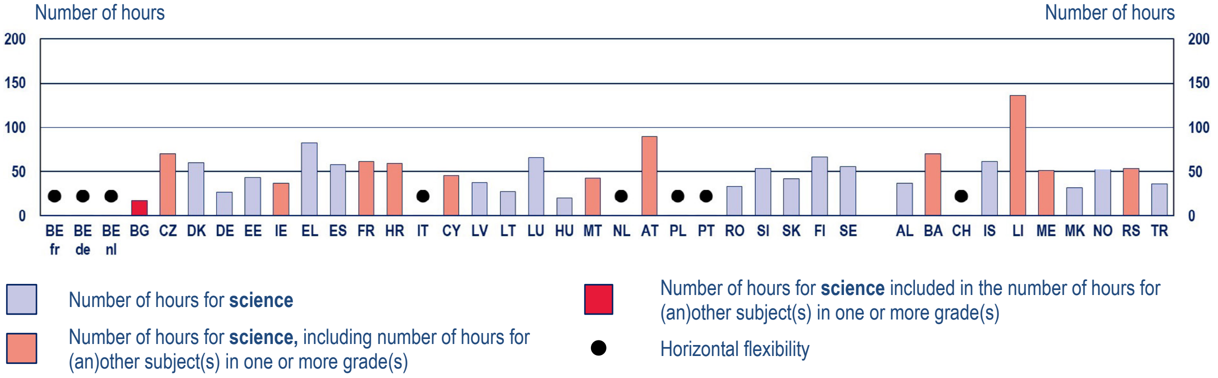
([58]) The data for Denmark are calculated based on some of the grades in primary education (see Figure 3.2 and country-specific notes).

3.4. Instruction time for science

This section focuses on science. It examines instruction time dedicated to it in primary and lower secondary education. In addition, as the previous section did for mathematics, it looks into the relationship between the number of hours dedicated to science and instruction time for science as a proportion of total instruction time in primary and lower secondary education. This analysis is helpful in apprehending how significant the teaching of science is in relation to the rest of the curriculum subjects.

Figure 3.5 presents the number of hours allocated to science per notional year in primary education. Focusing on the education systems that provide instruction time for science only, the number of taught hours per notional year ranges from 20 in Hungary to 82 in Greece. Comparatively, Greece has a particularly large number of hours, as the next country down on the scale (Finland) provides 67 hours to teach science at primary level. In most countries, the teaching load for science is situated between 30 and 60 hours per notional year. Countries falling below the lower end of this range are Germany, Lithuania and Hungary, while above the upper end of this range stand Luxembourg and Iceland, in addition to Greece and Finland.

Figure 3.5: Instruction time for science per notional year, ISCED 1, 2020/2021



BE fr	BE de	BE nl	BG	CZ	DK	DE	EE	IE	EL	ES	FR	HR	IT	CY	LV	LT	LU	HU	MT
●	●	●	17	70	60	26	44	37	82	58	61	59	●	45	38	27	66	20	43
NL	**AT**	**PL**	**PT**	**RO**	**SI**	**SK**	**FI**	**SE**		**AL**	**BA**	**CH**	**IS**	**LI**	**ME**	**MK**	**NO**	**RS**	**TR**
●	90	●	●	33	54	42	67	56		37	70	●	62	137	51	32	52	54	36

Source: Eurydice.

Explanatory notes

Instruction time per notional year in primary education: This corresponds to the total taught time in primary education divided by the number of years in primary education.

Horizontal flexibility: Top-level education authorities determine the total instruction time for a group of subjects within a specific grade. Schools / local authorities are then free to decide how much time to allocate to individual subjects.

Country-specific notes

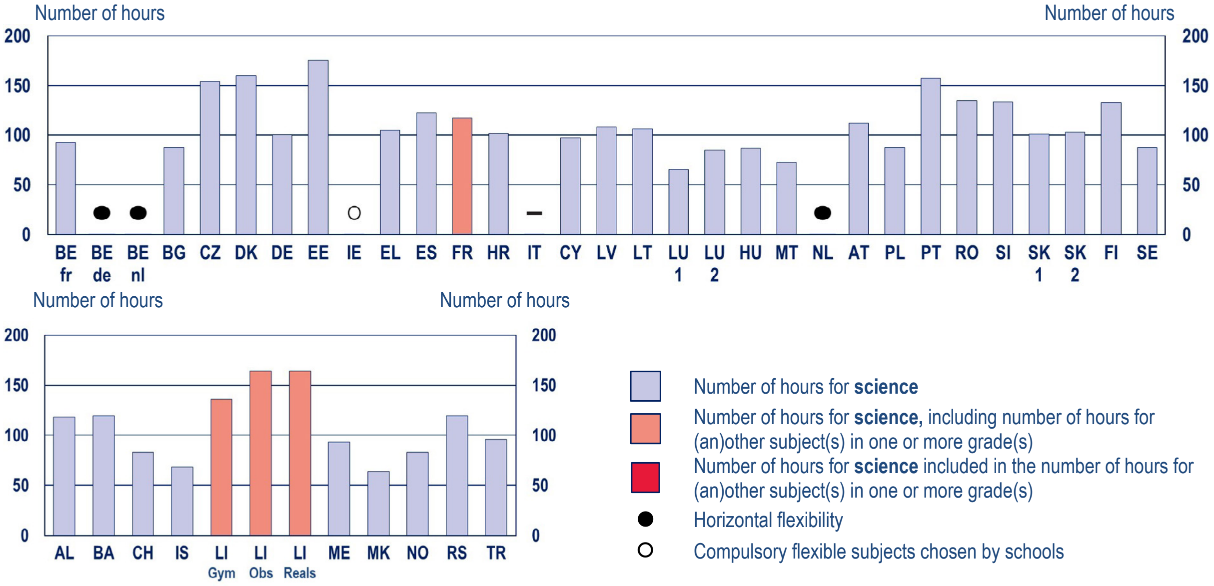
Bulgaria: Data do not include instruction time for science for the first two grades of primary education, which comprises four grades.
Czechia, Croatia, Liechtenstein and **Serbia**: Data include instruction time for social studies allocated in all grades of primary education.
Denmark: Data correspond to the taught time for the last six grades of primary education (accommodating 7-13-year olds), which comprises seven grades, so taught time is divided by 6. Horizontal flexibility applies in the first grade (accommodating 6-year olds).
Ireland and **Malta**: Data include instruction time for technology allocated in all grades of primary education.
France: Data include instruction time for social studies and ICT allocated in the first three grades of primary education, and instruction time for technology allocated in all grades of primary education.
Cyprus: In four out of the six grades of primary education, data include instruction time for technology.
Austria: Data include instruction time for social studies and technology allocated in all grades of primary education.
Poland: In the first three grades of primary education, which comprises four grades, horizontal flexibility applies. Instruction time is defined for science only in the last grade of primary education.

Bosnia and Herzegovina: In four of the five grades in primary education, data include instruction time for social studies.
Switzerland: In the 21 German-speaking and bilingual cantons, which constitute most of Switzerland, instruction time for science is integrated in instruction time for social studies. In the French-speaking cantons, science is a separate subject in most grades.
Montenegro: Data include instruction time for social studies in three of the five grades at primary level, and for technology in the first four grades at primary level.
North Macedonia: Owing to the COVID-19 pandemic, the number of instruction days was reduced from 180 to 159. Moreover, the length of lessons was shortened by 10 minutes (distance learning), further reducing the total instruction time. The 2020/2021 teaching programme was realised.

As discussed above (see Figure 3.1), instruction time for science, especially at primary level, can include instruction time for other subjects, particularly social studies and/or technology. This is the case for Czechia, Austria, Bosnia and Herzegovina, and Liechtenstein, which have the highest numbers of taught hours. At the other end of the scale, the very low amount of instruction time allocated to science in Bulgaria can also be explained by specific instruction time arrangements. Indeed, there are no teaching hours specifically for science as a separate subject during the first two years of primary education. Instruction time for science is included in a broader curriculum subject comprising science and social studies, with a slightly greater focus on social studies. Finally, amounts of instruction time for science in Ireland, Cyprus and Malta are relatively low (below 50 hours per notional year), considering that this time includes instruction time for technology (see country-specific notes below Figure 3.5).

Figure 3.6 illustrates the time devoted to science instruction in lower secondary education.

Figure 3.6: Instruction time for science per notional year, ISCED 2, 2020/2021



BE fr	BE de	BE nl	BG	CZ	DK	DE	EE	IE	EL	ES	FR	HR	IT	CY	LV	LT	LU 1	LU 2	HU	MT	NL
93	●	●	88	154	160	101	175	○	105	123	117	102	(-)	98	108	106	66	85	87	72	●
AT	**PL**	**PT**	**RO**	**SI**	**SK 1**	**SK 2**	**FI**	**SE**		**AL**	**BA**	**CH**	**IS**	**LI Gym**	**LI Obs**	**LI Reals**	**ME**	**MK**	**NO**	**RS**	**TR**
113	88	158	135	134	101	103	133	88		118	119	●	68	137	164	164	93	64	83	119	96

Source: Eurydice.

Explanatory notes

Instruction time per notional year in primary education: This corresponds to the total taught time in lower secondary education divided by the number of years in lower secondary education.

Horizontal flexibility: Top-level education authorities indicate the total instruction time for a group of subjects within a specific grade. Schools / local authorities are then free to decide how much time to allocate to individual subjects.

Compulsory flexible subjects chosen by schools: This corresponds to the total amount of compulsory instruction time indicated by the top-level authorities, which regional authorities, local authorities, schools or teachers allocate to subjects of their choice (or subjects they choose from a list defined by top-level education authorities).

Country-specific notes

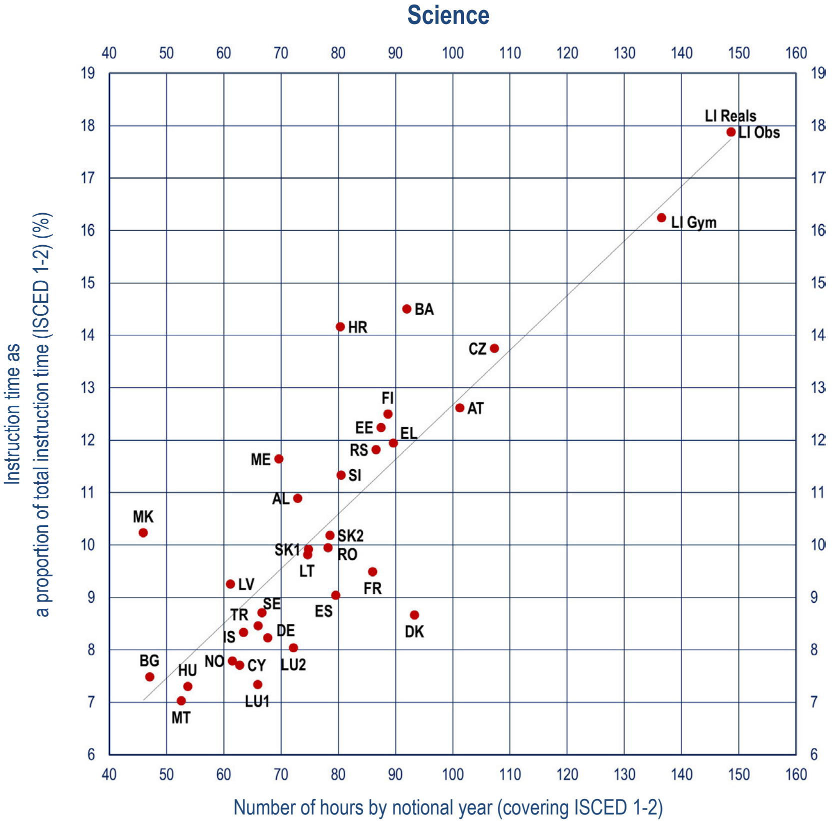
Ireland: Since the curriculum reform that started in 2014, schools have had considerable autonomy in designing their curricula. Concretely, it means that schools select their compulsory subjects (for instance science) from a large number of subjects. Schools also define the amount of instruction time to allocate to them. As for top-level education authorities, they determine the total compulsory instruction time and taught time for a few centrally selected subjects (i.e. mathematics, English, Irish, social studies, physical education and social, personal and health education).
France: Data include instruction time for technology in the first grade of lower secondary education.
Italy: Top-level education authorities do not define instruction time for science as a separate subject, but for a broader knowledge area comprising science and mathematics.
Luxembourg: LU1 corresponds to *enseignement secondaire classique* (classical secondary education); LU2 corresponds to *enseignement secondaire général* (general secondary education).
Slovakia: SK1 corresponds to the grades of lower secondary education (grades 5–9) in *Základná škola* (basic school); SK2 corresponds to grade 5 in *Základná škola* and the first four grades of *8-ročné gymnázium* (8-year grammar school). Calculations of instruction time for *8-ročné gymnázium* include data for the first year of ISCED 3.
Switzerland: Data show the situation of the 21 German-speaking and bilingual cantons, which constitute most of Switzerland.
Liechtenstein: LI Gym corresponds to *Gymnasium* (school type with advanced requirements); LI Obs corresponds to *Oberschule* (school type with basic requirements); LI Reals corresponds to *Realschule* (school type with intermediate requirements). Data include instruction time for social studies in all grades of *Oberschule* and *Realschule*. In *Gymnasium*, this is the case for the first three grades (out of four) of lower secondary education; top-level education authorities define instruction time separately for the two subjects in the last grade. This explains why *Gymnasium* has a lower amount of instruction time than the two other tracks: in the last grade of lower secondary education, in contrast to *Oberschule* and *Realschule*, data only include instruction time for science.
North Macedonia: Owing to the COVID-19 pandemic, the number of instruction days was reduced from 180 to 159. Moreover, the length of lessons was shortened by 10 minutes (distance learning), further reducing the total instruction time. The 2020/2021 teaching programme was realised.

As Figure 3.6 shows, the time devoted to science instruction increases substantially in lower secondary education. The amount of instruction time ranges from 64 hours in North Macedonia to 175 hours in Estonia. In most countries, the time spent on teaching science is greater than 100 hours per notional year. Besides North Macedonia, Luxembourg (*enseignement secondaire classique*), Malta and Iceland have particularly low amounts of instruction time for science (i.e. 66 hours, 72 hours and 68 hours respectively). Conversely, alongside Estonia, Denmark, Czechia, and Portugal provide the highest number of hours for teaching science (160 hours, 154 hours, and 158 hours respectively).

In comparison with primary education, the number of hours in lower secondary education is higher in all education systems, except in Luxembourg (*enseignement secondaire classique*) and Liechtenstein (*Gymnasium*), where the curriculum provides the same amount of instruction time for both levels. In around half of the education systems/tracks, the number of hours for teaching science at least doubles in lower secondary education. In Estonia, Hungary and Romania, this number quadruples, and in Bulgaria it is more than five times as high as in primary education. However, Bulgaria (in particular), Hungary and Romania have a particularly small amount of instruction time in primary education (see Figure 3.5).

Figure 3.7 presents the relationship between the aggregated number of hours dedicated to science in primary and secondary education by notional year (x-axis) and instruction time for science as a proportion of total instruction time in primary and lower secondary education (y-axis). Like in mathematics, the relationship between the two sets of data is strong and positive: the more hours are dedicated to science, the higher the proportion of science in the curriculum. A clear trend emerges, from Hungary (small number of hours and low percentage) to Czechia (large number of hours and high percentage). Liechtenstein (*Gymnasium*, *Realschule* and *Oberschule*) stands out, as instruction time for science includes instruction time for social studies (see Figures 3.5 and 3.6 and their country-specific notes).

Figure 3.7: Instruction time for science per notional year and as a proportion of total instruction time, ISCED 1-2, 2020/2021



Explanatory notes

Instruction time per notional year in primary and lower secondary education: This corresponds to the total taught time in hours in primary and lower secondary education divided by the number of years in primary and lower secondary education.

Horizontal flexibility: Top-level education authorities indicate the total instruction time for a group of subjects within a specific grade. Schools / local authorities are then free to decide how much time to allocate to individual subjects.

The figure does not show education systems/tracks with horizontal flexibility in all or most grades at primary level and/or lower secondary level (i.e. Belgium, Italy, the Netherlands, Poland and Portugal). In addition, it does not show Ireland, where science is not compulsory at seconddary level, or Switzerland, where instruction time for science is integrated into instruction time for social studies at primary level.

Source: Eurydice.

Country-specific notes

See Figures 3.5 and 3.6.

Similarly to what has been observed for mathematics, the percentage of taught time dedicated to science within the total teaching time is high in North Macedonia in comparison with countries with a similar number of taught hours. For Croatia, Bosnia and Herzegovina, and Montenegro, which show a similar pattern, instruction time for science includes taught time for social studies at primary level, which might introduce some bias into the comparison. Conversely, the percentage of instruction time dedicated to science is lower in Denmark than in other countries with a similar amount of instruction time. In Denmark, however, the approach used to calculate the amount of instruction time per notional year differs slightly from that used in other countries (please see country-specific note below Figure 3.5).

Summary

Time is an obvious dimension of any learning process. However, there is no research evidence pointing to an ideal amount of instruction time for learning mathematics or science. Instead, some studies show that additional time for the teaching of mathematics or science improves students' academic achievement. However, the significance of such an outcome must be carefully weighed against the limited number of research studies, which have very diverse research designs. Beyond instruction time, effective teaching is of paramount importance for successful learning to take place.

Defining total instruction time (i.e. for all curriculum subjects) is a responsibility of top-level education authorities in all countries. Allocating this total number of hours across all curriculum subjects is also the prerogative of top-level education authorities. In some countries, however, it is shared with schools / local authorities.

Instruction time for mathematics is greater at primary level than at secondary level in most education systems. In primary education, the number of notional hours dedicated to the teaching of mathematics ranges between 100 and 120 per year (59) in about half of the education systems/tracks; in the other half, it is greater than 120. In lower secondary education, this number of notional hours also varies between 100 and 120 in about half of the education systems; it is greater than 120 in a dozen education systems/tracks and lower than 100 in the remaining six.

For science, the overall picture provided by the data shows instruction time increasing when students attend lower secondary level in nearly all education systems/tracks (i.e. the opposite of the trend observed for mathematics). In more than half of the education systems/tracks, the number of notional hours per year at least doubles compared with primary education. The place of science in the curriculum makes comparison across countries more difficult, especially at primary level. At that level, in a dozen countries, science is part of a broader knowledge area, comprising more than one traditional discipline, such as science and social studies. In these cases, instruction time for science includes (or is included in) instruction time for other curriculum subjects, in particular social studies, technology and ICT.

When feasible, the comparison between instruction time dedicated to mathematics on the one hand and to science on the other hand produces a different picture depending on the education level considered. In primary education, the number of hours dedicated to mathematics exceeds the amount allocated to science in all education systems. In lower secondary education, mathematics still has more weight in the curriculum than science in slightly more than half of the education systems. However, in almost one third of education systems, the opposite holds true. Finally, in the remaining cases, mathematics and science have similar numbers of taught hours (60).

Finally, the analysis shows that, in most countries, a significant amount of instruction time corresponds to a comparatively significant weight of mathematics/science within the curriculum, the opposite being equally true (a low amount of instruction time corresponds to comparatively little weight of mathematics/science within the curriculum).

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(59) Instruction time per notional year at a given education level corresponds to the total taught time in hours at that education level divided by the number of years of that education level.

(60) The biennial Eurydice report on instruction time provides a more comprehensive analysis of the allocation of instruction time to all curriculum subjects in full-time compulsory education (European Commission / EACEA / Eurydice, 2021a).

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.

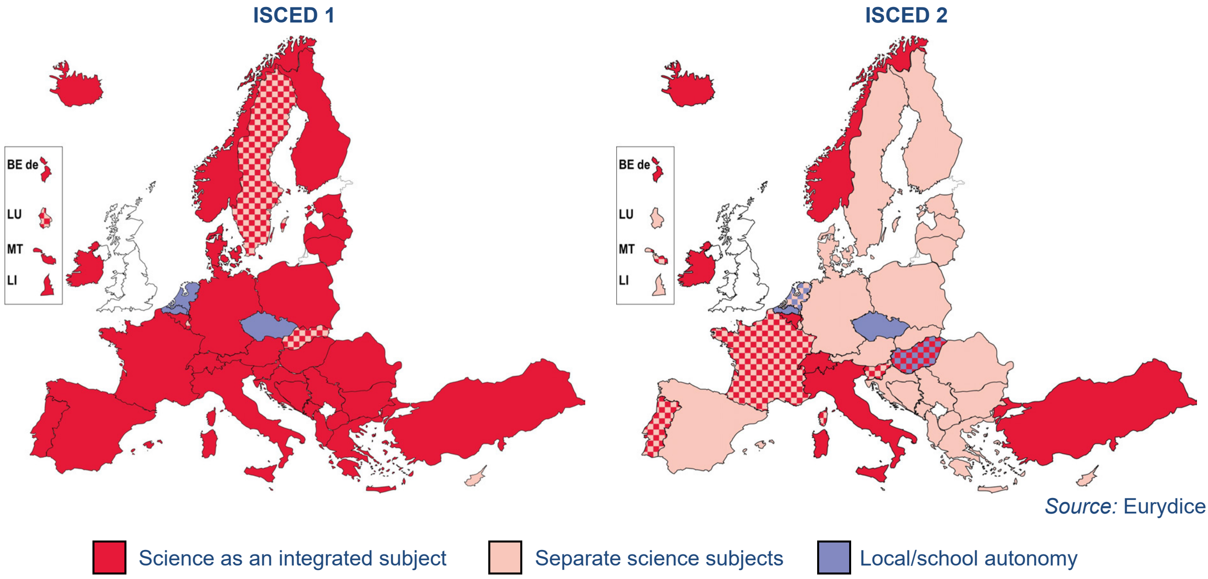
4.1. Organisation of science teaching in compulsory education

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.

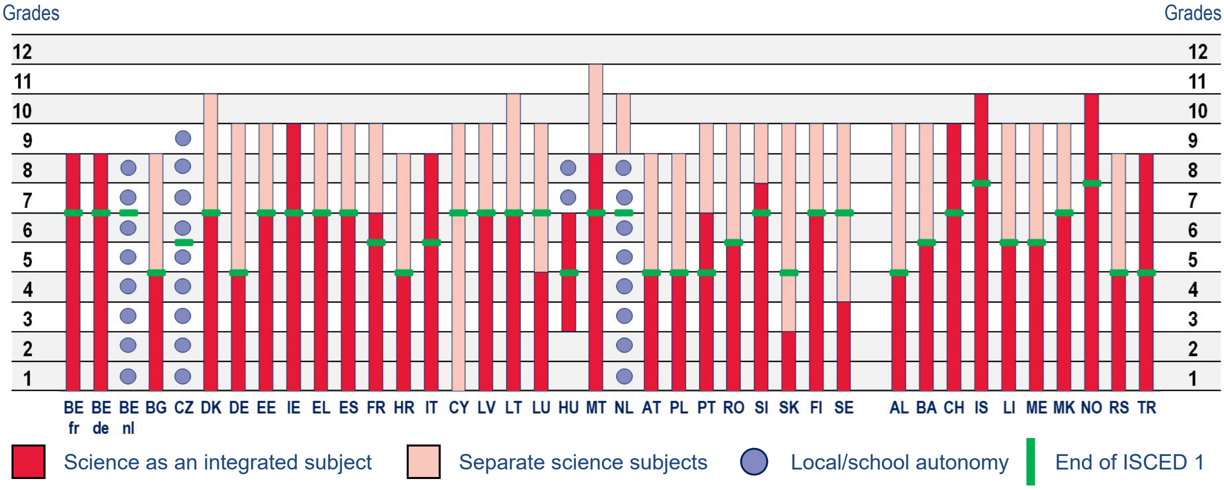
At the level of lower secondary education, the majority of European education systems prescribe in their curricula the teaching of separate science subjects. These are usually biology, physics, chemistry or geography. However, some education systems deviate from this general trend. For example, top-level 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.

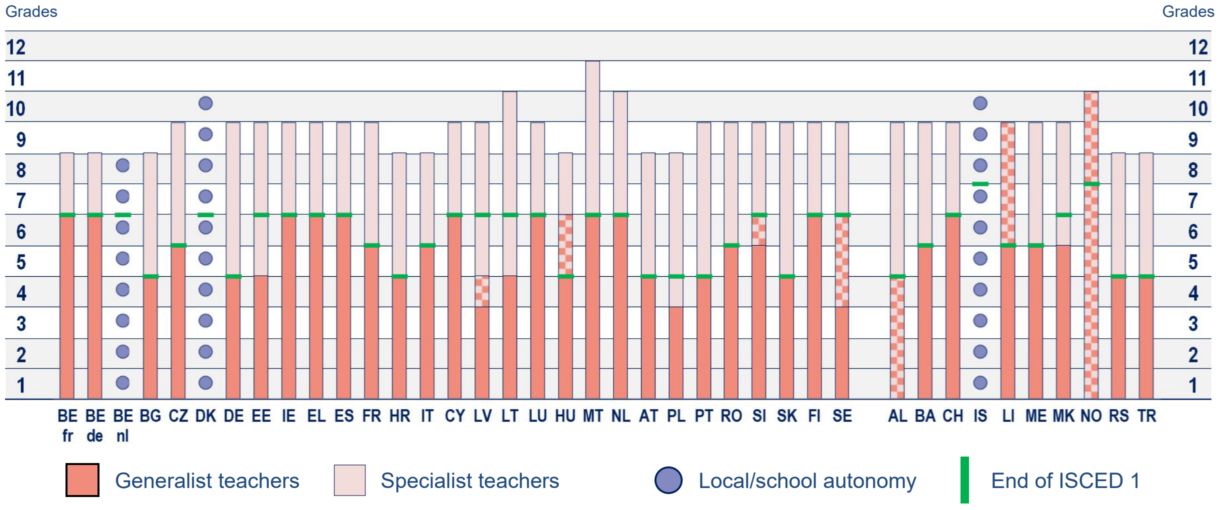
Overall, the analysis confirms the general picture presented above. The majority of European education systems require that generalist teachers provide instruction in mathematics and science at primary level (i.e. usually for a duration of around 4–6 years). In most cases, the end of instruction provided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

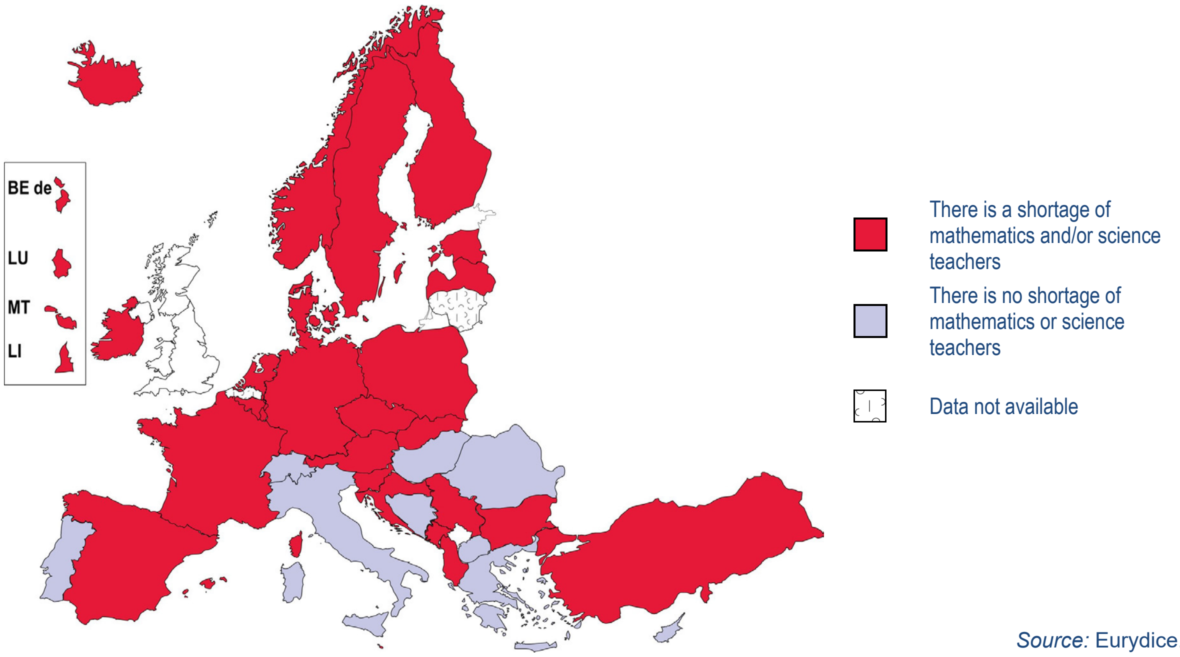
4.2.2. Supply of mathematics and science teachers

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.

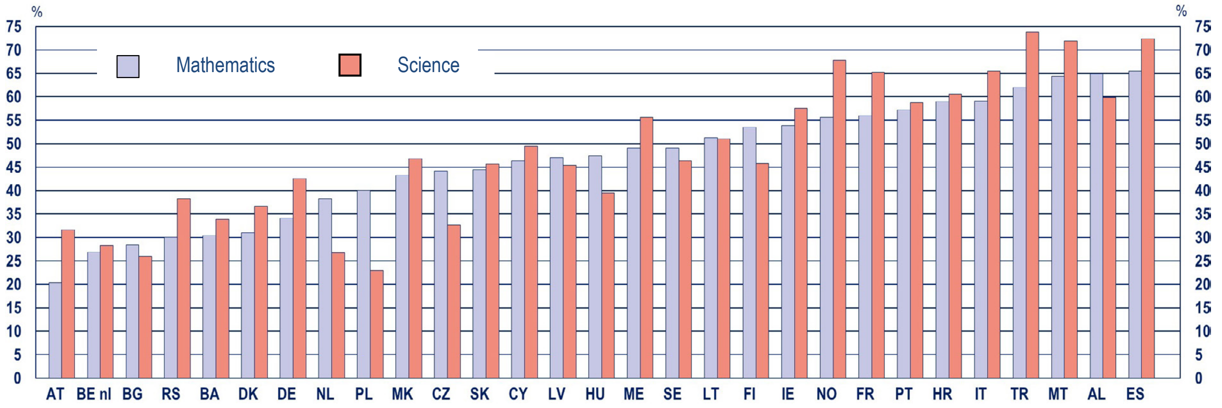
Finally, a number of education systems (e.g. Bulgaria, Czechia, Germany, Spain, France, Croatia, Luxembourg, Sweden and Liechtenstein) also report some general measures to address teacher shortages, such as communication campaigns and increased salaries or other incentives aiming to attract more people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

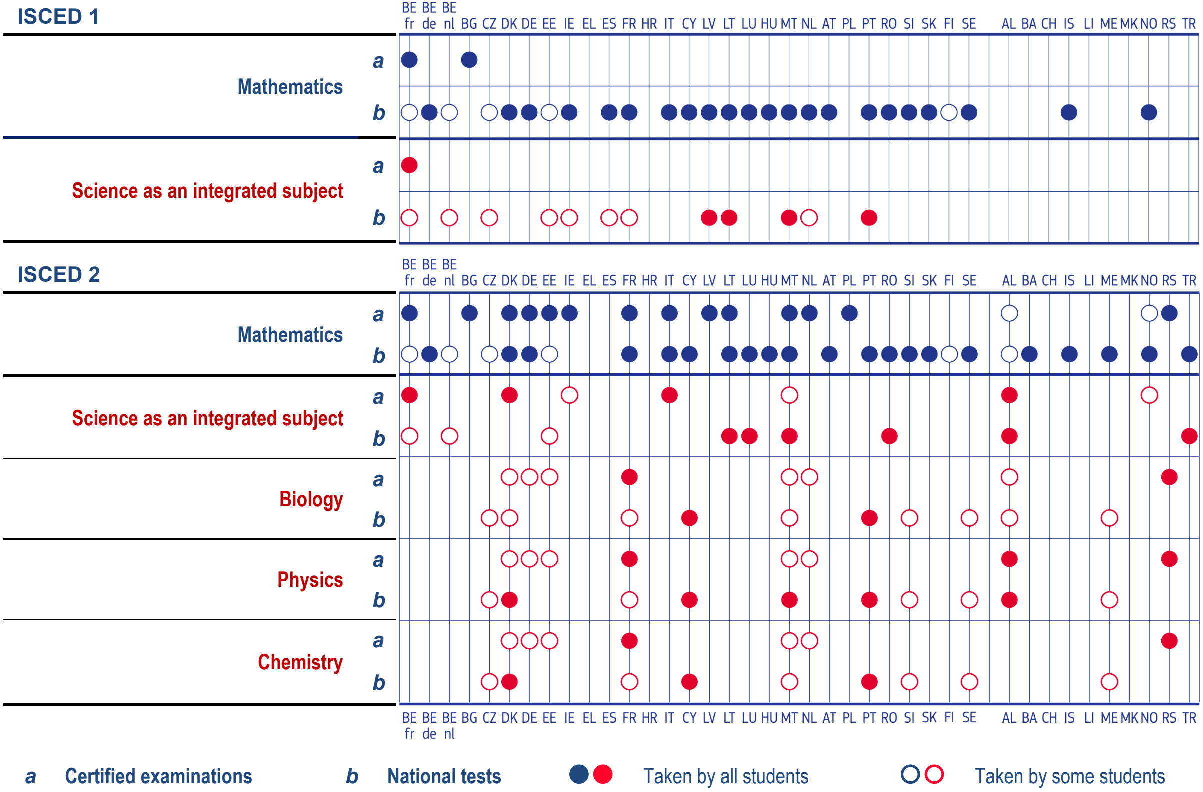
At secondary education level, more than one third of all education systems also carry out certified examinations and/or national tests in separate science subjects, such as biology, physics and chemistry. In addition to these subjects, other science subjects that are assessed in some education systems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

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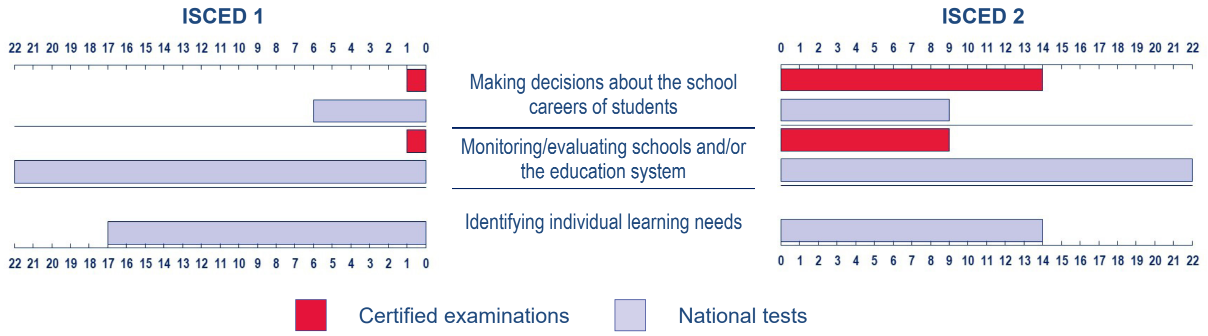
(61) In the draft amendment to the Law on the Education System, submitted to the Parliament of the Republic of Poland in March 2022, there is a provision for the complete abandonment of this exam by the Ministry of Education and Science. See: https://www.gov.pl/web/premier/projekt-ustawy-o-zmianie-ustawy-o-systemie-oswiaty-oraz-niektorych-innych-ustaw

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.

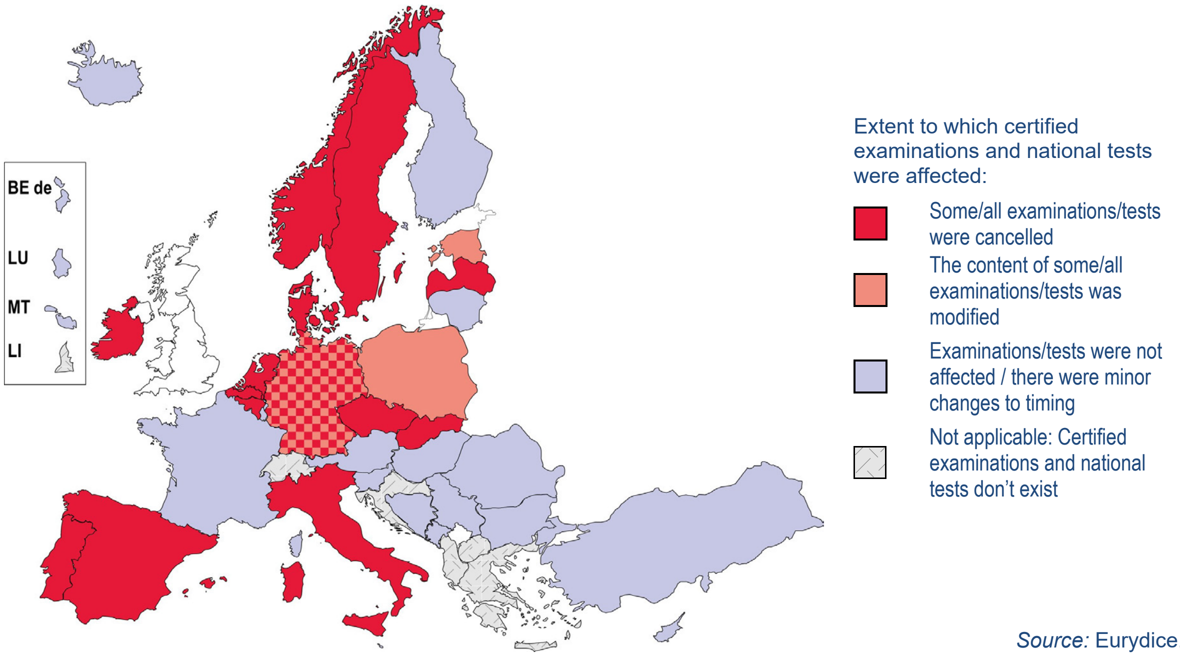
In **Poland**, the national examination in mathematics at the end of grade 8 has two main purposes. It assesses the extent to which students meet the requirements set in the core curriculum for primary education (for the three compulsory examination subjects), thereby providing feedback to students,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

CHAPTER 5: TEACHING AND LEARNING TO INCREASE MOTIVATION

Academic research has firmly established that motivation is an important predictor of school achievement (Howard et al., 2021; Kriegbaum, Becker and Spinath, 2018). Children learn more effectively when they are interested in what they learn. Moreover, they may achieve more when they see the usefulness and applicability of what they are learning (Urdan and Turner, 2005).

This chapter explores the presence of various topics in the curricula that may increase students' interest in, as well as understanding of, mathematics and science. It starts with a discussion of the application of mathematics in several functional contexts. It then explores the contextualisation of science teaching, namely the integration in curricula of topics that relate to the history of science as well as ethical considerations around socioscientific issues. A few examples of national strategies, programmes and other initiatives aiming to raise students' motivation through means other than curricula are presented.

The chapter also dedicates space to the integration of certain environmental sustainability issues in science subjects. Furthermore, the chapter examines how references to digital competences are made in mathematics and science curricula. This part does not address the distance-learning measures brought by the COVID-19 pandemic (a short overview of this topic is provided in Chapter 2).

Across Europe, curricula may include the issues explored in this chapter as objectives, attainment targets, expected learning outcomes, methodological guidelines, etc. It is important to note at the outset that curricula documents provide indications as to which dimensions should be incorporated into mathematics or science teaching and increase the likelihood that the topic is addressed. However, top-level documents do not tell us what actually happens in the classroom. When a certain issue is not directly mentioned in a curriculum or in other top-level regulations, the topic could nevertheless be part of the content of a textbook, other learning materials or student project work. Often, the teaching and learning programmes are general guidelines for teachers, but it is expected that they will use a range of resources to connect the subject with real-life applications and other contextual matters.

Most of the analysis in this chapter refers to grades 1–4 and grades 5–8 (62). This aligns with the international survey data on student achievement (see more in Chapters 1 and 7).

5.1. Real-life applications in teaching mathematics

There is no doubt that, in order to make sense of their learning, students need to make connections with their experiences outside the school. Geiger, Goos and Forgasz (2015) emphasise that numeracy is not only the mastery of basic arithmetic skills learned in school but also the ability to solve real-world problems. This is an important aspect at all grades of mathematics instruction at school. However, students often view mathematics as detached from reality (Aguirre et al., 2013; Vos, 2018). Some studies (Hunter et al., 1993; Perlmutter at al., 1997) suggest that children perceive taught mathematics as separate from everyday life already in primary school.

In order to get a glimpse into how the real-life application of mathematics is addressed in Europe, experts in 39 European education systems were asked to indicate whether certain selected examples are explicitly mentioned in their curricula. Moreover, the distinction was made between mathematics curricula and curricula of any other subject.

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(62) Some countries may structure their curricula in different ways; for example, learning outcomes may be specified for grades 1–3, grades 4–6 and grades 7–9. In such cases, the data show the segments of curricula that include grade 4 or grade 8. All such deviations are described in the notes of Annex II.

The analysis indicates that curricula often suggest teaching mathematics using functional contexts (see Figure 5.1). The general reference to the use of mathematics in real life is included in the curricula of almost all analysed education systems: in 37 education systems out of 39 in grades 1–4 and 38 education systems out of 39 in grades 5–8. Several countries also encourage the functional use of mathematics in curricula of other subjects.

The examples below illustrate how such general references are formulated.

In **Belgium (Flemish Community)**, one of the attainment targets of primary education states ‘pupils are able to apply the concepts, insights and procedures regarding numbers, measurements and geometry … efficiently in meaningful application situations, both inside and outside the classroom’ (63).

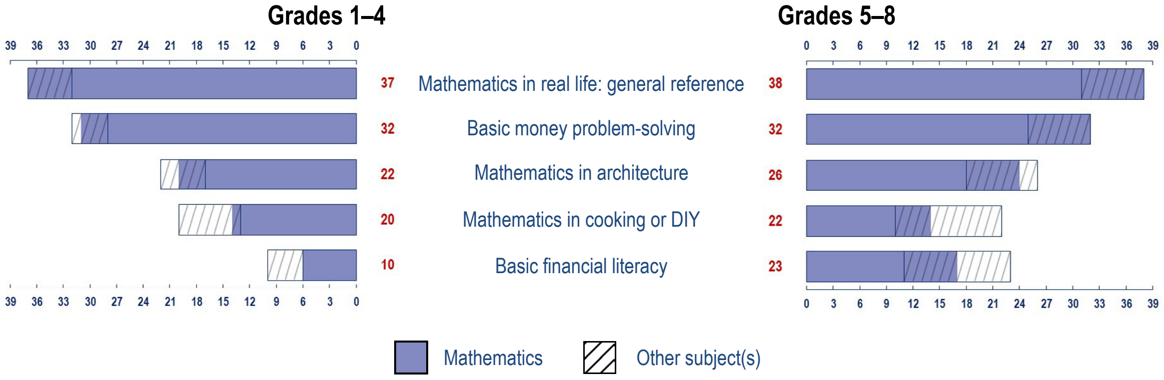
The mathematics curriculum for primary education in **Spain** sets out that the subject is to be learned by using it in functional contexts related to situations of daily life. In addition, it states that methodology in this area should be based on experience: the learning contents start from what is close, and should be approached in contexts of identification and problem-solving (64). Mathematics in real contexts must be included in all primary education curricula in Spain.

In **Italy**, the introduction to the subject of mathematics in the national guidelines for grades 1–8 states ‘mathematics gives tools for scientific description of the world and for tackling useful problems in everyday life’ (65).

In **Sweden**, the compulsory school curriculum specifies the overall aim of mathematics: ‘pupils should also be given the preconditions to develop knowledge to be able to interpret situations in daily life and mathematics, and also describe and formulate these by using mathematical forms of expression’ (66).

The national curriculum of **Liechtenstein** includes – in addition to specific subject competencies – three general learning outcomes: (1) the development of orientation and application of knowledge, (2) a strengthened ability to think, judge and criticise, and (3) the ability to apply mathematics as a language. The ‘development of orientation and application of knowledge’ part of the curriculum involves ‘using topics from the students’ environment such as electronic communication or dealing with money. The mathematical content has to be recognized, discussed, mathematized, represented and calculated, for example in themes such as population development, architecture, astronomy or climatology’ (67).

Figure 5.1: Frequency of selected real-life applications of mathematical concepts mentioned in curricula, 2020/2021



Explanatory notes

The number and the total length of the bar show in how many European education systems (out of 39 in total) a certain topic is explicitly mentioned in curricula. Shading indicates whether the topic is mentioned in mathematics curricula, in the curricula of any other subject(s) or in both.

Country-specific information is available in Annex II, Figure 5.1A.

DIY: do-it-yourself.

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(63) 4.Wiskunde – Strategieën en probleemoplossende vaardigheden (point 4.2).

(64) Royal Decree 126/2014, of 28 February, which establishes the basic curriculum for primary education.

(65) http://www.indicazioninazionali.it/... (p. 60).

(66) Curriculum for the compulsory school, preschool class and school-age educare (skolverket.se).

(67) LiLe (national curricula for kindergarten, primary and lower secondary education).

Figure 5.1 lists several examples of how mathematics can be explored through real-world contexts, namely basic money problem-solving, basic financial literacy, mathematics in architecture, and mathematics in cooking or do-it-yourself (DIY) activities. The most widespread functional context of mathematics is basic money problem-solving. Simple calculations and measurement involving money for computing total costs, changes, unit prices or purchase percentages are explicitly addressed in 32 education systems out of 39. Basic money problem-solving is part of curricula throughout grades 1–8; it is mostly discussed in mathematics lessons. Figure 5.1 also includes the theme 'basic financial literacy', which refers to calculation of credit and interest, understanding the distinction between gross and net income, making a budget, etc. These tasks may be considered the next level of difficulty in money-handling tasks and are much more commonly addressed in grades 5–8 than in the first four grades of primary education.

Use of mathematics in architecture is less widespread than basic money handling, but more common than basic financial literacy. All of these examples are explored in more than half of European education systems, mostly in mathematics lessons but also in subjects related to technology and arts. Finally, mathematical concepts may be employed in practical activities such as cooking or DIY. Such functional contexts are suggested in the curricula of around half of the analysed countries.

The following sections discuss each category highlighted in Figure 5.1 in turn.

Basic money problem-solving

The use of money provides an excellent opportunity to apply mathematics as a practical tool in everyday activities. In primary school, using money is a common practice in the area of measurement, as well as a basis to understand the concept of numbers and basic operations (Alpízar-Vargas and Morales-López, 2019). Money serves to build an understanding of concepts such as ordering, counting, comparing the equivalence between a certain number of objects with others of the same nature or with others of a different nature (means of exchange), value, etc.

> In **Belgium (Flemish Community)**, one attainment target of primary education is 'students can manage their money and recognise the value of money in real-life situations' (68).
>
> The **Latvian** curriculum for grade 1 determines that students should be able to 'understand the price of goods in euros and cents in situations with a domestic context (in pictures); use and create shopping lists with quantity and price; consider different ways in which the required amount can be paid' (69).
>
> In **Poland**, one of the learning outcomes related to mathematics in grades 1–3 refers to monetary calculations. Students are expected to convert the Polish zloty into subunits and vice versa, distinguish denominations on coins and banknotes, and understand differences in their purchasing power (70).
>
> The **Icelandic** National Curriculum Guide for Compulsory Schools (71) specifies that, by the end of grade 4, pupils should be able to 'use mathematics to solve tasks of everyday life and recognise the value of money', and, by the end of grade 7, they should 'know the main concepts concerning financial affairs and work on social or environmental problems where information is gathered, processed and solutions found'.

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(68) Lager onderwijs (primary education) (procedure 2.11).

(69) https://mape.skola2030.lv/resources/159 (pp. 52–53).

(70) The Polish core curriculum (https://isap.sejm.gov.pl/), p. 38.

(71) https://www.government.is/... (p. 221).

Basic financial literacy

Basic financial literacy is much more prominent in grades 5–8 than in the first four grades of primary school. Topics such as calculation of credit and interest, gross and net income or budget, are explicitly mentioned in 23 education systems for grades 5–8. In ten education systems, some of these topics are already explored by the end of the first grades of primary education. Calculation of percentages seems to be the most prominent mathematical concept applied in these contexts.

> In **Bulgaria**, the mathematics curriculum for grade 5 uses examples of interest and loans to explore the concept of percentages. Students should know the concept of interest, be able to apply it in problems and calculate simple interest, and apply their knowledge of percentages and simple interest in modelling problems in the field of economics and finance and to solve problems with applied character (72).
>
> In **Estonia**, one of the learning objectives (73) to be achieved during grades 7–9 is that the students 'interpret quantities expressed in percentages in other subjects and in everyday life, including expenses and dangers related to loans (simple interest only)'.
>
> In **Ireland**, one of the statements of learning in junior cycle mathematics is 'the student makes informed financial decisions and develops good consumer skills'. Students are expected to be able to investigate equivalent representations of rational numbers so that they can 'solve money-related problems including those involving bills, VAT [value added tax], profit or loss, % profit or loss (on the cost price), cost price, selling price, compound interest for not more than 3 years, income tax (standard rate only), net pay (including other deductions of specified amounts), value for money calculations and judgements, mark up (profit as a % of cost price), margin (profit as a % of selling price), compound interest, income tax and net pay (including other deductions)' (74).
>
> In **Croatia**, in grade 7, the expected learning outcomes include that the 'student recognizes, describes and connects the elements of the percentage account: percentage, percentage amount and base value in the problem situation. It is important to place the percentage account in the context of financial literacy, which includes the following: price increase, reduction in price, assessment of marketing tricks, gross salary, net salary, taxes' (75).
>
> In **Norway**, grade 5 pupils are expected to be able to create and solve tasks in a spreadsheet for personal finances (76).

The selected real-life application contexts are usually addressed in mathematics lessons, but some other fields of study also explicitly refer to such themes. Basic money problem-solving skills and basic financial literacy may be studied in separate subjects in the areas of social studies, entrepreneurship, and economic or business studies. These economic-oriented subjects are more common in grades 5–8 than in grades 1–4, when specialist teachers offer a broader range of specialised subjects (see more in Chapter 4).

Mathematics in architecture

Mathematical notions are also commonly used in architectural contexts. Learning about construction, technical drawing, dynamic geometry (see more in Section 5.5), etc., may help to increase understanding of space, shapes and measurement. Mathematics in architecture is explicitly mentioned in more than half of European countries' curricula. As Figure 5.1 shows, this topic is slightly more prominent in grades 5–8 than in grades 1–4. Mathematics in architecture is taught in 20 education systems in grades 1–4 and in 26 education systems in grades 5–8. These topics are usually addressed during mathematics lessons, but also appear in subjects such as arts and technology.

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(72) https://www.mon.bg/upload/13483/UP_V_Maths.pdf (pp. 2 and 5).

(73) Appendix 3 of Regulation No 1 of the Government of the Republic of 6 January 2011 – National curriculum for basic schools.

(74) https://www.curriculumonline.ie/... (p. 15).

(75) Curriculum for the subject of mathematics for primary and grammar schools in the Republic of Croatia; Decision on the adoption of the curriculum for the subject of mathematics for primary and grammar schools in the Republic of Croatia, OG7/2019.

(76) https://www.udir.no/lk20/mat01-05/...

In **Czechia**, in grades 6–9, the educational field 'design and construction' is part of the educational area 'people and the world of work'. One of the expected outcomes states 'student designs and constructs simple constructional elements and inspects and compares their functionality, load-bearing ability, stability, etc.' (77).

In **Spain** (autonomous community of Valencia), one assessment criterion in mathematics for grade 6 is that pupils can 'reproduce and classify figures in the environment (natural, artistic, architectural, etc.) based on some of their properties, with the appropriate resources (tape measure, photographs, dynamic geometry programs, etc.), using the appropriate vocabulary, to explain the world around us' (78).

In **Croatia**, in grade 8 mathematics, students apply Thales' instruction to construct (or draw) enlarged (or reduced) images (characters) in a given ratio. Possible research areas are suggested, including buildings in the environment, construction and art. Students also use dynamic geometry programs and other available interactive computer programs and tools, and educational games (79).

In **Malta**, there is a 'length, perimeter and area' topic in the 'measurement' strand of the subject of mathematics for grades 1–6. This topic is based on the following rationale: 'understanding how much space you have and learning how to fit shapes together exactly will help you when you paint a room, buy a home, remodel a kitchen or build a deck. The above are only a few life situations where being able to read, measure, calculate and understand length, perimeter and area is important. Helping our children understand and appreciate this may be fruitful' (80).

Serbia gives the following examples in guidelines for teachers: in grade 4, 'students' skills for space and area estimation should be developed through the understanding of mathematics in architecture and examples of real life context such as floor covering by tiles, estimation of area of playground and classroom etc.' (81).

Geometric concepts in the surrounding world, including architecture, can be an important basis for analysing objects in art education. Examples are provided below.

The **Estonian** National Curriculum for Basic Schools lists ways of integrating mathematics in all compulsory subject fields. For example, it explains that 'art and geometry (technical drawing, measurement) are closely interconnected. The development of art competence can be supported with resources that demonstrate geometry applications in art fields, such as architecture, interior design, ornamental art, design, etc.' (82).

In **Spain**, one of the assessment criteria in the 'arts and crafts' subject in primary education is to 'identify geometric concepts in the reality that surrounds the student, relating them to the geometric concepts contemplated in the area of mathematics with their graphic application' (83).

Mathematics in cooking or do-it-yourself activities

Cooking or do-it-yourself (DIY) activities are often used in the teaching of mathematics, to support children's numeracy learning at home (Metzger, Sonnenschein and Galindo, 2019), especially with young children (Vandermaas-Peeler et al., 2012, 2019). These functional contexts of mathematics are explicitly addressed in school curricula in around half of European countries.

In **Germany**, educational standards for the subject of mathematics for grades 1–4 give an example of what mathematical knowledge, skills and abilities are needed when baking a cake (84).

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(77) Framework education programme for basic education, p. 108.

(78) Decree 108/2014, of 4 July, of the Council, establishing the curriculum and developing the general organization of primary education in the Valencian Community, p. 16 575.

(79) Curriculum for the subject of mathematics for primary and grammar schools in the Republic of Croatia, p. 91, section MAT OŠ C.8.3; Decision on the adoption of the curriculum for the subject of mathematics for primary and grammar schools in the Republic of Croatia, OG7/2019.

(80) Mathematics – A revised syllabus for primary schools (2014), p. 67.

(81) Bylaw on teaching and learning programme for the fourth grade in primary education, p. 40.

(82) Appendix 3 of Regulation No 1 of the Government of the Republic of 6 January 2011 – National curriculum for basic schools, p. 3.

(83) Royal Decree 126/2014, of 28 February, which establishes the basic curriculum for primary education.

(84) Educational Standards for the Subject Mathematics in the Primary Sector (*Bildungsstandards für das Fach Mathematik im Primarbereich*), Resolution of the Standing Conference from 15/10/2004. p. 29.

In **Slovenia**, in mathematics lessons, pupils discuss key concepts from different perspectives based on experience and knowledge from other subjects in order to deepen knowledge and understanding of the concepts (e.g. measuring time during sports, recalculating recipes during home economics, creating a plan for a technical product (e.g. gift box)) ([85]).

As Figure 5.1 indicates, mathematics in cooking or DIY activities is often part of curricula in other fields of study. These topics may be addressed in the subjects labelled technology, wood technology, crafts, practical skills, home economics, etc. In some cases, for example in Ireland, these studies are optional, but generally available to the majority of students.

The **Estonian** curriculum for the field of technology states that specific problem-solving methods used in technology subjects require calculation and measurement skills, and the ability to use logic and mathematical symbols. During stage III (grades 7–9), students are expected to create menus for an event, calculate food costs and know how to compile a budget for an event ([86]).

In **Austria**, in the learning area 'technical work' in grade 2, children apply scales and recognise the importance of measurement in different technical contexts ([87]).

In **Switzerland**, the competence 'pupils can consciously use three-dimensional shapes in their products (e.g. geometric, organic, irregular shapes)' in the subject 'textile and technical crafts' is directly linked to the competence in the mathematics curriculum 'pupils can understand and use the terms side, diagonal, diameter, radius, area, midpoint, parallel, line, straight line, line, grid, intersection, intersect, perpendicular, symmetry, axial reflection, perimeter, angle, right angle, displacement, geo triangle' ([88]).

In **Iceland**, mathematics in cooking is part of the subject area 'home economics' ([89]). The Icelandic National Curriculum Guide for Compulsory Schools stipulates that by the end of grade 4 pupils should be able to 'follow simple recipes using simple measuring equipment and kitchen utensils' and 'use different media to acquire information on simple recipes'. By the end of grade 7, pupils are expected to 'independently follow recipes using the most common measuring equipment and kitchen utensils' and 'use different media to acquire information concerning cooking, nutrition and the handling of food'.

Teaching practices: relating lessons to students' daily lives

As this section reveals, curricula in Europe emphasise the importance of relating mathematics lessons to real-life examples and students' experiences. However, top-level documents cannot indicate the extent to which such practices are used in schools and classrooms. Instead, teachers' responses to international surveys may provide some insight into teaching practices.

The Trends in International Mathematics and Science Study (TIMSS) administered by the International Association for the Evaluation of Educational Achievement (IEA) asked teachers how often they relate lessons to students' daily lives. Figure 5.2 shows the answers from teachers who teach fourth grade mathematics. The data reveal that real-life examples are very often used during lessons. The mathematics teachers of 51.5% of fourth grade students in the EU indicated that they relate almost every lesson to students' daily lives; 30.9% reported doing so in about half of the lessons. 17.6% of fourth grade students in the EU are provided with real-life examples during only some lessons. Almost no teachers said they never relate lessons to students' lives.

There was some variation between countries. In Spain, Albania, Serbia and Croatia, mathematics teachers of more than 80% of grade 4 students used real-life examples in every or almost every lesson. This teaching practice was somewhat less common in Belgium (Flemish Community), Denmark, France, the Netherlands and Norway.

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(85) https://www.gov.si/... (p. 77-78).

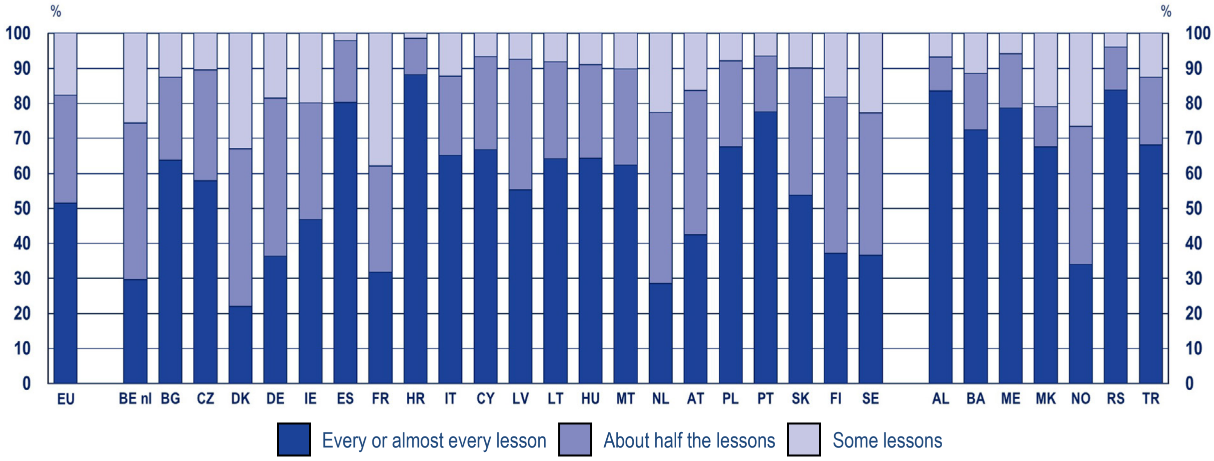
(86) https://www.hm.ee/...

(87) https://www.ris.bka.gv.at/....

(88) Lehrplan21, TTG.2.C.1, 2b and MA.2.A.1, g.

(89) https://www.government.is/... (p. 162).

Figure 5.2: Percentage of fourth graders whose mathematics teachers report relating lessons to students' daily lives, 2019



Source: Eurydice based on IEA, TIMSS 2019 database.

	EU	BE nl	BG	CZ	DK	DE	IE	ES	FR	HR	IT	CY	LV	LT	HU
Every or almost every lesson	51.5	29.7	63.8	57.9	22.1	36.4	46.9	80.3	31.9	88.2	65.1	66.7	55.3	64.2	64.3
About half the lessons	30.9	44.8	23.7	31.7	44.9	45.1	33.2	17.7	30.3	10.4	22.7	26.7	37.3	27.7	26.7
Some lessons	17.6	25.6	12.5	10.4	33.0	18.5	19.9	2.1	37.9	1.4	12.2	6.6	7.4	8.1	9.0
	MT	**NL**	**AT**	**PL**	**PT**	**SK**	**FI**	**SE**	**AL**	**BA**	**ME**	**MK**	**NO**	**RS**	**TR**
Every or almost every lesson	62.4	28.6	42.4	67.6	77.5	53.8	37.1	36.6	83.6	72.5	78.6	67.6	34.0	83.8	68.1
About half the lessons	27.5	48.9	41.3	24.6	16.0	36.3	44.7	40.7	9.7	16.1	15.6	11.4	39.5	12.3	19.4
Some lessons	10.1	22.5	16.2	7.8	6.5	9.9	18.2	22.7	6.7	11.4	5.8	21.0	26.5	3.9	12.4

Explanatory notes

The percentages were calculated based on question G12 (variable ATBG12A) from the teacher questionnaire: 'How often do you do the following in teaching this class? (a) Relate the lesson to students' daily lives', with possible responses being (1) 'Every or almost every lesson', (2) 'About half the lessons', (3) 'Some lessons' and (4) 'Never'. Response categories 3 and 4 were merged into a single category: 'some lessons'. Data were weighted by the mathematics teacher weight.

The percentages were calculated with the missing values excluded. Missing values exceed 25% in the Netherlands and Norway. 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.

5.2. Context-based science teaching

Context-based science teaching emphasises the philosophical, historical and societal aspects of science and technology. Incorporating students' everyday experiences and contemporary societal issues such as ethical or environmental concerns, science teaching aims to develop critical thinking skills and social responsibility (Gilbert, 2006; Ryder, 2002). This approach has been shown to increase students' motivation to engage in scientific studies, and possibly lead to improved scientific achievement and increased up-take of science as a career path (Bennett, Lubben and Hogarth, 2007; Irwin, 2000; Lubben et al., 2005).

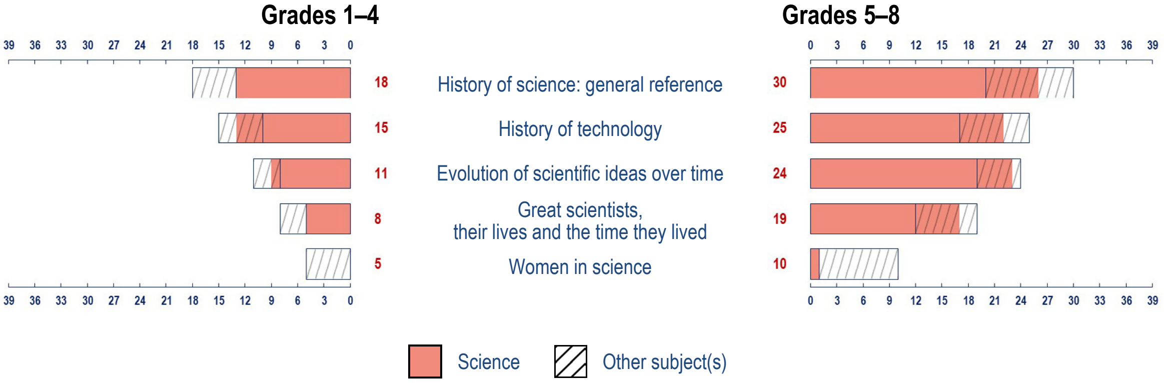
The following section explores in detail how two aspects of context-based science teaching are addressed in curricula in European countries, namely (1) history of science, and (2) science and ethics. Their potential impact on learning outcomes will be further analysed in Chapter 7.

5.2.1. History of science

The value of history as a tool in science teaching is well documented and widely accepted (Allchin, 1995; Henke and Höttecke, 2015). History can be used to enrich classroom practice, promote a deeper understanding of scientific concepts, infuse relevance and contextualise curricula (Abd-El-Khalick and Lederman, 2000; Chamany, 2008). Numerous studies suggest that historical analysis of scientific events may improve students' understanding of the nature of science (Abd-El-Khalick and Lederman, 2000; Wolfensberger and Canella, 2015) and the scientific method itself (Kortam, Hugerat and Mamlok-Naaman, 2021).

History of science or the development of science over time is part of the school curricula in many European countries (see Figure 5.3). The history of human thought about the natural world is addressed in half of European education systems at primary level (grades 1–4). This becomes more prominent in higher grades. At lower secondary level (grades 5–8), most European education curricula make general reference to the history of science. Usually, these topics are addressed in science learning areas, but they may also be part of history lessons or included as cross-curricular teaching principles.

Figure 5.3: Frequency of selected aspects of history of science mentioned in curricula, 2020/2021



Explanatory notes

The number and the total length of the bar show in how many European education systems (out of 39 in total) a certain topic is explicitly mentioned in curricula (or other relevant top-level steering documents). Shading indicates if the topic is mentioned in the science curriculum, mentioned in the curriculum for any other subject and/or as a cross-curricular topic.

Country-specific information is available in Annex II.

Figure 5.3 lists how often selected aspects of history of science are explicitly mentioned in curricula in Europe. Examples in the field of history of technology are discussed in the curricula of 15 education systems in grades 1–4. This theme becomes much more prominent in grades 5–8, where it is explored in 25 education systems. Evolution of scientific ideas over time is addressed in 11 education systems during the first four grades of primary education and in 24 education systems in grades 5–8. The topic of the embodiment of history in the lives of great scientists is less common. Scientific discoveries and the biographies of scientists who made them are discussed in eight education systems in grades 1–4. This angle of looking at history of science is more common in grades 5–8. Great scientists, their lives and the time they lived are mentioned as examples to be used in 19 education systems in grades 5–8. Women in science is the least common of these themes during the first eight grades of school.

The examples below show how the history of science is included as a general reference in science subject curricula.

The subject description of physics in the **Estonian** National Curriculum for Basic Schools states 'the values of students are shaped by associating the solutions to problems with the general cultural/historical context. At the same time, the role of physicists in the history of science is studied as well as the meaning of physics and its applications for the development of humankind' (90).

The **Latvian** new compulsory education standard for science is based on 'big ideas', one of which is that applications of science often have ethical, social, economic and political implications. The history of science is part of this concept (91).

The general part (introduction) of the **Polish** core curriculum for grades 4–8 includes the statement 'physics lessons offer an opportunity to show the achievements of humanity in the development of civilisation'. The biology core curriculum for grades 5–8 states 'it is important to discuss some issues, e.g. the structure of DNA or mechanisms of evolution in the light of important scientific discoveries' (92).

The **Romanian** physics curriculum for grades 6–8 specifies the following learning objective: 'identify historical landmarks in the development of the theories or terms related to the discussed physical phenomena' (93).

In **Slovakia**, the aims of the physics subject area include the following: 'understand the historical development of knowledge in physics as a science and the influence of technical development on the development of knowledge and society' and 'assess the usefulness of scientific knowledge and technical inventions for the development of society, as well as the problems associated with their use for man and the environment' (94).

In many countries, the history of science forms part of the history curricula or is discussed in other social science subjects such as citizenship.

In **Belgium (German-speaking Community)**, the history curriculum in grades 5–6 covers the following topics, among others: the beginnings of the scientific/technical world view; discoveries and inventions; and renaissance and humanism in the modern era: the technical achievements as prerequisites for a new awakening and a new view of the world and of humankind (95).

In **Croatia**, the history of science is part of the history subject curricula (96).

In **Slovenia**, in the history subject area there is a theme on the history of science, which involves discussions on, for example, the beginnings of science (in grade 6) and important artists and scientists from the period of humanism and renaissance (in grade 8) (97).

In **Albania**, history-of-science topics are addressed in social science subjects such as citizenship, in which the lives of great scientists or specific inventions are discussed in a narrative way (98).

In **Bosnia and Herzegovina**, the history subject area follows the entire development of society, including the development of science. Significant scholars and their works are named for each of the historical epochs. Students in grades 6–9 are introduced to the importance of scientific achievements and their consequences on the development of society as a whole (99).

The following sections discuss each category of Figure 5.3 in turn, from the most common to the least common.

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(90) Appendix 4 of Regulation No 2 of the Government of the Republic of 6 January 2011 – National curriculum for upper secondary schools, p. 51.

(91) https://likumi.lv/ta/id/...

(92) Regulation of the Minister of Education of 14 February 2017 on the core curriculum for general education in primary school, Annex No 2, core curriculum for general education in primary school, pp. 25 and 141.

(93) http://programe.ise.ro/... (p. 5).

(94) https://www.statpedu.sk/..., pages 2–3.

(95) http://www.ostbelgienbildung.be/....

(96) Curriculum of the subject history for primary schools and grammar schools in the Republic of Croatia; decision on the adoption of the curriculum for the subject history for primary schools and grammar schools in the Republic of Croatia.

(97) https://www.gov.si/... (p. 8) (grade 6); p. 16 (grade 8).

(98) https://www.ascap.edu.al/programet-e-klases-3-dhe-8/

(99) History curriculum from sixth to ninth grade.

History of technology

The history of technology provides ample examples of how scientific discoveries affect daily life over centuries or during recent decades. It is part of the curricula of 15 education systems in grades 1–4 and 25 education systems in grades 5–8, usually included in science subjects. In lower secondary education, development of technology may also be included in the learning areas that link design with technology, or in information technology classes.

> In **Bulgaria**, the information technology curriculum for grade 8 recommends that students know basic facts from the history of computer systems, as well as basic facts from the history of mobile communications and the characteristics of different generations of mobile communications (100).
>
> In **Denmark**, one of the goals of the subject 'physics and chemistry' during grades 7–9 is formulated as follows: 'the student has knowledge of central technological breakthroughs. The student can describe connections between technological development and the development of the society' (101).
>
> The **Greek** grade 8 curriculum for natural sciences, in the area of physics, proposes several projects that discuss the history of technology. For example, during a project 'from Heron to the locomotive and to the internal combustion engines', students write, using bibliographic sources, a chronicle of the discovery of the locomotive. They connect the evolution of these machines with corresponding eras in the evolution of human civilisation (e.g. industrial revolution). They consider the use of such machines alongside modern environmental problems (102).
>
> In **Cyprus**, the design and technology subject in grade 6 has a chapter called 'mechanisms, wheels and pulleys', with a dedicated topic on the history of means of transport, discussing the discovery of the wheel and the evolution of the car (103).
>
> In **Latvia**, technology development falls under the technology learning area education standard and is developed as a cross-curricular idea. One of the learning outcomes for grade 9 is to give examples of how advances in natural sciences affect a person's daily life (development of media, household technologies and health) (104).

Evolution of scientific ideas over time

History of science is commonly taught by tracing and reflecting on the development of scientific concepts and models (Henke and Höttecke, 2015). Learning about the history of the emergence of a concept over many decades or even centuries enables students to see how the horizon of scientific enquiry changes (Allchin, 1995). The evolution of scientific ideas over time (e.g. historical views on atomic structure, models of the universe, and origins of diseases) is another way for students to approach and structure ideas.

> In **Spain**, the assessment criteria for 'physics and chemistry' in grade 8 include 'acknowledge that atomic models are interpretative instruments of the different theories, and the need to use them for interpretation and understanding of the internal structure of matter' and 'compare the different atomic models proposed throughout history and discuss the evidence that contributed to the development of these theories' (105).
>
> In **Portugal**, the learning area 'physics–chemistry' aims to contribute to an awareness of the scientific, technological and social significance of human intervention in our environment and in culture in general. For example, the content in grade 7 includes the topic 'universe and distances in the universe'. Students should be able to 'explain the role of observation and the instruments used in the historical evolution of knowledge of the universe, through research and selection of information' (106).
>
> In **Slovenia**, the objectives of the chemistry syllabus in grade 8 include that 'pupils understand the importance of the history of the development (research) of the structure of the atom in relation to the development of human society' (107).

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(100) https://www.mon.bg/upload/13464/UP_8kl_IT_ZP.pdf (pp. 2 and 5).

(101) https://emu.dk/... (p. 5).

(102) http://www.et.gr/... (p. 534).

(103) https://scheted.schools.ac.cy/...; http://www.moec.gov.cy/...; https://archeia.moec.gov.cy/... (pp. 55–84).

(104) https://likumi.lv/ta/id/... (13.1.1).

(105) Royal Decree 1105/2014, of 26 December, which establishes the basic curriculum of compulsory secondary education and baccalaureate (pp. 259 and 264).

(106) http://www.dge.mec.pt/...(p. 5).

(107) https://www.gov.si/... (p. 8).

Great scientists, their lives and the time they lived

The history of science may be illustrated with short historical stories and biographies of great scientists (Kortam, Hugerat and Mamlok-Naaman, 2021). By discussing the struggles and failures of scientists, teachers are able to motivate students (Lin-Siegler, 2016). Stories about scientists show the human side of science, and highlight that science is practised by and for real people. Moreover, the discussion of great scientists may potentially establish role models and thus help to recruit more participants in science (Allchin, 1995).

The **Irish** primary school curriculum for science for grades 5 and 6 states that the child should be enabled to recognise the contribution of scientists to society. The discussed themes include 'work of scientists in the past and present' (108).

The **Lithuanian** curricula for science education for grades 5–8 highlights that 'it is necessary to encourage students to engage in independent research and environmental activities, to take an interest in the life and work of famous world and Lithuanian scientists' (109).

In **Hungary**, in physics lessons for students in grades 7 and 8, students learn important details of the lives of prominent physicists (e.g. Newton, Archimedes, Galileo, Jedlik). They learn about the impact of certain chapters of technical development on society and history. One of the tasks is an oral and/or poster presentation of the life and work of a naturalist (e.g. Copernicus, Newton) (110).

In **Slovenia**, the objectives of the physics syllabus in grade 8 include that 'pupils describe the historical development of astronomy and the work of some famous astronomers (Ptolemy, Copernicus, Galileo, Kepler, Newton, etc.)' (111).

In **Switzerland**, in grades 3–6, pupils can access and present information on inventors and their technical developments (e.g. Marconi – radio; Franklin – lightning conductor). In grades 7–9, pupils can access information on selected scientists or scientific teams (e.g. Galileo, Le Verrier, Adams and Galle, Curie, Einstein, the team around Watson and Crick) and discuss what scientists do and how they arrive at their findings (112).

Women scientists

Discussing the contribution of great women scientists may highlight that science is not only a male profession and provide female role models for girls. It may also instigate the debate on structural, interpersonal and identity-related challenges that women scientists have faced throughout history. Furthermore, such discussion may draw students' attention to the ongoing under-representation of women in scientific professions. However, Figure 5.3 shows that the topic of women in science is rarely addressed during the first eight grades of school. In a few countries, equality between women and men is included as a cross-curricular topic or as a general teaching principle. Sometimes, women's roles and difficulties in accessing the science profession are discussed as part of the history curricula.

In **Spain**, one of the cross-curricular elements in primary and secondary education is the development of the values that promote equality between men and women. The new educational law (Organic Law 3/2020 (LOMLOE) Amending the Organic Law of Education 2/2006 (LOE)), which has been in force since the 2021/2022 school year, provides for the following basic content at ISCED 2: 'The scientific labour and the scientists: contribution to the biological and geological sciences and its importance in our society' and 'The role of women in science' (113).

In **Malta**, the learning outcomes framework for science in grade 7 includes the unit 'scientists at work', for which a website on women scientists is listed among resources for teachers (114).

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(108) https://curriculumonline.ie/... (p. 97).

(109) https://duomenys.ugdome.lt/... (p. 685).

(110) https://www.oktatas.hu/kozneveles/... (physics, pp. 6, 7 and 13).

(111) https://www.gov.si/... (p. 8).

(112) Lehrplan21, Learning area 'nature, man, society' for grades 1–6 (NMG.5.3.d); and 'nature and technology' for grades 7–9 (NT.1.1.b).

(113) https://www.boe.es/boe/..., p. 41611.

(114) https://curriculum.gov.mt/... (p. 8).

5.2.2. Science and ethics

Scientific literacy includes not only sufficient understanding of science and technology, but also a critical analysis of social effects of scientific developments (Pleasants et al., 2019). Concentrating on socioscientific issues when teaching science allows for the cultivation of scientific literacy (Zeidler, 2015). Socioscientific issues are controversial social issues that involve technological or scientific questions (Zeidler and Keefer, 2003) and highlight the ethical consequences brought by advances in these fields. The open-ended social problems with conceptual links to science create ideal contexts for bridging school-taught science and the lived experience of students (Sadler, 2011).

Figure 5.4: Frequency of selected aspects of ethics in science mentioned in curricula, 2020/2021

Explanatory notes

The number and the total length of the bar show in how many European education systems (out of 39 in total) a certain topic is explicitly mentioned in curricula (or other relevant top-level steering documents). Shading indicates if the topic is mentioned in the science curriculum, mentioned in the curriculum for any other subject and/or as a cross-curricular topic.

Country-specific information is available in Annex II.

Figure 5.4 shows that science and ethics issues are not very commonly addressed during the first eight grades of school. When present, socioscientific issues are usually debated in biology lessons in lower secondary education (see more on the science domain content of various European countries in Annex I). However, ethical issues in science might also be part of other fields of study or integrated into science teaching as a cross-curricular topic. General reference to science and ethics is given in 15 education systems during the first four grades of primary school. These issues are discussed more often in later grades. Approximately half of European education systems provide a general reference to ethical issues in science during grades 5–8.

The examples of socioscientific issues presented in Figure 5.4 are rarely explicitly mentioned in the curricula for grades 1–4. Very few education systems address ethical aspects of genetically modified organisms (GMOs), the morality of weapons development or ethical considerations in animal testing. These issues are discussed slightly more often in grades 5–8 than in grades 1–4. Ethical aspects of GMOs are explicitly mentioned in the curricula of 11 education systems in grades 5–8. In these grades, the morality of weapons development is a topic in 10 education systems. Ethical considerations in animal testing is the least common theme. It is addressed in six education systems in grades 5–8.

The examples below show how ethics in science is included as a general reference in school curricula in European countries during the first eight grades.

In **Germany** (Bayern), in the biology curriculum for grade 8, students are invited to 'describe ethical problems taken from selected sources, name pros and cons and explain their own take on the issue' (115).

In **Estonia**, social and citizenship competence is part of the syllabus for all the compulsory subject fields, including natural sciences. The syllabus of natural sciences includes the following goal: 'students learn to evaluate the impact of human activities to the natural environment, acknowledge local and global environmental issues and find solutions for them. Importance is given to solving dilemma problems, where decisions have to be made considering science perspectives as well as aspects related to human society – legislative, economical, ethical, and moral perspectives' (116).

In **Spain**, the description of the 'biology and geology' learning area for grade 7 includes that 'students must develop attitudes conducive to reflection and analysis on the great scientific advances of today, their advantages and the ethical implications'. For grades 7 and 8, the curriculum further specifies that students should 'use ethical values in the scientific and technological fields, in order to avoid its inappropriate application and solve the moral dilemmas that sometimes arise, especially in the fields of medicine and biotechnology' (117).

In **France**, in grades 1–6, the concept of science and ethics concerns the development of responsible behaviour in relation to the environment and health. In grades 7 and 8, it involves examining the developments in the economic and technological fields, and understanding the social and ethical responsibilities that result from them (118).

In **Croatia**, the biology curriculum for grade 8 covers ethics in biological research. It includes the following description: 'students discuss the responsibilities of scientists and society as a whole when using the results of biological discoveries' (119).

The **Latvian** curriculum for biology includes the following learning outcome: '[the student] evaluates ethical, economic and political aspects of science achievements' (120).

The introduction to the **Polish** core curriculum for general education in primary schools, for grades 1–3, includes the following school task: 'the organisation of classes … that offer the possibility to get to know the values and interrelations of natural environment components, get to know the values and norms originating from a healthy ecosystem and behaviours resulting from these values' (121).

The **Portuguese** curriculum formulates the following learning outcome in natural sciences for grade 8 students: 'critically analyse the environmental, social and ethical impacts of scientific and technological developments' (122).

In **Finland**, pupils are given opportunities to practise making choices and acting in a sustainable way. For example, in biology lessons for grades 7–9, pupils examine the opportunities and challenges of biotechnology (123).

The following sections discuss each category of Figure 5.4 in turn, from the most common to the least common aspects.

Ethical aspects of genetically modified organisms

The topic of genetically modified organisms (GMOs) has been used as a suitable context for students to actively reflect and argue about complex social issues related to science (Christenson and Chang Rundgren, 2014). There is still a great deal of controversy surrounding issues relating to GMOs

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(115) www.lehrplanplus.bayern.de/... (B8 1.3).

(116) Appendix 4 of Regulation No 2 of the Government of the Republic of 6 January 2011 – National curriculum for upper secondary schools, p. 51.

(117) Royal Decree 1105/2014, of 26 December, which establishes the basic curriculum of compulsory secondary education and baccalaureate, pp. 205 and 541.

(118) https://www.education.gouv.fr/...

(119) Curriculum for the subject biology for primary and grammar schools in the Republic of Croatia; Decision on the adoption of the curriculum for the subject biology for primary and grammar schools in the Republic of Croatia, OG7/2019, p. 30.

(120) https://mape.skola2030.lv/resources/124 (p. 70).

(121) Regulation of the Minister of Education of 14 February 2017 on the core curriculum for general education in primary school, Annex No 2, core curriculum for general education in primary school, p. 17.

(122) http://www.dge.mec.pt/... (p. 11).

(123) National Core Curriculum for Basic Education, pp. 379–384.

(Castéra et al., 2018). Ethical aspects of GMOs are part of the curricula for lower secondary education in several European countries.

In **Denmark**, in the subject of biology, students are expected to have knowledge of the environmental impacts of genetic manipulations and the possible influence of such manipulations on evolution by the end of grade 9 ([124]).

In **Sweden**, biology teaching in grades 7–9 deals with the following core content: 'genetic engineering, opportunities, risks and ethical questions arising from its application' ([125]). The new course syllabus, valid from 1 July 2022, reformulates the topic as 'some genetic engineering methods as well as opportunities, risks and ethical issues related to genetic engineering' ([126]).

In **Switzerland** and **Liechtenstein**, the learning area 'nature and technology' for grades 7–9 includes the following competence: 'pupils are able to inform themselves in a guided manner about the significance of scientific and technical applications for humans, especially in the areas of health, safety and ethics (e.g. genetic engineering, nanomaterials, preservation of milk, antibiotics)' ([127]).

In **Turkey**, the topic 'genes' is covered in detail in grade 8. It includes biotechnology and ethical issues regarding genetic studies ([128]).

Morality of weapons development

The morality of weapons development is another example of a socioscientific issue that may be used in teaching. Debates about the development of weapons highlight the contradictory roles that science and scientists play in society (Morales-Doyle, 2019).

In **Czechia**, the educational area 'people and society' in lower secondary education includes an educational field history. One of the expected outcomes in the topic 'modern area' includes 'using examples, demonstrates the abuse of technology during the World Wars and its consequences' ([129]).

The **Polish** core curriculum for general education in primary school, for grades 5–8, includes the following learning objective for the technology subject area: 'recognising the value of and risks related to technology in terms of integral human development and respect for human dignity. Description of risks to modern civilisation caused by technological progress (wars, terrorism …)' ([130]).

In **Bosnia and Herzegovina**, in community lessons during grades 6–9 students study the development of weapons and gain an understanding of the negative consequences of their use ([131]).

Ethical considerations in animal testing

Curricula in schools in Europe include many examples of caring about animals and their natural habitats (see, for example, the biodiversity theme in Section 5.4). However, ethical considerations in animal testing is very rarely part of the curricula during the first eight grades of school.

In **Croatia**, during biology lessons, primary school students are expected to discuss the responsibilities of scientists and society as a whole when using the results of biological discoveries. The connections between biological discoveries and the development of civilisation, the application of technology in everyday life and human impact on natural processes are explained using the following examples: artificial selection, cloning, GMOs, crossbreeding and ethics of animal use in scientific research ([132]).

([124]) https://emu.dk/..., p. 5.

([125]) https://www.skolverket.se/..., p. 170.

([126]) https://www.skolverket.se/..., p. 3.

([127]) Lehrplan21.

([128]) https://mufredat.meb.gov.tr/... (pp. 48 and 49).

([129]) Framework education programme for basic education (https://www.msmt.cz/file/43792)

([130]) Regulation of the Minister of Education of 14 February 2017 on the core curriculum for general education in primary school, Annex No 2, core curriculum for general education in primary school, p. 182 (p. IV.2.).

([131]) https://www.rpz-rs.org/... (p. 63).

([132]) Curriculum for the subject biology for primary and grammar schools in the Republic of Croatia, p. 30.

In **Switzerland**, a teacher guide for the subject 'ethics, religions, society' (ISCED 2) includes the following example questions for discussion: 'Do animals have feelings, do they have rights, is it okay to use animals and plants for experimentation in school, etc.?' ([133])

5.3. Large-scale initiatives to motivate students in mathematics or science

The previous sections examined curricula and learning objectives that may contribute to increasing students' motivation to learn mathematics and science. This section provides a brief insight into national strategies, programmes and other initiatives aiming to raise students' motivation through other means. The November 2021 Council recommendation on blended learning approaches for high-quality and inclusive primary and secondary education ([134]) recommends that Member States develop longer-term strategic approaches to blended learning. This includes blending the school site and other physical environments, and blending different learning tools, both digital (including online learning) and non-digital.

This section discusses new, innovative teaching methods embedding different tools for learning and/or combining different environments to enrich the learning experience. Such initiatives may include the participation of external professionals; aim to create an appropriate balance between teacher- and student-led learning on the one hand, and collaborative and independent learning on the other; and engage students in experiments using up-to-date infrastructure or digital technologies.

Several education systems promote the development of new educational standards and teaching practices, often in partnership with tertiary education institutions. Teachers can also be supported through professional development programmes and training courses.

In **Germany**, the Standing Conference of the Ministers of Education and Cultural Affairs has repeatedly addressed the development of school teaching in mathematics, information technology, natural sciences and technology (MINT) subjects ([135]). By introducing educational standards in this area, it has facilitated the description of demanding and achievable objectives in the form of competences.

In **Italy**, the project 'Science education' is designed to promote enquiry-based laboratory teaching in science, not as a theoretical statement but through innovative practical proposals, diversified content, methodologies, tools and levels of competence ([136]).

The **Austria**-wide initiative '*Innovationen machen Schulen top!*' ('Innovations make schools great!') has been active for many years in improving mathematics, informatics, natural sciences, German and technology teaching by involving a broad network of partners. This initiative supports teachers in Austrian schools to implement innovations in these subjects with the help of experts who accompany the teachers to improve their teaching ([137]). In addition, the project '*Mathematik macht Freu(n)de*' ('Mathematics makes friends') aims to enrich schools with a new mathematics teaching culture. Prospective teachers support secondary school students with learning difficulties and address their fear of mathematics ([138]).

In **Slovenia**, the national project 'NA-MA Poti' on natural science and mathematical literacy, empowerment, technology and interactivity aims to develop and test pedagogical approaches and flexible forms of learning ([139]).

([133]) Ethics in compulsory education (in the context of the introduction of Lehrplan21), p. 16.

([134]) Council Recommendation of 29 November 2021 on blended learning approaches for high-quality and inclusive primary and secondary education 2021/C 504/03, OJ C 504, 14.12.2021.

([135]) Recommendation of the Standing Conference on Strengthening Mathematics, Science and Technology Education (*Empfehlung der Kultusministerkonferenz zur Stärkung der mathematisch-naturwissenschaftlich-technischen Bildung*), Resolution of the Conference of Ministers of Education and Cultural Affairs from 07/05/2009.

([136]) http://www.scuolavalore.indire.it/superguida/scienze/

([137]) https://www.imst.ac.at/

([138]) https://mmf.univie.ac.at/

([139]) https://www.zrss.si/projekti/projekt-na-ma-poti/

The LUMA Centre in **Finland** is a science education network of Finnish universities. In order to inspire and motivate children and youth in science, technology, engineering and mathematics (STEM), the centre develops new methods and activities in science and technology education. Furthermore, it supports the lifelong learning of teachers working at all levels of education, and strengthens the development of research-based teaching (140).

In 2013, the '*Förderung MINT Schweiz*' ('Promotion of STEM in Switzerland') initiative started in **Switzerland**, with a special focus on digitisation. The third cycle of the initiative runs from 2021 to 2024. Among other projects, the initiative includes STEM-relevant courses and workshops for active teachers and students of teacher-training institutions (141).

In **Montenegro**, in order to provide support for teachers to implement the new key competences framework, an online training programme for teachers has been organised. In addition, an internet platform to support participants has been developed (142).

Some education systems concentrate on enriching students' learning experiences with extracurricular activities or activities included in the school day with the participation of external professionals. This can be done through the promotion of mathematics, science or other thematic clubs in schools (e.g. in Czechia, Spain and Portugal), by creating opportunities for students to actively participate in research projects or problem-solving activities (e.g. in Estonia, Malta and Finland), or by organising large-scale extracurricular activities (e.g. in Croatia, Luxembourg and Switzerland).

In the autonomous community of Andalucía in **Spain**, there is a science, technology, engineering, arts and mathematics (STEAM) project on aerospace research, which is carried out in classrooms in primary and secondary education (ISCED 1-2). One of its objectives is to promote the integration of STEAM tasks and activities in the curriculum (143).

The **Croatian** Makers Movement (144) has developed and implemented one of the largest extracurricular STEM programmes in the EU, involving over 200 000 children in Croatia. The goal is to provide students with access to the best technology that supports their learning process and sparks their curiosity about making new discoveries.

5.4. Environmental sustainability in science education

'Embedding environmental sustainability in all education and training policies, programmes and processes is vital to build the skills and competences needed for the green transition', states the recent European Commission proposal for a Council recommendation on learning for environmental sustainability (145). The proposal further urges Member States to 'develop comprehensive curricula frameworks, allowing the time and space for in-depth learning for environmental sustainability so learners can develop sustainability competences from an early age'.

Against this background, this section looks at whether and how environmental sustainability, including biodiversity themes, is addressed in science curricula in Europe. It also briefly describes whether such topics are included in the curricula of subjects other than science (e.g. arts, crafts, ethics and technology) or addressed in a cross-curricular theme.

5.4.1. Selected environmental sustainability topics

Environmental sustainability is a complex and ambiguous learning area that is difficult to delineate (Molderez and Ceulemans, 2018). The European sustainability competence framework 'GreenComp' defines sustainability as 'prioritising the needs of all life forms and of the planet by ensuring that human activity does not exceed planetary boundaries' (Bianchi, Pisiotis and Cabrera Giraldez, 2022,

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(140) https://www.luma.fi/en/

(141) https://akademien-schweiz.ch/fr/themen/mint-forderung/; https://akademien-schweiz.ch/de/themen/mint-forderung/

(142) https://www.ikces.me/

(143) https://www.adideandalucia.es/...

(144) https://croatianmakers.hr/en/home/

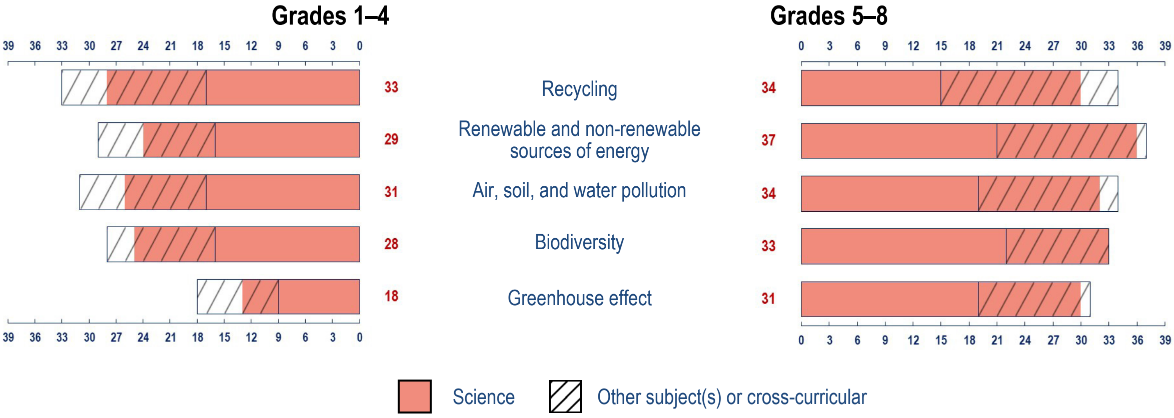
(145) European Commission proposal for a Council recommendation on learning for environmental sustainability, COM(2022) 11 final, 2022/0004(NLE).

p. 12). The following five common topics are used in this section to grasp how such notions are included in science curricula in Europe (see Figure 5.5):

- recycling,
- renewable and non-renewable sources of energy,
- air, soil and water pollution,
- biodiversity,
- greenhouse effect.

The list does not aim to be exhaustive; it rather strives to provide a structured frame of analysis to explore this vast and interconnected learning area. Some of the selected topics are broad (e.g. biodiversity) whereas others are quite specific (e.g. greenhouse effect). This is to account for different levels of detail in the curricula of various European countries. Moreover, in line with the rather formal approaches in science teaching and learning frameworks, the analysis emphasises knowledge-based topics rather than values or behaviours.

Figure 5.5: Frequency of selected environmental sustainability topics mentioned in curricula, 2020/2021



Explanatory notes

The number and the total length of the bar show in how many European education systems (out of 39 in total) a certain topic is explicitly mentioned in curricula (or other relevant top-level steering documents). Shading indicates if the topic is mentioned in the science curriculum, mentioned in the curriculum for any other subject and/or as a cross-curricular topic.

Country-specific information is available in Annex II.

The analysis reveals that the selected environmental sustainability topics form a compulsory part of curricula in all European countries (see country-specific data in Figure 5.6A in Annex II). The only country that did not mention any of the selected topics in its curricula is the Netherlands, where schools enjoy a very high level of autonomy. However, care for the environment is a compulsory part of ISCED levels 1 and 2 in the Netherlands.

Environmental sustainability issues usually form an integral part of science subjects. In primary education, for example, nature and its beauty and diversity, as well as the need to take care of the environment, are often studied in the integrated science subject or discussed in the learning areas that include both social and environmental aspects. In lower secondary education, learning about environmental sustainability takes place in biology, geography, physics and chemistry lessons. Moreover, in approximately one third of the countries, some of the selected environmental sustainability topics are part of the curricula of other subjects, primarily arts, crafts, ethics and technology.

Of the analysed topics, recycling is the most commonly addressed in learning about environmental sustainability in grades 1–4. Themes on waste, how to sort waste and how to reduce the amount of waste that people generate are present in the curricula of 33 education systems during the first four grades of primary education. These issues are explored in 34 education systems in grades 5–8. The topic on renewable and non-renewable sources of energy is the most common sustainability topic in grades 5–8, addressed in 37 education systems. In grades 1–4, pupils learn to distinguish between polluting and clean energy sources in 29 education systems. Air, soil and water pollution is part of the curricula of 30 education systems in grades 1–4 and of 34 education systems in grades 5–8. Biodiversity is addressed in 28 education systems during the four first grades and in 33 education systems in the following four grades. The technical process of the greenhouse effect is more commonly explored in grades 5–8 (31 education systems) than in grades 1–4 (18 education systems).

The following sections discuss each category of Figure 5.5 in turn, from the most common to the least common.

Recycling

Many of the countries state in learning goals associated with the early grades of primary education that students should learn how to sort waste (e.g. in the 'nature and society' subject at grade 3 in Croatia (146), in natural sciences during grades 1–3 in Poland (147) and in the integrated science subject 'the world around us' at grade 2 in Serbia (148). More advanced grades add more learning outcomes related to how waste is generated; students in these higher grades are asked to reflect and draw conclusions.

> In **Latvia**, a learning outcome for grade 6 in science is the student 'purposefully sorts materials used in everyday life according to labelling and regulations about sorting waste and argues that recycling is an opportunity in the economy of raw materials and energy (149).
>
> In **Portugal**, eighth grade natural sciences students should be able to explain the importance of the collection, treatment and sustainable management of waste and propose measures to reduce risks and minimise damage from water contamination as a result of human activity. Students should relate waste and water management to the promotion of sustainable development (150).
>
> In **Sweden**, the chemistry curriculum in grades 4–6 includes the conversion of raw materials to end products, how they become waste and how that waste is handled and returned to nature (151). The new course curriculum valid from 1 July 2022 reformulates the topic as 'Processing of raw materials into products, such as metals, paper and plastic. How the products can be reused or recycled' (152).
>
> The **Icelandic** curriculum guide includes the following competence criteria for the natural sciences: by the end of grade 4, pupils are expected to discuss the relationship between humans and nature, and to be able to sort waste; and by the end of grade 7, pupils are expected to be able to describe humanity's use of natural resources and to draw conclusions about the purpose of sorting waste (153).
>
> In **Montenegro**, the biology curriculum for the grade 8 includes the following educational outcomes: the student explains the importance of good waste management and describes the importance of recycling (154).

In Europe, the topic of recycling is often present in the learning areas related to technology, home economics, arts and crafts.

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(146) Curriculum for the subject nature and society for primary schools in the Republic of Croatia, p. 52; Decision on the adoption of the curriculum for the subject nature and society for primary schools in the Republic of Croatia, OG7/2019.

(147) Regulation of the Minister of Education of 14 February 2017 on the core curriculum for general education in primary school, Annex No 2, Core curriculum for general education in primary school, p. 40 (IV.1.8).

(148) http://www.pravno-informacioni-sistem.rs/... (p. 47).

(149) Government regulation No. 747 – compulsory education standard (13.2.2).

(150) http://www.dge.mec.pt/... (pp. 8–11).

(151) https://www.skolverket.se/... (p. 192).

(152) https://www.skolverket.se/... (p. 3).

(153) https://www.government.is/... (p. 183).

(154) https://zzs.gov.me/... (p. 25).

In **Bulgaria**, in the technology and entrepreneurship learning area, during grades 3 and 4, students discuss and identify ways to separate waste; learn about the benefits of recycling paper, metal, glass and plastic; carry out research and model a recycling plant; learn to recognise materials that can be recycled; and collect materials for recycling ([155]).

In **Ireland**, in grades 7–9 home economics, students learn to demonstrate ways in which clothing and/or household textile items can be repaired, reused, repurposed, recycled and upcycled ([156]).

In **Poland**, in grades 5–8, the learning objectives in the subject of technology include 'shaping the ability to segregate and reuse waste found in the immediate environment'. In one of the learning contents, it is specified that the student should be able to 'distinguish and apply the principles for the separation and treatment of waste made of different materials and electronic components' ([157]).

In **Switzerland** and **Liechtenstein**, recycling is part of the 'textile and technical crafts' subject. In grades 3–6, pupils should be able to distinguish products and assign them to selected disposal categories (batteries, paint, solvents, light bulbs, recyclable plastics). In grades 7–9, pupils should know the products that require special disposal measures and know how to recycle or reuse them sensibly (old clothes, electronic devices, wooden products, etc.) ([158]).

Renewable and non-renewable sources of energy

In primary education, students learn to distinguish between clean and polluting energy sources, while in lower secondary education they are expected to evaluate the environmental impact of the energy demands and to analyse and discuss the conditions needed to achieve sustainable energy management. Almost all European education systems (37 out of 39) explicitly refer to renewable and non-renewable sources of energy in curricula for grades 5–8.

In **Czechia**, one of the expected outcomes in the educational field of physics in lower secondary education (grades 6–9) is that students are able to evaluate the advantages and disadvantages associated with the use of various sources of energy in terms of their environmental impact ([159]).

In **Spain**, learning standards for natural sciences in primary education include 'identify and explain some of the main characteristics of renewable and non-renewable energies, identify different sources of energy and raw materials' ([160]).

In **Luxembourg**, in grades 7 and 8 in the subject of science, students are expected to 'know the term renewable energies and their use' and be able to discuss the debates on renewable energy' ([161]).

In **Poland**, in grades 5–8, one of the specific biology learning contents in the field 'ecology and environmental protection' requires that the student 'presents renewable and non-renewable natural resources and proposals for rational management of these resources in accordance with the principle of sustainable development'. In geography, the student should be able to 'analyse natural and non-natural conditions favouring or limiting the production of energy from non-renewable and renewable sources' ([162]).

Air, soil and water pollution

Air, soil and water pollution is explicitly addressed in the science curricula for grades 1–4 of 25 education systems. This issue is further explored in 31 education system in grades 5–8. Usually, pupils are expected to be able to indicate the most significant sources of air and water pollution (e.g. in

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([155]) https://www.mon.bg/upload/12210/UP_TehnPredriemachestvo_3kl.pdf (p. 3) and https://www.mon.bg/upload/13772/UP14_TehnPred_ZP_4kl.pdf (p. 4).

([156]) https://www.curriculumonline.ie/...

([157]) Regulation of the Minister of Education of 14 February 2017 on the core curriculum for general education in primary school, Annex No 2, Core curriculum for general education in primary school, p. 182 (VI.2) and p. 183 (III.8).

([158]) Lehrplan21 (TTG.3.B.2.b / TTG.3.B.2.c).

([159]) Framework education programme for basic education, p. 66.

([160]) Royal Decree 126/2014, of 28 February, which establishes the basic curriculum for primary education, p. 19.

([161]) https://ssl.education.lu/eSchoolBooks/Web/ES/1100/1/Programmes, Document PROG_6G_SCNAT (p. 21).

([162]) Regulation of the Minister of Education of 14 February 2017 on the core curriculum for general education in primary school, Annex No 2, Core curriculum for general education in primary school, p. 141 (biology, VII.9) and p. 123 (geography, XI.2).

science education in grades 1–4 in Lithuania ([163]) and in chemistry lessons during grades 7 and 8 in Hungary ([164])), and to know ways of protecting the environment from pollution.

> In **Czechia**, the cross-curricular environmental education subject (for ISCED levels 1 and 2) includes the following thematic areas: water (relationship between water quality and quality of life, importance of water in human activities, safeguarding water quality, drinking water in the world and in Czechia, possible solutions to challenges), atmosphere (importance to life on earth, threats to the atmosphere, climate change, global interconnectedness, air quality in Czechia) and soil (interconnectedness of environmental components, source of nutrition, threats to soil, changes in the need for agricultural land, the new function of agriculture in the landscape).
>
> In **Poland**, in grades 5–8, the learning contents in chemistry include listing the sources, types and effects of air pollution, and describing ways to protect the air from pollution ([165]).
>
> In **Slovenia**, the integrated science curricula for grade 3 includes the following aim: pupils know that traffic pollutes the air, water and soil, and know some behaviours that help to avoid pollution (e.g. travelling on foot, by bike, by train) ([166]).

Biodiversity

The value and uniqueness of nature as well as threats to biodiversity and ecosystems are very common sustainability themes in science curricula, especially biology curricula. Schools in many European countries aim to instil sustainable attitudes and behaviours towards the environment and teach children to argue for solutions to preserve biodiversity.

> In **Estonia**, an important topic in natural sciences in grades 1–3 is seasons and their effect on biodiversity and the diversity of the local environment. One of the learning outcomes for the completion of grade 3 is ‘observe the beauty and uniqueness of nature and value the biodiversity of their surroundings’. A substantial part of the learning content in grades 4–6 is diversity of life on earth and various living environments. In grades 7–9, the theme ‘ecology and environmental protection’ includes the following learning outcomes: solve problems connected to the protection of biodiversity, value biodiversity and have a responsible and sustainable attitude ([167]).
>
> In **Croatia**, in biology lessons in grade 8, students analyse the impact of human activity on biodiversity; describe natural selection and mutations as aspects of evolution, noting the importance of fossils and transitional forms for the study of evolution; and explain the connection between living conditions and the human activity and population density of an area ([168]).
>
> In **Italy**, the biology domain within the integrated science subject defines the following learning objective for grades 6–8: ‘Assume ecologically sustainable behaviours and personal choices. Respect and preserve biodiversity in environmental systems’ ([169]).
>
> In **Cyprus**, in grade 5, the unit ‘natural environment: biodiversity-conservation and protection’ has the following attainment targets: recognise the need to preserve biodiversity and argue for solutions to a local biodiversity problem ([170]).
>
> In **Hungary**, during science lessons in grades 5 and 6, students treat the diversity of life forms as a value to be preserved, recognise the aesthetic beauty inherent in a biodiverse environment and argue against endangering biodiversity.

Greenhouse effect

The greenhouse effect is addressed in grades 5–8 in various subject lessons – biology and geology (e.g. Spain), chemistry (e.g. Greece, Montenegro), biology (e.g. Cyprus), geography (Belgium

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([163]) https://www.sac.smm.lt/... (p. 235; 5.6.1).

([164]) https://www.oktatas.hu/kozneveles/... (chemistry, pp. 12 and 13).

([165]) Regulation of the Minister of Education of 14 February 2017 on the core curriculum for general education in primary school, Annex No 2, Core curriculum for general education in primary school, p. 146 (IV.10).

([166]) https://www.gov.si/... (p. 16).

([167]) https://www.hm.ee/...

([168]) Curriculum for the subject biology for primary and grammar schools in the Republic of Croatia; Decision on the adoption of the curriculum for the subject biology for primary and grammar schools in the Republic of Croatia, OG7/2019.

([169]) http://www.indicazioninazionali.it/... (p. 70).

([170]) http://archeia.moec.gov.cy/... (pp. 88 and 89).

(German-speaking Community)) – or in integrated science lessons (e.g. Denmark, Lithuania, Portugal).

In **Denmark**, in grade 6, one of the aims of the 'nature and technology' subject specifies that students should have knowledge of energy efficiency and the greenhouse effect (171).

In **Malta**, the primary education science syllabus for grade 6, as part of the topic 'Sharing our world: habitats', lists the following aims: 'know that the environment is a system which can be harmed' and 'know about dangers posed to the environment such as over population, pollution, the destruction of rain forests, acid rain, greenhouse effect, poaching …' (172).

In **Portugal**, in grade 8 natural sciences, students are expected to relate the influence of living beings to the evolution of the earth's atmosphere and the greenhouse effect on earth (173).

In **Slovenia**, in the natural science subject in grade 7, pupils learn about the causes of increased greenhouse gas emissions (carbon dioxide, methane, nitrogen oxides) and the associated overheating of the atmosphere (increased greenhouse effect), which is reflected in climate change and terrestrial and aquatic ecosystems (174).

5.4.2. Integration of environmental sustainability in curricula

As concluded in the previous section, environmental sustainability issues are part of the curricula of all of the European countries. They usually form an integral part of science subjects. In addition, environmental sustainability may also be treated as a cross-curricular theme, a primary value or an overarching goal of the curricula of all subjects. A recent report by the European Commission argues that sustainability should be transversal and intrinsic in education to enable students to tackle climate change and relearn to live in tune with the planet (Bianchi, 2020). However, Figure 5.6 shows that sustainability issues are weaved into the content planning and pedagogies of every learning area in fewer than half of the European countries in primary and lower secondary education.

In Europe, there are several patterns in terms of how the meta-issue of environmental sustainability is phrased in curricula. Several countries emphasise the environment.

'Environmental education' is included as a cross-curricular subject in **Czechia** (175).

'Environmental education' has been anchored as an interdisciplinary teaching principle in the **Austrian** school system since 1979. Environmental education aims to raise awareness of the limitations of our living conditions, and intends to promote readiness and competence to act in order to be actively involved in shaping the environment (176).

In **Serbia**, the environmental sustainability cross-curricular competence is titled 'responsible relationship with the environment' (177).

The term 'sustainability' is used in Iceland.

Sustainability is one of the six fundamental pillars in the **Icelandic** National Curriculum Guide for Compulsory Schools. The pillars 'should be evident in all educational activities and in the content of school subjects and fields of study, both regarding the knowledge and the skills that children and youth are to acquire … Education towards sustainability aims at making people able to deal with problems that concern the interaction of the environment, social factors and the economy in the development of society' (178).

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(171) https://emu.dk/... (p. 7).

(172) https://curriculum.gov.mt/en/Curriculum/Year-1-to-6/... (p. 59).

(173) http://www.dge.mec.pt/... (p. 7).

(174) https://www.gov.si/... (p. 20).

(175) Framework education programme for basic education, p. 135.

(176) https://www.bmbwf.gv.at/Themen/schule/...

(177) Law on the Education System Foundations (*Zakon o osnovama sistema obrazovanja i vaspitanja*), the Official Gazette of the Republic of Serbia, 2017, Article 12 'General cross-curricular competences'.

(178) https://www.government.is/... (pp. 14–19).

In line with the approach promoted by the United Nations Educational, Scientific and Cultural Organization (179), the most common title is 'education for sustainable development' (e.g. Germany, Switzerland, Liechtenstein and Montenegro), and 'sustainable development' is also used (in Croatia). These terms link economic growth – or processes to generate prosperity – with work to preserve the planet and the environment.

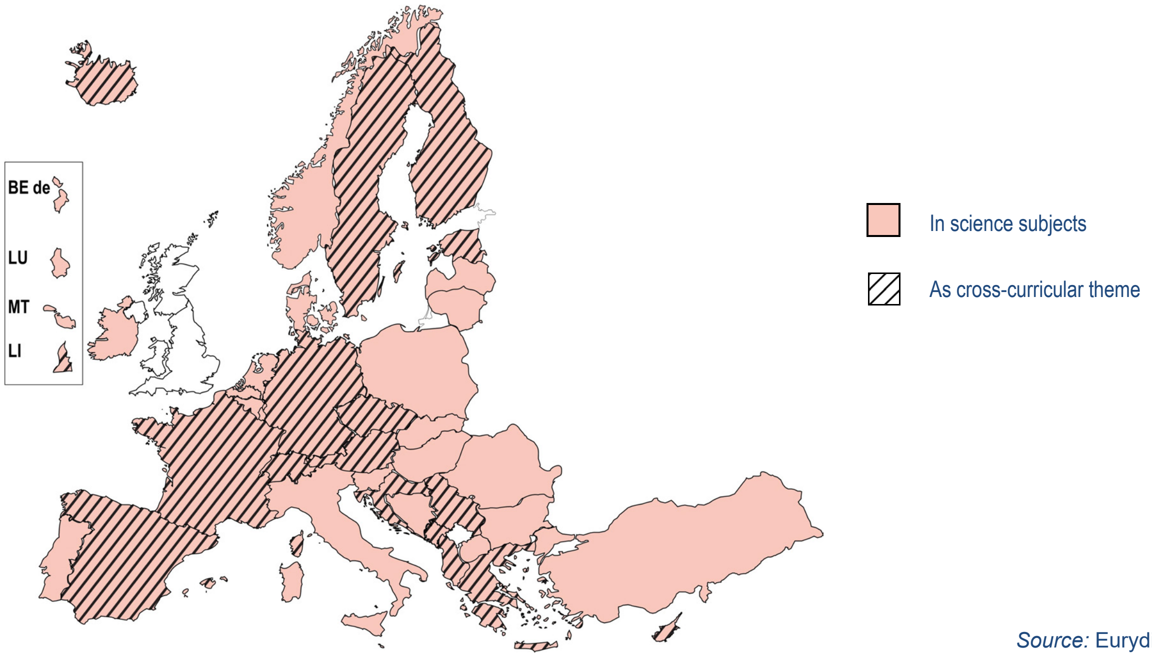
In **Germany**, education for sustainable development is a cross-curricular topic, as defined in the Standing Conference of the Ministers of Education and Cultural Affairs resolution on education for sustainable development (180) and in the orientation framework for the learning area of global development (181).

In **Croatia**, the 'sustainable development' cross-curricular theme (182) supports the development of knowledge about the functioning and complexity of natural systems and knowledge about the consequences of human activities, the benefits of solidarity among people and the importance of acting responsibly towards the environment.

In **Switzerland** and **Liechtenstein**, a cross-curricular topic called 'education for sustainable development' focuses on the natural environment in its complexity and diversity, and on addressing its importance as a basis for human life (183).

In **Montenegro**, goals and principles for sustainable development education have been introduced in the past decade. The education for sustainable development content is part of compulsory subjects, elective subjects, cross-curricular topics and extracurricular activities at all education levels (pre-primary education, primary education, general secondary education and initial vocational education and training). The cross-curricular topics identified are climate change; green economy; environmental protection; sustainable towns and settlements; biodiversity; health education; education and human rights; and entrepreneurial learning (184).

Figure 5.6: Environmental sustainability in curricula, ISCED 1-2, 2020/2021



Source: Eurydice.

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(179) Education for sustainable development is recognised as an integral element of Sustainable Development Goal 4 on quality education. UNESCO is responsible for the coordination of the framework for the implementation of education for sustainable development beyond 2019 (See more at: https://en.unesco.org/themes/education-sustainable-development).

(180) https://www.kmk.org/...

(181) https://www.kmk.org/...

(182) Curriculum of cross-curricular topics on sustainable development for primary and secondary schools; Decision on the adoption of the curriculum for the cross-curricular topics on sustainable development for primary and secondary schools.

(183) https://fl.lehrplan.ch/index.php?code=e|200|4

(184) https://zzs.gov.me/...

Explanatory notes

Environmental sustainability as a cross-curricular theme implies that sustainability, sustainable development and/or environmental issues are explicitly defined as overarching or interdisciplinary teaching principles. Environmental sustainability may also be defined as a key competence, an aim, a pillar, etc. Cross-curricular themes are often defined in the general part of curricula. However, they may also be established in other top-level steering documents.

The category 'In science subjects' includes situations in which environmental sustainability topics are explicitly addressed in any of the science subjects (see Annex I, Curricular organisation of science teaching in compulsory education).

Country-specific note

Belgium (BE nl): The figure shows the situation in grades 1–6 (ISCED 1). The cross-curricular key competence 'sustainability' applies to the first stage of ISCED 2 (grades 7 and 8).

In Estonia, Greece (185), Spain, France and Sweden, the cross-curricular topic includes both elements of environmental sustainability, namely 'the environment' and 'sustainable development'.

In **Estonia**, the 'environment and sustainable development' cross-curricular topic guides pupils to (1) value biological and cultural diversity and ecological sustainability; (2) develop personal environmental opinions and participate in environmental decision-making initiatives, offering solutions to environmental problems at personal, social and global levels; (3) understand nature as a whole system and the mutual interdependence between human beings and the surrounding environment and human beings' dependence on natural resources; (4) understand the connections between various aspects of cultural, social, economic, technological and human development and the risks associated with human activities; and (5) take responsibility for sustainable development and acquire values and behavioural norms that support sustainable development (186).

In **France**, environment and sustainable development education is part of every school's mission and is provided in every grade. Its objective is to make children aware of environmental issues and the ecological transition. It enables acquisition of knowledge relating to nature, the need to preserve biodiversity, the understanding and evaluation of the impact of human activities on natural resources, and the fight against global warming (187).

In **Sweden**, education for environment and sustainable development is specified as a task for schools. Sustainability, including the historical, international and ethical aspects, should be part of all teaching regardless of course or subject. 'An environmental perspective provides opportunities not only to take responsibility for the environment in areas where they themselves can exercise direct influence, but also to form a personal position with respect to overarching and global environmental issues. Teaching should illuminate how the functions of society and our ways of living and working can best be adapted to create sustainable development' (188).

Finally, schools in three of the European countries offer a separate subject on environmental sustainability. This subject is mandatory in Cyprus (ISCED 1) and elective in Greece (ISCED 1 and 2) and North Macedonia (ISCED 2).

In **Greece**, the 'environment and education for sustainable development' subject is offered in primary and lower secondary schools, either in 'skills labs' (included in the school timetable; compulsory) or, in lower secondary education, as an optional subject as part of 'school activities' outside the compulsory daily timetable (189).

In **Cyprus**, in grades 1–6, sustainability topics are included in science curricula and are studied as cross-curricular topics. In addition, in grades 5 and 6, there is a separate mandatory subject named 'environmental education / education for sustainable development' (190).

In **North Macedonia**, all schools offer an elective subject called 'environmental education' in grades 7–9 (191).

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(185) Theoretical framework for curriculum 'environment and education for sustainable development'; Law 4547/2018 (G.G. 102/τ.Α΄/12.06.2018, Article 52).

(186) https://www.hm.ee/...

(187) La Charte de l'environnement de 2004 (Article 8); loi d'orientation et de refondation de l'École de juillet 2013 (Article 42); loi pour une école de la confiance de juillet 2019 (Article 9); Strengthening education for sustainable development: Agenda 2030 (*Renforcement de l'éducation au développement durable : Agenda 2030*, Circulaire du 24-9-2020).

(188) https://www.skolverket.se/... (p. 8).

(189) Curriculum 'environment and education for sustainable development'; Teachers' guide book.

(190) https://peeaad.schools.ac.cy/...

(191) Elective subjects available in grades 7–9: our fatherland; environmental education; life skills; health; dance and popular dances; programming; technical education; informatics project; art project; music project; and sport.

5.5. The use of digital learning technologies in mathematics and science

The integration of digital technologies in teaching and learning practices may increase interest in mathematics and science (Ibáñez and Delgado-Kloos, 2018). A meta-analysis of recent studies concluded that the use of digital technology has a positive effect on student outcomes in mathematics and science (Hillmayr et al., 2020). Moreover, the recent period characterised by the COVID-19 pandemic, which led to the adoption of distance or blended teaching and learning in many countries, demonstrated the importance of digital competences (see more in Chapter 2).

An in-depth Eurydice report – *Digital Education at School in Europe* – mapped the integration of the development of learners' digital competences in school curricula using three main categories (European Commission / EACEA / Eurydice, 2019, pp. 28–30).

- **As a cross-curricular theme.** Digital competences are understood to be transversal and are therefore taught across all subjects in the curriculum. All teachers share the responsibility for developing pupils' digital competences.
- **As a separate subject.** Digital competences are taught as a discrete subject area similar to other traditional subject-based competences.
- **Integrated in other subjects.** Digital competences are incorporated into the curricula of other subjects or learning areas (e.g. mathematics, science, languages and arts).

The report showed that digital competences are part of the curriculum in the vast majority of the European countries. Teaching digital competences as a cross-curricular theme is the main way of integrating digital competences in primary and lower secondary education. In primary education, several countries also have a compulsory separate subject. In lower secondary education, teaching digital competences as a separate, specialised subject, such as informatics or computer science, is more widespread (European Commission / EACEA / Eurydice, 2019, pp. 28–32).

This section explores whether digital competences are present in mathematics and science curricula for the first eight grades of education. It views digital technologies and digital competencies as facilitators of learning in mathematics and science. Learning activities include problem-solving using digital technology as well as digital content creation (e.g. charts, graphs and other images) for topics related to mathematics or science.

In addition, the analysis also discusses whether and how digital literacy is integrated in science curricula. This refers to searching for scientific content online and evaluating the credibility of online scientific content (e.g. finding reliable sources). Digital literacy in mathematics was not analysed.

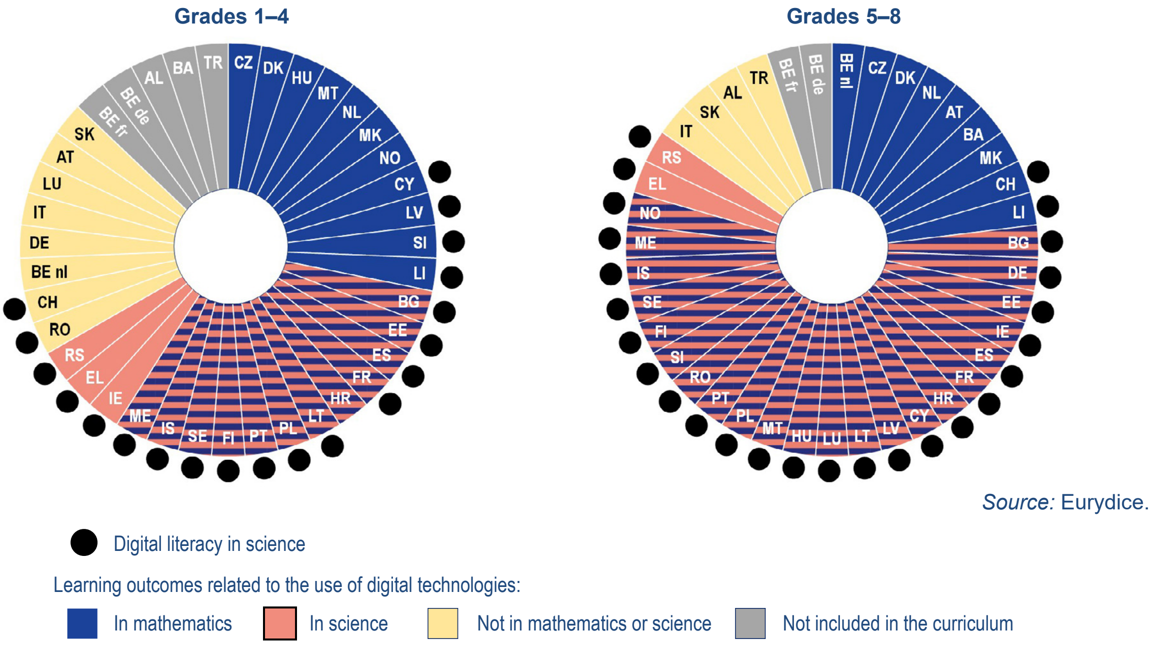
Figure 5.7 shows that learning outcomes related to the use of digital technologies in mathematics and science curricula are present in most of the European countries. By the end of grade 4, the use of digital technology in mathematics or science lessons is introduced in two thirds of countries. By the end of grade 8, mathematics or science curricula in 33 education systems require that pupils use digital technologies to solve problems or analyse or display data. In addition, curricula in approximately half of the European countries for grades 1–4 emphasise digital literacy in science. In grades 5–8, tasks and learning goals related to the critical assessment of scientific information online are included in science curricula in 26 countries.

Some examples of how learning outcomes related to the use of digital technologies and digital literacy are included in mathematics and science curricula are discussed in the following sections.

It is important to note that a few European education systems do not specify any learning outcomes related to the use of digital technologies or digital literacy in their national curricula during the first eight grades of instruction. In 2020/2021, five education systems (Belgium (French and German-speaking Communities), Albania, Bosnia and Herzegovina, and Turkey) did not explicitly mention digital competences in their curricula for primary education. Furthermore, two education systems in Belgium (French and German-speaking Communities) also did not explicitly mention them in their national curricula for secondary education. However, the French Community of Belgium recently adopted the Digital Strategy, according to which, from the 2023-2024 school year, digital competences will be included in curriculum from the third year of primary school (192).

In addition, several education systems stipulate some learning outcomes related to the use of digital technologies in curricula, but not specifically in mathematics and science subjects. In such cases digital competences are primarily integrated as cross-curricular learning outcomes (see more in European Commission / EACEA / Eurydice, 2019).

Figure 5.7: Digital competences in mathematics and science curricula, grades 1–8, 2020/2021



Source: Eurydice.

Learning outcomes related to the use of digital technologies in mathematics

The analysis of curricula reveals that learning outcomes related to the use of digital technologies are more common in mathematics than in science. In Europe, the mathematics curricula of 23 education systems include learning outcomes related to the use of digital technologies during the first four grades of primary education.

> In **Denmark**, after completing grade 3, students should be able to use digital tools/technologies for mathematical studies, simple drawings and calculations (193).
>
> In **Croatia**, in mathematics in grade 3, students should be able to list different types of data displays, and present data in tables and bar charts using digital technology (194).

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(192) *Stratégie numérique pour l'éducation en Fédération Wallonie-Bruxelles* (enseignement.be).

(193) https://emu.dk/... (pp. 6–12).

(194) Curriculum for the subject of mathematics for primary and grammar schools in the Republic of Croatia; Decision on the adoption of the curriculum for the subject of mathematics for primary and grammar schools in the Republic of Croatia,

During grades 5–8, the use of digital technologies is part of the mathematics curricula of 31 European countries. Digital tools are often recommended to study, solve and communicate mathematical problems.

In **Spain**, the mathematics curriculum for grades 7 and 8 states that students should select suitable technological tools to carry out numerical, algebraic or statistical calculations when doing so manually is not possible or not recommended (195).

The **Latvian** curriculum for mathematics in grade 8 states that the student 'selects, formulates the purpose of the research, plans the research, the necessary data and the way of obtaining them; selects the most appropriate digital tools to collect and display data, formulates conclusions in accordance with the set goal' (196).

In the **Netherlands**, in grades 7 and 8, using calculation equipment and computers has an important and versatile place in mathematics education: students learn to use them as an aid, application tool, source of information and means of communication (197).

The **Icelandic** National Curriculum Guide for Compulsory Schools stipulates that pupils should be able to 'use' (grade 4) and to 'select and use' (grade 7) 'suitable tools, including concrete data, algorithms, number lines, calculators and computers, for research and conversation on mathematical problems' (198).

In **Norway**, the curriculum for mathematics in grades 1–10 defines 'digital skills' as one of the five basic skills. Digital skills relate to the ability to use graphing tools, spreadsheets, dynamic geometry software and programming to explore and solve mathematical problems. They also include finding, analysing, processing and presenting information using digital tools. The development of digital skills refers to choosing and using, to an increasing degree, digital tools that are well-reasoned as aids for exploring, solving and presenting mathematical problems (199).

Some countries state the importance of enhancing the understanding of mathematical concepts and algorithmic thinking through digital tools.

In **Cyprus**, the use of technology as a supportive tool for teaching and learning is one of the goals of the mathematics curriculum, and is explicitly described in its introductory sections. Moreover, several attainment targets make direct reference to the use of digital tools for investigating and understanding particular mathematical concepts and procedures (200).

In **Austria**, from grade 5, digital learning resources should be used in mathematics to support student-centred, experimental forms of learning. The critical comparison of inputs and outputs with regard to the problem being solved using different programs and devices can contribute to the development of problem and software-assisted analysis, formulation and evaluation skills (201).

The didactic recommendations in **Slovenia** for grade 6 mathematics advise the use of computer spreadsheets in problem-solving and data processing. Pupils collect and edit data and enter them into an appropriate spreadsheet. At the same time, they learn about the operation and usability of computer spreadsheets (202).

In **Finland**, in grades 7–9, one of the key content areas related to the objectives of mathematics specifies 'the pupils deepen their algorithmic thinking … They use their own or ready-made computer programs as a part of learning mathematics' (203).

Creating charts or other graphical representations using digital technology is also common in mathematics lessons.

OG7/2019.

(195) Primary education: Royal Decree 126/2014, of 28 February, which establishes the basic curriculum for primary education; secondary education: Royal Decree 1105/2014, of 26 December, which establishes the basic curriculum of compulsory secondary education and baccalaureate.

(196) https://mape.skola2030.lv/materials/...

(197) https://www.rijksoverheid.nl/...

(198) https://www.government.is/... (p. 223).

(199) https://www.udir.no/lk20/mat01-05/...

(200) http://mathd.schools.ac.cy/...

(201) https://www.ris.bka.gv.at/... (pp. 62 and 63).

(202) https://www.gov.si/... (p. 41).

(203) https://www.oph.fi/... (pp. 234–239 and pp. 374–379).

In grades 7–9 mathematics in **Ireland**, students use digital technology to develop numerical skills and understanding. The following examples of possible student learning activities are provided for this key skill element: students engage with digital technology to analyse and display data numerically and graphically, to display and explore algebraic functions and their graphs, to explore shapes and solids, to investigate geometric results in a dynamic way, and to communicate and collaborate with others (204).

In **Spain**, learning standards in the mathematics curriculum for grades 7 and 8 include 'use technological resources to create graphical representations of functions with complex algebraic expressions, and extract qualitative and quantitative information about them … Design graphical representations to explain the problem-solving process, through the use of technological means' (205). In the autonomous community of Castilla y León, the learning standards in the mathematics curriculum for grades 7 and 8 include 'create their own digital documents (text, presentation, image, video, sound, etc.), as a result of the search process, analysis and selection of relevant information, with the appropriate technological tool, and share them for discussion or dissemination' (206).

In **Cyprus**, in grade 6, the following achievement target is specified in the area of statistics and probability: students can read and build bar charts, pictograms, pie charts, line graphs and spreadsheets, and differentiate continuous and categorical data with or without the use of technology (207).

Learning outcomes related to the use of digital technologies in science

Learning objectives linked to the use of digital technologies in science curricula are present in 15 of the 39 European education systems in grades 1–4 and in 24 of the education systems in grades 5–8. In these education systems, science curricula often include recording, storing and analysing scientific data using digital technologies.

In **Germany** (Baden-Württemberg), in physics in grades 5–8, students document physical experiments, results and findings with the help of digital technology (e.g. sketches, descriptions, tables, diagrams and formulae) (208).

In **Estonia**, under the learning content of the natural science subject in grades 1–8, examples of practical work and the use of ICT are provided for every topic. There are 69 lists of such examples in the syllabus for this subject. The complexity of ICT tools to be used and activities to be performed increases gradually (209).

In **Ireland**, in grades 3 and 4, the science curriculum states that 'children's investigations and explorations can be enhanced by using information and communication technologies in recording and analysing information, in simulating investigations and tests that support scientific topics' (210).

In science education in grades 7 and 8 in **Lithuania**, one of the skills to be acquired is to 'apply knowledge gained in mathematics and ICT lessons to process and present research results orally or in writing'. This includes following instructions to create a pie or bar chart using a spreadsheet (e.g. Microsoft Excel). In these grades, students learn to process research results with the aid of a computer (211).

In **Poland**, learning objectives in geography curricula for grades 5–8 include using plans, maps and ICT tools to acquire, process and present geographical information (212).

In several countries, students are expected to create a chart, a presentation, a digital poster or an image on a scientific topic.

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(204) https://www.curriculumonline.ie/... (p. 8).

(205) Royal Decree 1105/2014, of 26 December, which establishes the basic curriculum of compulsory secondary education and baccalaureate, p. 383.

(206) Decree 26/2016, of July 21, which establishes the curriculum and regulates the implementation, evaluation and development of primary education in the community of Castile and Leon, 12.1, p. 410.

(207) Achievement and attainment targets, grade 6, p. 84.

(208) http://www.bildungsplaene-bw.de/... (p. 9).

(209) https://www.hm.ee/...

(210) https://curriculumonline.ie/... (p. 9).

(211) https://duomenys.ugdome.lt/... (p. 884).

(212) Regulation of the Minister of Education of 14 February 2017 on the core curriculum for general education in primary school, Annex No 2, Core curriculum for general education in primary school, p. 116 (II.2).

A learning standard in physics and chemistry in grade 8 in **Spain** specifies 'make a presentation, using ICT, about the properties and applications of an element and/or chemical compound of special interest out of a guided bibliographic and/or digital search' ([213]).

In **Latvia**, a learning outcome for geography (grades 8 and 9) is the creation of cartographic material (including digital) using data obtained from various sources (teaching materials, online resources and open-access databases) and fieldwork (using geographic information systems, Global Positioning System, observations) to depict and describe the spatial dimensions of geographical phenomena ([214]).

In **Hungary**, in biology lessons in grades 7 and 8, students capture, search and interpret images, videos and data, use them critically and ethically, and use digital tools in their work ([215]).

Digital literacy in science

Information and data literacy has become a key digital competence in contemporary society (see more in European Commission, JRC, 2022). With the spread of misinformation and disinformation, and the influence of antiscientific movements, it is important that students acquire tools to navigate and critically assess information (Siarova et al., 2019). Finding scientific content by searching online and verifying the credibility of information from various online sources are therefore part of the science curricula of most European countries.

In geography and economics lessons in grade 6 in **Bulgaria**, students perform tasks related to searching for, finding and processing information on certain topics using the internet, and prepare multimedia presentations on a given geographical topic ([216]).

The **Estonian** syllabus for the field of natural sciences (grades 1–8) defines the following general goal: 'while studying natural sciences, students gather information from different sources of information, evaluate and use this information critically.' The subject descriptions of geography (grades 7 and 8) and physics (grade 8) include the following statement: 'an important role is played by the skill of using different sources of information (including the internet) and critically assessing the information they find there' ([217]).

In **Spain**, a learning standard for physics and chemistry in grade 8 includes 'identify the main characteristics linked to reliability and objectivity of the existing information flow on the internet and other digital media' ([218]).

In grades 7 and 8 in science education in **Lithuania**, one of the skills to acquire is to 'express ideas, find and summarise scientific information', which includes 'find scientific information online using a search engine like Google; list several reliable sources of scientific information; use electronic science guides, encyclopaedias, computer-based learning materials' ([219]).

Summary

This chapter aimed to highlight some approaches that schools are encouraged to take when fostering certain real-life and contextual aspects of numeracy or scientific literacy. As discussed, mathematical literacy does not only include the ability to perform computations, but also entails the understanding and application of the learned concepts in real life. Similarly, scientific literacy goes beyond the ability to recite scientific laws and explain natural phenomena (Siarova et al., 2019). It refers to reflective citizenship, understanding the impact of science and technology on human activity and the natural world, and understanding the limitations and risks of scientific theories ([220]).

Analysis of the curricula of European countries reveals that there is considerable emphasis on connecting mathematics teaching to children's real-life experiences during the first 8 years of school.

([213]) https://www.boe.es/boe/..., p. 259.

([214]) https://likumi.lv/ta/en/en/id/... (p. 45; 12.3.6).

([215]) https://www.oktatas.hu/kozneveles/...

([216]) https://www.mon.bg/upload/13442/UP_6kl_Geo_ZP.pdf (p. 11).

([217]) https://www.hm.ee/... (pp. 5, 41 and 50).

([218]) https://www.boe.es/boe/... (5.2), p. 258.

([219]) https://duomenys.ugdome.lt/... (p. 885).

([220]) Council recommendation of 22 May 2018 on key competences for lifelong learning, OJ C 189, 4.6.2018.

Computations involving money are the most common example of the functional use of mathematics. More complex financial literacy tasks (e.g. calculation of credit and interest, gross and net income, or budget) are present in the curricula for grades 5–8 in the majority of European countries. Examples of using mathematics in architecture or do-it-yourself activities are often mentioned to improve pupils' understanding of space, shapes and measurement, while cooking is used to support numeracy concepts in primary education. The international assessment survey data from the 2019 TIMSS confirm that the majority of fourth grade mathematics teachers relate almost every lesson to students' daily lives.

In science, reflections on the historical and societal contexts of scientific developments, as well as on the ethical implications of such developments, are less common in grades 1–4 than in grades 5–8. Fewer than half of the European countries refer to the history of science in curricula for grades 1–4. Only one third specify the importance of discussing socioscientific issues or ethics in science. These complex themes and questions are more prominent in grades 5–8. Curricula often mention technological breakthroughs and their impact on daily life, or the historical development of scientific models. References to science and ethics are present in the lower secondary curricula of half of the European countries, especially in biology curricula. However, biographies of great scientists and the times when they lived is a less common theme. The role of women in science is mentioned in the curricula of only a handful of countries.

Several countries indicate that these contextual, reflective approaches to science teaching and learning are introduced later, in upper secondary education, which is beyond the scope of this report. However, many complex topics on environmental sustainability are present in science curricula for the first four grades of primary education. European countries cited rich examples of how students learn about recycling, the importance of sorting waste, saving water and energy, preserving biodiversity, etc. By grade 8, students learn about renewable and non-renewable sources of energy, and the greenhouse effect, and are encouraged to adopt ecologically sustainable behaviours.

Digital technologies are widely used as facilitators of learning in mathematics and science. In two thirds of the European countries, pupils in primary education are expected to use digital technology to carry out simple calculations and create a chart or a presentation on a scientific topic. By the end of grade 8, the large majority of education systems require students to be able to use and select appropriate digital tools to solve mathematical or scientific problems, analyse data and create visual representations. Several countries include dynamic geography applications and even some basic programming tasks to aid the understanding of mathematical concepts. In science, digital tools are used to record and analyse scientific experiment data, display the results and facilitate communication. Moreover, finding scientific content by searching online and verifying the credibility of information from various online sources are part of the science curricula of most European countries.

In addition, more than half of the European countries report national strategies, programmes and other initiatives that aim to raise students' motivation in mathematics and science through means other than curricula. Some education systems concentrate on enriching students' learning experiences by providing specialised workshops with guest professionals, as well as clubs and after-school activities.

CHAPTER 6: SUPPORTING LOW ACHIEVERS

Reducing the share of low achievers is essential for achieving the twin goal of having quality and inclusive education systems in Europe. However, in recent decades, the proportion of students who do not have a basic understanding of mathematics or science has not decreased in most European countries. The European target of 15% as the maximum share of underachieving 15-year-old students has been met by only a handful of education systems (see Chapter 1). In addition, as Chapter 1 also showed, individual student characteristics such as socioeconomic background, and to a lesser extent gender, influence the likelihood of underperformance (see also European Commission / EACEA / Eurydice, 2020). Students who perform poorly do not acquire the level of knowledge, skills and competences they might have if personal, educational or social conditions were different. Therefore, it is imperative to analyse what kind of strategies and measures could be successful in reducing low achievement in mathematics and science, and what building blocks are necessary for moving towards more effective and inclusive education systems.

Student support systems are essential for raising achievement levels and addressing individual learning problems and difficulties (see European Commission / EACEA / Eurydice, 2020). However, the kind of support that students receive largely depends on which school they attend. Several studies and reports emphasise the importance of school leadership, a supportive school environment, high-quality teachers and effective classroom learning strategies for successfully reducing low achievement (OECD, 2012; see also Cullen et al., 2018; Dietrichson et al., 2017).

So what could be the role of top-level authorities in this regard? This chapter is devoted to examining top-level frameworks for student support systems and measures in Europe in mathematics and science education. The first step towards supporting low-achieving students is to determine who they are and identify their learning needs. Therefore, the first section examines the different assessment mechanisms through which students who need learning support can be identified. Then the chapter provides a broad overview of top-level frameworks of student support, outlining the main models that exist in Europe. The last section discusses how support is organised in schools across European education systems, and what kind of impact the COVID-19 pandemic has had on this.

6.1. Identifying learning needs

The first step towards developing successful and effective student support is to identify individual problems and learning needs. Given the impact of socioeconomic factors and family background on student achievement, it is important to understand as early as possible which children may require additional support. Continuous monitoring of children's performance is all the more important because learning difficulties – specifically difficulties in mathematics – are found not to be stable over time, as children can outgrow their developmental delays (Gersten, Jordan and Flojo, 2005). This also highlights that the timing of learning support may be even more important than its duration.

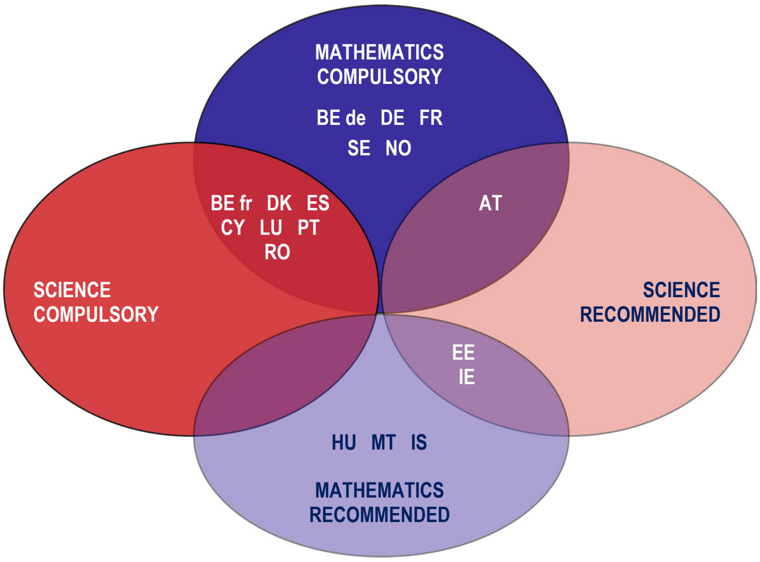
European education systems rely on different assessment mechanisms to identify students who need learning support. These are rarely subject specific, and thus are most often not related specifically to mathematics or science achievement. Such assessment mechanisms 'serve to identify students who are at risk of failure, to uncover the sources of their learning difficulties and to plan for an appropriate supplemental intervention or remediation' (OECD, 2013, pp. 140–141).

The most common way to identify low-achieving students is ongoing monitoring in the classroom. This most often takes the form of continuous testing and **grading**, which exists in virtually all European education systems. Based on this grade-based or relative achievement approach, low-achieving students are identified either from the final grades they receive or from their achievement levels relative to others. Examples of the former are low achievers being defined as having a 'score of less than six tenths' (Italy) or as 'having a grade lower than 5 on a scale of 1–10' (Romania). An example of the latter is low-achieving students being defined as those obtaining lower than average results (Croatia). In education systems relying solely on this assessment mechanism, low achievement is often associated with 'school failure', and support is usually provided to avoid grade repetition.

A second assessment mechanism applied in European education systems to identify students' needs for learning support takes the form of **top-level competence-based tests** that aim to identify individual learning needs (see also Chapter 4). On top of the continuous monitoring practice of teachers, these tests provide an additional instrument for identifying low-achieving students and their learning support needs. Where such tests are used, top-level authorities design their content based on the competences and/or learning outcomes specified in steering documents, and students not achieving these competences or learning outcomes should receive additional support. Top-level tests can be offered or imposed by top-level authorities; in the latter case, schools are obliged to implement them in given time periods.

Figure 6.1 shows the education systems in which top-level authorities offer this kind of testing or make it compulsory for students at primary and/or lower secondary level in mathematics and/or science. When tests aiming to identify individual learning needs are compulsory, firstly, top-level authorities specify both the content and the timing of the tests to be organised, and secondly, participation is compulsory for all students, irrespective of their performance.

Figure 6.1: Top-level compulsory or recommended tests with the aim of identifying individual learning needs in mathematics and science, ISCED 1-2, 2020/2021



No such top-level tests:
BE nl, BG, CZ, EL, HR, IT, LV, LT, NL, PL, SI, SK, FI, AL, BA, CH, LI, ME, MK, RS, TR

Source: Eurydice.

Explanatory note

The figure includes top-level national tests with the aim of identifying individual learning needs, taking place at ISCED 1 and/or at ISCED 2. For all national tests, see Chapter 4, Figure 4.6. The figure shows these top-level tests as they were planned for the 2020/2021 school year. In a few cases, these tests were cancelled due to the COVID-19 pandemic (see Chapter 4, Figure 4.8).

Country-specific notes

Belgium (BE fr), Germany, Spain and **Sweden**: Compulsory tests are carried out at ISCED 1 only.
Ireland, Hungary and **Malta**: Recommended tests are carried out at ISCED 1 only.
Denmark, Cyprus, Luxembourg and **Romania**: Compulsory tests in science are carried out at ISCED 2 only.

As the data reveals, the practice of compulsory top-level testing with the objective of identifying individual learning needs is rare; it does not take place in two thirds of education systems. Only 13 education systems organise such compulsory top-level tests in mathematics, and only seven education systems do so in science. Differences between the subject areas are especially pronounced in primary education, where these tests most often concern the basic literacy and numeracy competences of students. At this level, students' scientific competences are tested in three education systems only (Belgium (French Community), Spain and Portugal).

Several education systems stress the need for early intervention, and therefore organise top-level testing with the objective of identifying individual learning needs in the first and/or second grades of primary education. This is the case in Germany (Berlin-Brandenburg), France, Portugal, Romania and Sweden. These early national tests are often followed by additional ones in later grades.

> In **France**, national tests with the aim of identifying learning needs are administered to all students in mathematics, twice in grade 1 and once at the beginning of grade 2. These early tests are followed by another in mathematics at the beginning of grade 6 (and then in grade 10).
>
> In **Portugal**, students take assessment tests in grades 2, 5 and 8. Mathematics competences are tested in all grades in each academic year; however, scientific competences are tested on a rotating basis (i.e. not every year) in grades 5 and 8.
>
> In **Romania**, testing to identify learning needs takes place in every second grade from grade 2 to grade 8 in mathematics, and in grade 6 in science.
>
> In **Sweden**, national support material in mathematics for grades 1–3 (mandatory for teachers to use) is provided for the mapping and evaluation of pupils' knowledge development. According to the Swedish National Agency for Education regulations, the mapping should take place twice in grade 1 and once in grade 3 (221). These early tests are followed by a national test in grade 6, which also aims to identify learning and support needs. National tests administered at later stages, however, serve different purposes.

Belgium (French Community), Denmark, Spain, Cyprus, Austria and Norway also organise several compulsory national tests, from grade 3 onwards.

> In **Belgium (French Community)**, compulsory national diagnostic tests are organised for grades 3 and 5 (and later at ISCED level 3). They are organised in a triennial cycle, with each subject (mathematics and science among them) tested once every 3 years. Only a representative sample (determined by the steering service, based on the socioeconomic index of the school, the province and the education network) is used for the analysis of results. The purpose of this selection is to evaluate learning in the previous cycle.
>
> In **Denmark**, the aim of the national tests is to strengthen the evaluation culture in primary and lower secondary schools and to have a uniform tool that can be used for evaluation across the country. The national tests – which are organised in grades 3, 6 and 8 in mathematics and in grade 8 in science – supplement other forms of evaluation. The tests may provide an insight into the individual student's level of competence in the tested areas, but the national tests alone do not provide detailed knowledge of the individual student's academic level and learning needs. The results of the national tests can be included in the overall assessment of the students and of the class, along with knowledge of the students from, for example, ongoing evaluation, observations, tests (i.e. diagnostic tests) or assignments.
>
> In **Spain**, there are two tests aiming to identify learning needs in primary education: one in grade 3 (in mathematics) and one in grade 6 (in mathematics and science). There is another test in grade 10 (222).
>
> In **Cyprus**, testing takes place in grades 3, 6 and 7 in mathematics, and in grade 7 in science.
>
> In **Austria**, in mathematics, the individual competence measurement PLUS (iKMPLUS) basic modules are compulsory in grades 3 and 4, as well as in grades 7 and 8.
>
> In **Norway**, mandatory numeracy tests are organised in grades 5, 8 and 9.

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(221) The Swedish National Agency for Education's regulations on compulsory national assessment support in Swedish, Swedish as a second language and mathematics, SKOLFS 2016:66 (*Skolverkets föreskrifter om obligatoriska nationella bedömningsstöd i svenska, svenska som andraspråk och matematik i årskurs*).

(222) Law 8/2013 of 9 December, for the improvement of educational quality, was in force in 2020/2021. A new legal framework for national testing entered into force in the 2021/2022 academic year.

Belgium (German-speaking Community) and Luxembourg run one compulsory competence-based test per education level.

> In **Belgium (German-speaking Community)**, primary schools regularly take part in the VERA (*Vergleichsarbeiten*) 3 test for mathematics in grade 3, which is a top-level test, the results of which are communicated to the schools, teachers and parents. A similar test (VERA 8) is organised in secondary schools for grade 8.

Besides compulsory tests that schools and teachers have to use as an assessment tool when identifying students' learning difficulties and their learning support needs, countries can also recommend that national test results are used for such purposes on a voluntary basis. In some education systems (e.g. in Estonia, Ireland and Iceland), the use of multipurpose national tests is recommended for identifying students' learning needs (see also Chapter 4, Section 4.3.2).

> In **Estonia**, national tests in mathematics and science take place at the beginning of grades 4 (primary education) and 7 (beginning of lower secondary education). These are sample-based electronic tests in which approximately 5% of schools are required to take part; for the others, the test is voluntary. However, the vast majority of schools participate and use the results for the purpose of identifying students' learning needs.
>
> The **Icelandic** National Curriculum Guide for Compulsory Schools sets the basis for standardised testing in mathematics to be conducted three times during a student's compulsory education (in grades 4, 7 and 9). These tests can be used for the purpose of identifying students' learning needs.

In other education systems, top-level authorities design freely available tests with the main purpose of detecting students' learning difficulties. In these cases, top-level authorities do not make testing compulsory for all students, but these tests are available (and recommended) for teachers to use when they deem necessary. In other words, teachers can rely on these tests as additional assessment tools supporting them in identifying or confirming the specific learning problems of students and their needs for support. Such tests exist in Hungary and Malta in mathematics, and in Austria in mathematics and science.

> In **Hungary**, a diagnostic developmental examination system (DIFER) is available for teachers to assess those grade 1 pupils whose development of basic skills should be more strongly supported in the future. Teachers can rely on this system's tests to help them establish the necessary support measures.
>
> In **Malta**, low-achieving students in grades 4 and 5 who need additional support in class take a mathematics diagnostic test provided by the mathematics support teacher. Consequently, they follow an alternative programme adapted to their specific needs. This diagnostic test is administered once, as soon as the class teacher realises that the particular student is a low achiever who is not mastering curriculum content as well as the rest of the class.
>
> In science, informal competence measurement (IKM) tests are developed by the top-level authority in **Austria** to test the competences of grade 7 and grade 8 students in science. The tests are freely available and teachers can use them voluntarily. Such voluntary tests are also available in mathematics.

National tests and their potential impact on learning outcomes will be further analysed in Chapter 7.

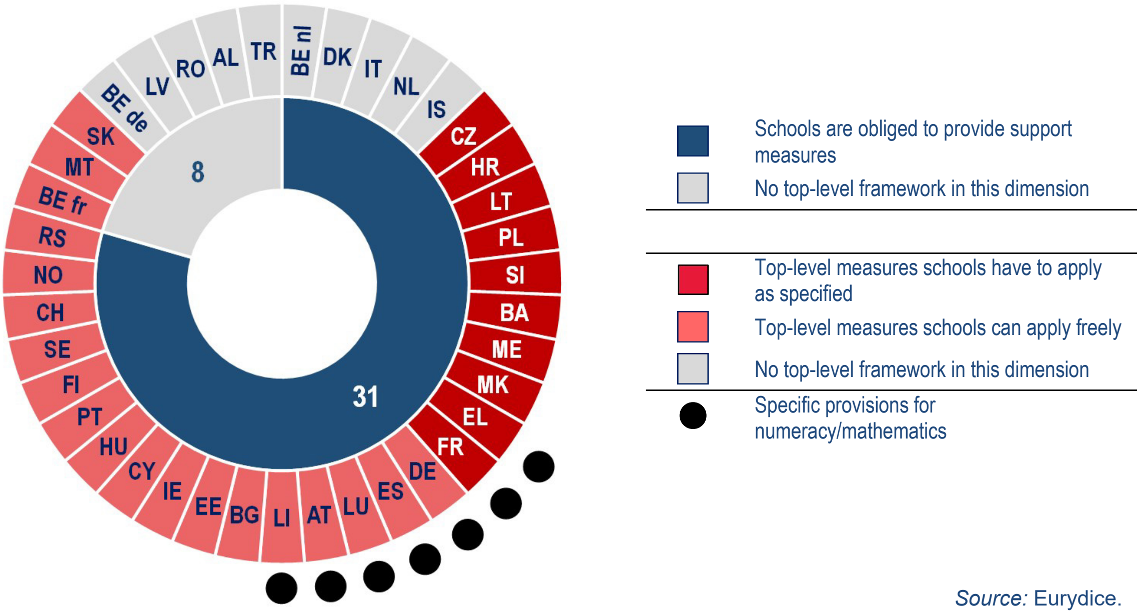
6.2. Top-level frameworks for providing learning support

After their learning needs are identified, students with learning problems and difficulties must receive the appropriate learning support to be able to achieve their full potential. While the next section will detail the concrete learning support measures that are applied in European education systems, this section provides an overview of the broad frameworks and top-level policy approaches. These top-level frameworks may contain:

- the obligation of schools to provide learning support to low-achieving students;
- the support measures that can or should be applied;
- subject-specific provisions.

Very broadly, where top-level frameworks exist – as illustrated by Figure 6.2 – authorities can follow different strategies, examined along three main dimensions. Firstly, they can oblige schools to take steps towards identifying and supporting students' learning problems and difficulties. In such frameworks, students are usually entitled to receive effective learning support, and schools have the obligation to comply with this requirement. Secondly, top-level authorities can provide more or less detailed guidelines or recommendations for schools on how to support low-achieving students. In a more prescriptive framework, these guidelines can contain the exact steps schools need to take to identify and support students with learning difficulties. Alternatively, top-level recommendations can provide schools with different options they can implement, enabling them to make effective support available for those in need. Thirdly, education systems may decide to outline specific provisions for certain learning areas, notably in mathematics. In the 2020/2021 school year, such subject-specific provisions were not provided for science in any education system.

Figure 6.2: Top-level frameworks for providing learning support in mathematics and science, ISCED 1-2, 2020/2021



Source: Eurydice.

Explanatory note

The inner circle distinguishes between education systems that oblige schools to provide learning support to students who need it and those that do not. The outer circle shows whether and how top-level authorities determine the concrete support measures schools can or should apply when providing support to low-achieving students. Finally, the black dots around the circle indicate whether top-level frameworks include subject-specific provisions.

Country-specific notes

Belgium (BE fr): The top-level framework concerns ISCED 2 only.
Czechia: Specific support measures are decided by the schools, counselling centres and parents in cooperation.
Greece: Specific provisions for numeracy skills are at ISCED 1 only.
France: A specific plan addressing low achievement in science will enter into force in the 2022/2023 academic year, in addition to the scheme for mathematics launched in 2018.
Cyprus: The obligation to provide support applies to ISCED 1 only.
Luxembourg: Specific provisions for numeracy/mathematics skills are at ISCED 2 only.

Top-level authorities may also specify the appropriate financial and human resources necessary for the provision of learning support, and ensure that they are in place. The human resources aspects of learning support will be discussed in Section 6.3.2.

Along the first dimension (the inner circle in Figure 6.2), the majority of European education systems do oblige schools to provide learning support to students who need it. Even in the absence of more detailed regulations, this obligation exists in 31 education systems. Nevertheless, this does not necessarily mean that, in the eight education systems without such obligations, support measures are not applied in schools at all; the top level might simply keep this decision within the realms of school autonomy.

The second dimension (the outer circle in Figure 6.2) concerns whether and how top-level authorities determine the concrete support measures schools can or should apply when providing support to low-achieving students. In around one quarter of European education systems (10), top-level authorities specify concrete and detailed steps schools need to follow when organising learning support provision. In these cases, top-level regulations usually specify the format of support to be applied (e.g. small-group tutoring), sometimes depending on the types of need, the teaching personnel involved, and when and how support provision should be organised. In such prescriptive frameworks, schools are always obliged to provide learning support where needed.

> In **Greece**, where support for low achievers in primary schools is essentially provided for only literacy and numeracy, schoolteachers are responsible for setting up small classes (of up to five students) for remedial teaching (*enischytiki didaskalia*) (223). Remedial teaching runs for 1–2 school hours a day and up to 6 school hours a week, during or after school hours. For lower secondary students, remedial teaching and compensatory education (*antistathmistiki ekpaidefsi*) (224) takes place in school centres for educational support (SKAE) in groups of a minimum of 10 and a maximum of 15 students. Depending on the number of applications, the teachers' board of each school can propose that the school functions as a school centre for educational support. All schools provide such compensatory education; where necessary, this is provided in collaboration with neighbouring remedial teaching centres.

> In **Croatia**, schools are obliged to organise additional tuition (*dopunska nastava*) for students who need help in learning. When such student support is needed, additional tuition is organised in small groups, usually of up to eight students. Additional tuition is organised for subjects for which there is a need for support, and the students have to attend these classes regularly. The number of preparatory and additional classes is planned by schools according to the actual needs, with the prior consent of the Ministry of Science and Education (225).

A more widespread approach, which is used in around half of European education systems (19), is top-level authorities specifying potential ways to provide support, which schools can apply freely depending on the needs of students or the school's organisational capacity. Alternatively, specifications in top-level frameworks may be relatively vague, and schools can freely decide how to implement them. These frameworks most often, but not always, oblige schools to provide learning support, and stress the importance of school autonomy in learning support provision.

> In **Finland**, according to the Basic Education Act (226), pupils are entitled to sufficient learning support as the need arises. To ensure the early identification of needs, pupils' progress and their school attendance must be continuously assessed. The school's operating methods, teaching arrangements and learning environment, as well as their suitability for the pupil, are examined first. On the basis of this examination, the possibility of making changes in these aspects to find suitable pedagogical solutions is assessed. In the examination and planning of the support, all available assessment results are utilised, and earlier support provided for the pupil is taken into account. Forms of support prescribed in the Basic Education Act include remedial teaching, part-time special needs education, interpretation and assistance services, and special aids. These support forms may be used separately or to complement

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(223) Presidential Decree 429/1991 (Government Gazette No 167 / A / 30-9-1985) on assessment and remedial teaching of lower secondary school students; Law 4823/2021 (Government Gazette No 136 / A / 3-8-2021), article 100 on extra-curricular teaching hours covering remedial teaching.

(224) Law 4368/2016 (*Government Gazette* No 181 / A / 18-11-2019), Article 28 on issues of special needs education; and Law 4485/2017 (*Government Gazette* No 114 / A / 4-8-2017) on organisation and operation of higher education, regulations for research and other provisions.

(225) Primary and Secondary School Education Act (*Zakon o odgoju i obrazovanju u osnovnoj i srednjoj školi*), *Official Gazette*, 89/2008, 86/2010, 92/2010, 105/2010, 90/2011, 5/2012, 16/2012, 86/2012, 126/2012, 94/2013, 152/2014, 07/2017, 68/2018, 98/2019, 64/2020.

(226) Basic Education Act (*Perusopetuslaki*) 21.8.1998/628, regulations and instructions (2014:96).

each other. The support received by the pupil must be based on long-term planning and adjustable as the pupil's needs for support change. Support is provided for as long as necessary.

Finally, in around one quarter of education systems (10), it is not the top level that is responsible for specifying learning support measures. In some cases, top-level authorities delegate this task to local authorities (e.g. in Denmark and Iceland), but most often schools have the autonomy to decide how to support students with learning difficulties. In some systems, schools are still obliged to provide learning support, even if the format is not specified.

The third dimension into which top-level frameworks can be categorised is whether they include subject-specific provisions (i.e. whether learning support measures are specified for a specific learning area) (see the black dots around the circle in Figure 6.2). As Figure 6.2 shows, such subject-specific provisions exist in seven education systems, and they all concern learning support in mathematics or numeracy skills ([227]).

In **Germany**, the Resolution of the Standing Conference of German Ministers of Education and Cultural Affairs on the principles for the support of students with special difficulties in reading and spelling or in arithmetic ([228]) emphasises the need for recognising learning difficulties at an early stage in order to be able to start support as early as possible and to develop an individual support plan, specifically related to reading, spelling and arithmetic skills.

In **Austria**, differentiated teaching is recommended specifically in the case of difficulties concerning arithmetic problem-solving ([229]).

Students with special educational needs

In the majority of European education systems, support provided to students with special educational needs within mainstream education falls under a separate top-level framework. Even education systems without a top-level framework for supporting low-achieving students tend to have one for students with special educational needs; only Albania and Turkey do not have top-level frameworks for supporting such students within the mainstream education system. These frameworks often outline specific support provisions for this group of students (adapted curriculum content and assessment, individual learning plans, protection from grade repetition, etc.). These specific provisions are not included in the analysis above.

Nevertheless, the distinction between low achievers and students with special educational needs is not always clear-cut. Some education systems emphasise that all students should receive the type and level of instruction they need irrespective of how small or big their learning difficulties may be. Some of these education systems tend to mainstream the category of 'special educational needs', categorising all students with smaller or greater learning difficulties under this or a similar umbrella term (e.g. in Czechia, Ireland, Poland, Iceland and Serbia).

In **Poland**, pupils with low educational performance ('with educational failure, with specific learning difficulties') are included in the category of pupils with special educational needs who require support and are offered psychological and pedagogical assistance. In addition to low-achieving students, this group also includes exceptionally gifted students, students in crisis or traumatic situations, socially neglected students, students previously educated abroad and culturally diverse students (e.g. immigrants or Polish children returning from abroad). Schools and counselling and support centres provide various forms of support to students with special educational needs, depending on the individual student's needs ([230]).

([227]) A specific framework for learning support in science will enter into force in France in the 2022/2023 academic year.

([228]) Resolution of the Standing Conference of German Ministers of Education and Cultural Affairs on the principles for the support of students with special difficulties in reading and spelling or in arithmetic (*Grundsätze zur Förderung von Schülerinnen und Schülern mit besonderen Schwierigkeiten im Lesen und Rechtschreiben oder im Rechnen*).

([229]) Guidelines for dealing with pupils with difficulties in learning arithmetic in schools (Circular 2017/27) (*Richtlinien für den schulischen Umgang mit Schülerinnen und Schülern mit Schwierigkeiten beim Rechnenlernen*).

([230]) Regulation of the Polish Minister of National Education of 9 August 2017 on the rules for organisation and provision of psychological and educational support in public nursery schools, schools and educational institutions (consolidated text, Some other education systems aim to end the 'categorisation' of students altogether, creating a continuum of educational responses based on students' needs (e.g. in Portugal, Finland and Norway).

> In **Portugal**, Decree-Law No 54/2018 (1) abandons student categorisation systems, including the category of special educational needs, (2) abandons the special legislation model for students with special educational needs, (3) establishes a continuum of responses for all students, and (4) focuses on educational responses and not on categories of students.

Nevertheless, the analysis in this chapter does not include students with special educational needs in case separate top-level frameworks apply to them.

6.3. Learning support measures in mathematics and science

Having examined the broader policy framework in which schools operate in relation to supporting low-achieving students, this section takes a closer look at the concrete learning support measures specified in top-level regulations, recommendations or guidelines (i.e. the ways in which schools are supposed to help students facing learning difficulties). More specifically, this section provides an overview on what the main forms of support are, who provides such support in schools and how support measures have evolved since the beginning of the COVID-19 crisis.

6.3.1. How are low-achieving students supported?

Learning support for low-achieving students can be organised in several different ways, from differentiated instruction within the classroom to out-of-school homework support. This subsection first examines the support measures specified in top-level regulations, recommendations or guidelines (excluding provisions for special educational needs in case they fall under a separate framework). While such top-level documents often indicate how learning support can or should be organised in schools, they rarely address teaching practices and the ways in which teachers could address the presence of students with different achievement levels in the classroom. Therefore, the second part of this subsection briefly discusses classroom teaching practices based on the International Association for the Evaluation of Educational Achievement's (IEA) Trends in International Mathematics and Science Study (TIMSS) 2019 survey. Specifically, it looks at the prevalence of differentiated teaching and ability grouping in the classroom in mathematics and science.

Top-level learning support measures in mathematics and science

Few would debate the usefulness of additional support provided for those who need it. Additional tutoring and individually tailored student support have been found to be beneficial to students who require more focused attention (see, for example, Dietrichson et al., 2017; Lee-St. John et al., 2018; Santibañez and Fagioli, 2016). Additional tutoring can also mean more opportunities to learn, and increased learning time alone has the potential to improve student performance (see Chapter 3 for more details).

Nevertheless, in what form learning support is provided might also matter. Studies have evaluated the effectiveness of both in-school and out-of-school support or remedial instruction, mostly concentrating on literacy and numeracy. The effectiveness of within-class interventions – both small-group tutoring and independent work partially integrated into usual classroom practice – was demonstrated by, for example, Moser Opitz et al. (2017). Along similar lines, Montague (2011) argues that direct instruction

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Journal of Laws of 2020, item 1280) (*Rozporządzenie Ministra Edukacji Narodowej z dnia 9 sierpnia 2017 r. w sprawie zasad organizacji i udzielania pomocy psychologiczno-pedagogicznej w publicznych przedszkolach, szkołach i placówkach*).

within the classroom – for example based on 'drill and practice' – can help students with learning difficulties in mathematics.

Regarding out-of-school support, several studies have found modest, but positive, impacts of such programmes on students' achievement (see, for example, Ariyo and Adeleke, 2018; Laurer et al., 2006; Scheerens, 2014; Yin, 2020). However, Scheerens (2014) notes that the literature is not sufficiently robust regarding the actual impact of additional activities or homework support outside the normal school day, mainly due to the population size covered, the volume and variety of activities, and differences in their quality. In addition, research has not focused much on comparing the effectiveness of in-school and out-of-school support, mostly due to the difficulties related to the lack of reliable comparative research design in this area. Chapter 7 will provide further insights regarding learning support during and outside the school day.

Top-level steering documents specify one or more support measures for low-achieving students in the majority of European education systems. Figure 6.3 illustrates the prevalence of selected learning support measures in Europe according to such top-level specifications. As the figure shows, top-level authorities in around three quarters of education systems recommend the use of one-to-one or small-group tutoring when providing support to low achievers. This includes nearly all education systems with a top-level framework for learning support provision.

Most of this tutoring takes place during the formal school day, although some education systems organise additional tutoring in after-school hours (231). Several education systems (e.g. in Belgium (Flemish Community), Czechia, Germany, Estonia, Greece, Spain, Luxembourg, Poland, Liechtenstein and Serbia) also make use of different options and provide support in a diversified way, both during and outside the school day.

In **France**, in primary education, providing complementary educational activities (*activités pédagogiques complémentaires*, APC) is an obligation for all teachers. These activities are organised outside the formal school day, and require the consent of the pupils' parents. In secondary education, 3 hours per week can be dedicated to personalised support in grade 6, and 1–2 hours per week can be dedicated to this in grades 7–9. This support takes place during the school day, in the class. In addition, homework support is provided in secondary schools after the formal school day (232).

In **Poland**, for students with learning difficulties, in particular those with difficulties in meeting educational requirements specified in the core curriculum, a specific regulation (233) recommends organising remedial classes in groups of up to eight participants. The classes are organised in particular school subjects, for example mathematics.

In **Slovenia**, the Basic School Act (234) states that basic schools are obliged to adapt teaching and learning methods for pupils with learning difficulties during lessons, and to provide remedial lessons during the formal school day and other forms of individual or small-group assistance. Remedial lessons are conducted before or after classes, and take place for 45 minutes a week in each major subject.

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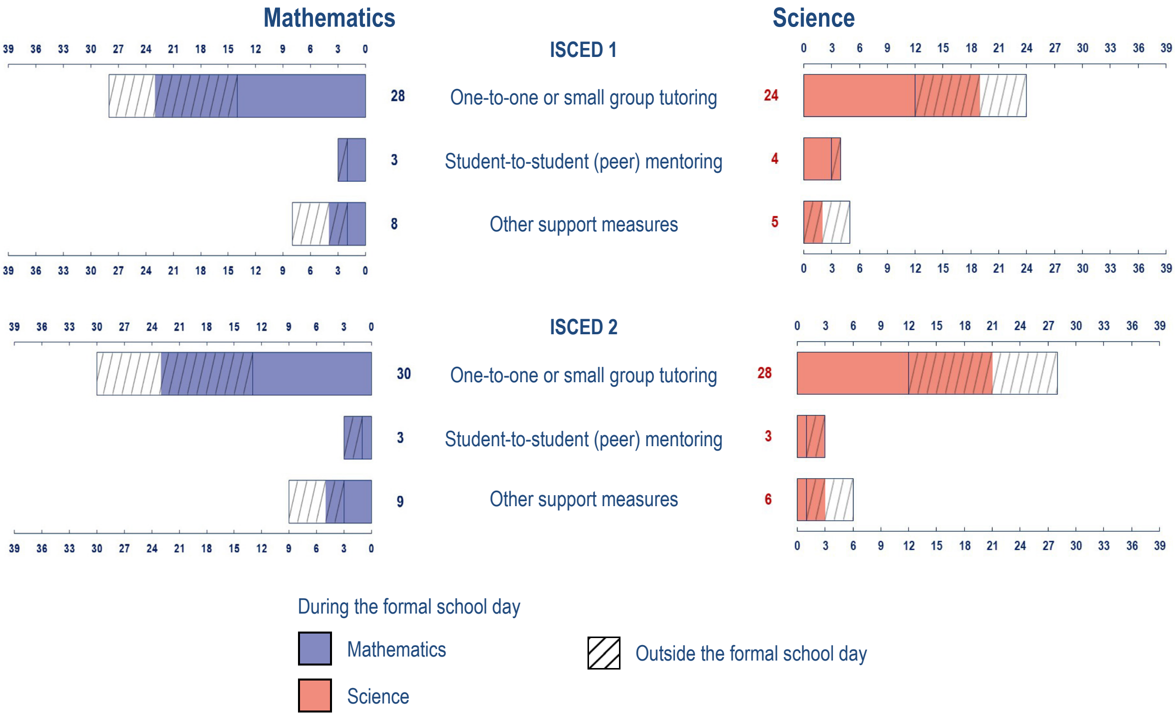
(231) See Annex II, Figure 6.3A, for country-specific information.

(232) https://www.education.gouv.fr/devoirs-faits-un-temps-d-etude-accompagnee-pour-realiser-les-devoirs-7337

(233) Regulation of the Polish Minister of National Education of 9 August 2017 on the rules for organisation and provision of psychological and educational support in public nursery schools, schools and educational institutions (consolidated text, *Journal of Laws of 2020*, item 1280) (Rozporządzenie Ministra Edukacji Narodowej z dnia 9 sierpnia 2017 r. w sprawie zasad organizacji i udzielania pomocy psychologiczno-pedagogicznej w publicznych przedszkolach, szkołach i placówkach (tekst jednolity: Dz.U. z 2020, poz. 1280)).

(234) Basic School Act, Article 12(a).

Figure 6.3: Top-level learning support measures in mathematics and science, ISCED 1-2, 2020/2021



Source: Eurydice.

Explanatory notes

The number and the total length of the bar show in how many European education systems (out of 39 in total) a support measure is prescribed or recommended by top-level documents. Shading indicates whether the support takes places during or outside the formal school day, or both. Country-specific information is available in Annex II, Figure 6.3A.

Only long-term measures are taken into account; temporary measures due to the COVID-19 pandemic are not included in the figure. For more information on COVID-19-related measures, see Section 6.3.3.

While one-to-one or small-group tutoring is the most widespread form of learning support provision, in a few cases top-level documents prescribe or recommend the use of other support measures. One of them is peer mentoring, the value of which is emphasised by some researchers (see, for example, Charlton, 1998). However, its effectiveness is also debated (Gersten et al., 2009). The presence of peer mentoring in top-level recommendations has been reported by Germany, Spain and Luxembourg for both mathematics and science, while Cyprus reports recommending this support measure in science education.

> In **Germany**, peer mentoring is named as a support measure for low-achieving students in some *Länder* (e.g. Nordrhein-Westfalen). Some students can be trained as 'learning coaches' (*Lerncoaches*), who can in turn help those they supervise to better manage their own learning.
>
> In **Cyprus**, guides for teachers recommend that students work in groups that are formed with students from multiple achievement levels during science education in primary schools. As a result, during classwork, low achievers can benefit from interaction with higher-achieving students (235).
>
> In **Luxembourg**, the 2004 Law on the Organisation of Secondary Schools (236) mentions the possibility that a student in the upper classes may be entrusted, at his or her request, by the school head, with academic and personal support measures, to be a tutor of a student in the lower classes or in the fourth grade of secondary school. The school head appoints a teacher to supervise the tutor.

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(235) https://fysed.schools.ac.cy/index.php/el/

(236) *Loi du 25 juin 2004 portant organisation des lycées*.

Other learning support measures include summer schools or summer remedial instruction (in both mathematics and science in Bulgaria (primary education), France and North Macedonia (both education levels), and Sweden (secondary education) and in mathematics in Austria); individual learning plans or programmes (Belgium (French Community), Czechia, Germany and Malta); and training workshops for families (Spain) (237).

> In **Germany**, for the individual support of students with special educational need in mathematics, support plans / learning plans are developed and used to provide individual support in class. They are to be discussed with all teachers involved, the parents and the students, as part of the school's overall plan (238).

Figure 6.3 also reveals that differences between the subject areas are not substantial, although there are slightly more education systems specifying support measures for low achievers in mathematics than for those in science. When the top-level authority specifies support measures, it most often does so for all or most subject areas, with very few subject-specific recommendations (see also Section 6.2). Similarly, differences between the education levels are small, although slightly more support measures are specified for lower secondary than for primary education.

Targeted support

Most top-level support measures target low-achieving students in general, without special attention to specific vulnerable groups. Indeed, most education systems do not have targeted measures when it comes to the goal of reducing low achievement: mainstream measures are assumed to be able to reach those needing support, irrespective of their background.

Nevertheless, a few education systems have identified specific target groups or have put targeted support programmes and measures in place. Such target groups include:

- schools in disadvantaged regions (e.g. in Czechia and Portugal);
- schools with a large number of children from low socioeconomic backgrounds (e.g. in Belgium (French and Flemish Communities) and Ireland);
- low-achieving students from low socioeconomic backgrounds or rural areas, or low-achieving Roma students (e.g. in Spain (Basque Country), Italy, Hungary, Poland, Romania, Slovakia and Serbia).

Teaching practices: differentiated teaching and ability grouping in the classroom

Differentiated teaching and ability grouping are among the most widely cited examples of providing support to students with different achievement levels within the classroom. However, the practices of differentiated teaching and ability grouping have mixed reviews. Research evidence mostly points towards small to moderate positive effects of differentiated teaching and within-class ability grouping on student achievement in mathematics and science (see, for example, Bal, 2016; Salar and Turgut, 2021; Smale-Jacobse et al., 2019; Tieso, 2003). Nevertheless, some experimental studies found no such effects (see, for example, Pablico, Diack and Lawson, 2017) or concluded that the effect of differentiation depended on teachers' training and professional development in differentiated

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(237) An example of a training workshop for families is the workshop 'How to help your children in their studies?', held at IES Jaime Ferrán Clúa (Madrid).

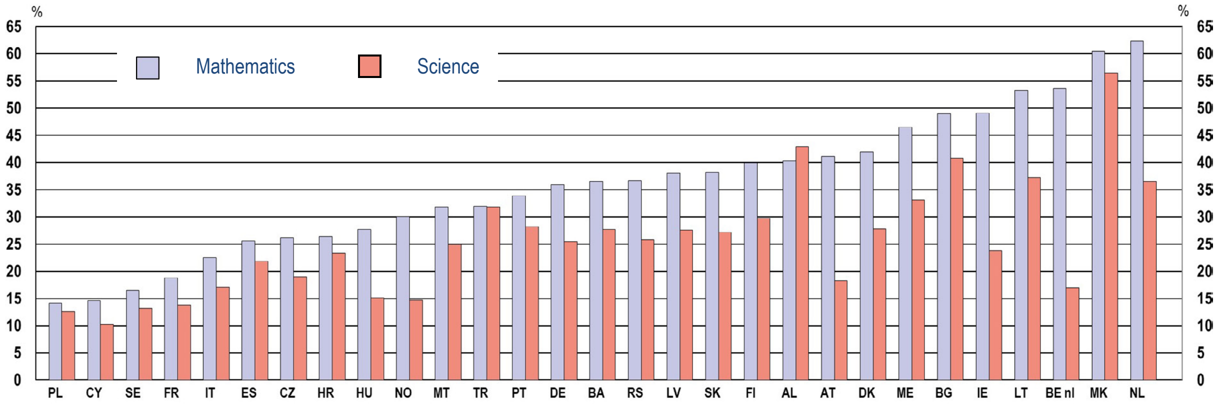
(238) Resolution of the Standing Conference of German Ministers of Education and Cultural Affairs on the principles for the support of students with special difficulties in reading and spelling or in arithmetic, 4 December 2003 (*Grundsätze zur Förderung von Schülerinnen und Schülern mit besonderen Schwierigkeiten im Lesen und Rechtschreiben oder im Rechnen*).

instruction (Prast et al., 2018). Other researchers underline the negative effects of teaching high- and low-achieving students separately and employing different teaching methods (such as widening learning gaps or stigmatisation; see, for example, Boaler, Wiliam and Brown, 2000; Chmielewski, 2014; Gamoran et al., 1995).

While top-level steering documents often recommend support measures that take place outside the classroom or in addition to the usual teaching activities, it is more difficult to find top-level recommendations on instruction practices for the whole class. However, international assessment surveys can provide a good insight into teaching practices based on teachers' responses.

Based on the TIMSS 2019 survey, Figure 6.4 depicts the percentage of fourth graders whose mathematics or science teachers report that students work in same-ability groups in the majority of lessons. As the figure reveals, ability grouping is much more common in mathematics than in science in primary education. In almost all education systems with available information, as well as in the EU-27 on average, mathematics teachers report working in same-ability groups more frequently than science teachers do.

Figure 6.4: Percentage of fourth graders whose mathematics or science teachers report working in same-ability groups in the majority of lessons, 2019



	EU	PL	CY	SE	FR	IT	ES	CZ	HR	HU	NO	MT	TR	PT	DE
Mathematics	27.9	14.1	14.7	16.4	18.8	22.5	25.6	26.2	26.4	27.7	30.0	31.8	31.9	33.9	35.9
Science	19.8	12.6	10.2	13.2	13.7	17.0	21.8	19.0	23.3	15.1	14.7	25.0	31.7	28.2	25.4
	BA	**RS**	**LV**	**SK**	**FI**	**AL**	**AT**	**DK**	**ME**	**BG**	**IE**	**LT**	**BE nl**	**MK**	**NL**
Mathematics	36.4	36.6	38.0	38.1	40.0	40.3	41.1	41.9	46. 5	48.9	49.1	53.2	53.6	60.4	62.3
Science	27.7	25.8	27.5	27.1	29.7	42.9	18.2	27.8	33.1	40.8	23.8	37.2	17.0	56.4	36.4

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 ATBM02H and ATBS02M (linked to the question 'In teaching mathematics/science to this class, how often do you ask students to do the following? / Work in same ability groups', with possible responses being (1) 'Every or almost every lesson', (2) 'About half the lessons', (3) 'Some lessons' or (4) 'Never'). The response categories 1 and 2 were merged into a single category: 'The majority of lessons'. Standard errors are available in Annex III.

The percentages were calculated with the missing values excluded. Missing values exceed 25% in the Netherlands and Norway for both mathematics and science teachers.

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

Differences between mathematics and science teaching practices are smallest – and not significant – in Poland, Turkey, Albania and North Macedonia. In these countries, ability grouping is used in both subject areas to a similar extent. In contrast, differences are biggest in Norway, Austria and Belgium (Flemish Community), where ability grouping is a much more widespread practice in mathematics than in science.

In mathematics, ability grouping is most widespread in the Netherlands and North Macedonia, where teachers of more than 60% of students report grouping students based on ability in the majority of lessons. This practice also covers the majority of students in Lithuania and Belgium (Flemish Community). At the other end of the scale, teachers of less than 20% of students frequently apply the practice of ability grouping in Poland, Cyprus, Sweden and France.

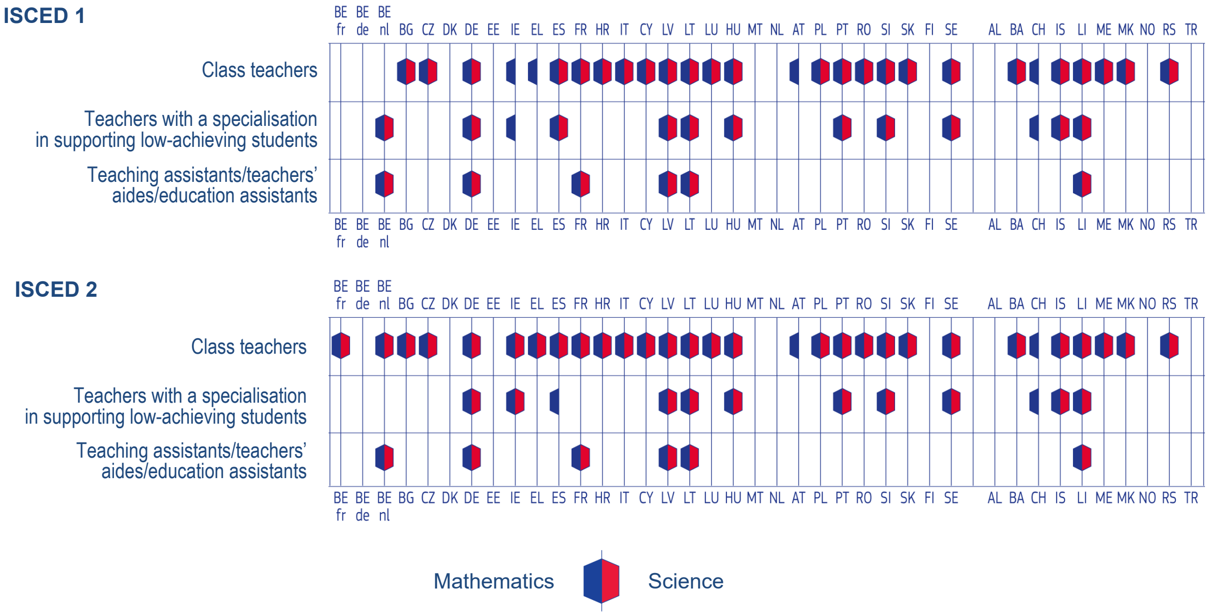
The picture changes a little when it comes to science education. In science, frequent ability grouping applies to the majority of students only in North Macedonia (56.4%). It covers around one third or more of grade 4 students in Turkey, Albania, Bulgaria, Lithuania and the Netherlands. As was the case for mathematics, ability grouping in science is least practised in Poland, Cyprus, Sweden and France, where teachers of less than 15% of students report frequently using this practice.

6.3.2. Who provides learning support?

Academic research has emphasised the importance of the human resources aspects of learning support provision: the teaching staff or school staff providing such support and the training they receive in order to fulfil this task successfully and effectively. Some studies emphasise the need for continuous training activities for class teachers (Montague, 2011; Moser Opitz et al., 2017), whereas others suggest that, in addition to class teachers, employing teachers specialised in learning support can better contribute to reducing the number of low-achieving students (Motiejunaite, Noorani and Monseur, 2014).

Figure 6.5 shows how top-level regulations or recommendations envisage the human resources aspects of learning support provision. The analysis distinguishes between three categories of teaching staff: (1) class teachers, (2) teachers with a specialisation in supporting low-achieving students and (3) teaching assistants / teachers' aides / education assistants. Class teachers, the first category, are the ones who are in charge of teaching students in the classroom. They can be either generalist or specialist teachers (see Chapter 4, Figure 4.3) – in the latter case, different teachers might be responsible for learning support provision depending on the subject area. The second category refers to teachers who have received special training in the identification of and support for students facing difficulties. These teachers often, although not necessarily, teach only low-achieving students (i.e. serve as 'remedial teachers'). The role of remedial teachers in tackling low achievement will be further analysed in Chapter 7. Finally, teaching assistants / teachers' aides / education assistants are staff who assist teachers with instructional responsibilities. Teaching assistants may assist in the classroom, but may also serve as the sole instructor for a class or group of students.

Figure 6.5: Teaching staff providing one-to-one or small group tutoring in mathematics and science, ISCED 1-2, 2020/2021



Source: Eurydice.

As Figure 6.5 reveals, class teachers provide learning support in all education systems with top-level regulations on this aspect (in 28 systems in primary education and in 30 in lower secondary education), and they are regarded as the sole providers of such support in around half of them. Despite their central role, class teachers are required to undergo training in low achievement and related support during initial teacher education in only seven education systems: Germany, Estonia, Croatia, Lithuania, Luxembourg, Austria and Poland. Nevertheless, some education systems note that publicly funded continuous professional development programmes on this type of support are organised for teachers.

In **Bulgaria**, within the national programme 'Together in the care of each student' (239), activities related to the joint work of primary and secondary school teachers are funded. These activities include planning lessons and developing didactic materials for joint implementation or jointly conducting lessons in different subjects, including mathematics and natural sciences.

In **Ireland**, the School Excellence Fund is an initiative to encourage innovation and excellence in education, supporting schools to work together in tackling educational disadvantage and improving learning outcomes for students. In 2011, the Department of Education launched their national strategy to improve literacy and numeracy among children and young people. One area of action is providing improved professional development for teachers. In addition, in the framework of the Delivering Equality of Opportunity in Schools (DEIS) action plan – an initiative focusing on supporting students in schools with a high concentrations of students from socio-economically disadvantaged backgrounds – all teachers of the early primary years receive specific training on teaching mathematics to disadvantaged children (240).

In **Spain**, within the framework of the programme for orientation, advancement and educational enrichment (PROA+) 2020/2021, teacher-training programmes are organised on new methodologies, individualised resources or cooperative learning (241).

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(239) https://www.mon.bg/upload/22572/4NP_Zaedno-vsekiUchenik-20.pdf

(240) See more at: https://www.gov.ie/en/policy-information/4018ea-deis-delivering-equality-of-opportunity-in-schools/

(241) Resolution of 31 July 2020, of the Secretary of State for Education, which publishes the Agreement of the Council of Ministers of 21 July 2020, which formalises the distribution criteria to the autonomous communities, approved by the Education Sector Conference, as well as the distribution resulting from the credit allocated in 2020 to the territorial cooperation programme for the orientation, advancement and educational enrichment in the educational emergency situation of the 2020/2021 academic year caused by the COVID-19 pandemic (#PROA+ 2020/2021).

In addition to class teachers, teachers specialised in supporting low-achieving students participate in learning support provision in 13 education systems in primary education and in 12 at lower secondary level. The role of specialised teachers varies from coordinating learning support provision to actual teaching, often depending on the needs of children or the size of schools. Teaching assistants are involved in learning support provision in six education systems. In some cases, top-level authorities provide the possibility for schools to ask for the appropriate resources for their needs.

> In **Belgium (Flemish Community)**, there is regular consultation between the care coordinator and the class teachers. The care coordinator follows the same children during several school years, to be well informed about changes in their needs. Together with the class teacher, the care coordinator searches for suitable aids (e.g. support teachers) to support children who are having difficulties. In primary school, children are supported both in and outside the classroom. In the classroom, support is usually provided during independent work set by the teacher and the care coordinator. However, some children need more individual support, which takes place in a task class (*taakklas*). In smaller schools, the care coordinator will also take on the tasks of the support teacher; in larger schools, there is a clear division of tasks.
>
> In the **German** *Länder*, support services are made possible through additional staffing. Additional staffing can refer to (1) the allocation of additional teacher hours per week for (subject) teachers in usual classes and supplementary remedial instruction, (2) additional teachers being assigned to hotspots of socioeconomic deprivation, or (3) the involvement of professionals with special competencies. For the support of lower-performing students, additional remedial teachers, pedagogical assistants, other pedagogical staff or special education teachers are deployed (242).
>
> In **Estonia**, low achievers are supported by their class teachers or support specialists depending on their needs, upon the decision of school heads. Support measures are chosen and implemented in cooperation with the parents.
>
> In **Ireland**, the school leader or a special education needs coordinator allocates the work of special education teachers to manage the provision of additional support for pupils. Schools participating in the Delivering Equality of Opportunity in Schools (DEIS) programme (243) are encouraged to nominate a teacher to train as a specialist mathematics recovery teacher. These teachers provide intensive, individualised or small-group teaching for low-attaining children in the first class for 10–15 weeks.
>
> In **Lithuania**, teachers specialised in supporting low-achieving students are called special educators (*specialieji pedagogai*). They are not specialised in a given subject, but support all students with learning problems. In addition, teaching assistants (*mokytojo padėjėjai*) also help low-achieving students. Teaching assistants work together with the teacher, in the classroom, providing extra assistance to students and information to the parents or guardians.
>
> In **Switzerland**, teachers with a specialisation in supporting low achievers assist class teachers in small-group or one-to-one tuition in all schools. Class teachers, however, do not always delegate this support completely to the specialised teacher; they are involved as well, depending on, for instance, the number of pupils concerned.
>
> In **Iceland**, personnel decisions depend on the available resources. In some cases, for instance in the case of schools in smaller municipalities, teachers specialised in supporting low-achieving students are not always available. In these cases, the support is provided by the class teachers.

In addition to the class teachers, specialised teachers or teaching assistants, other professionals (speech therapists, psychologists, social workers, etc.) may also participate in providing support to students. In Cyprus, specialised teachers (mathematicians, physicists) employed by the State Institutes for Further Education can provide learning support in lower secondary education. In Slovakia, in addition to class teachers, other staff with teaching qualifications or students in teacher-training programmes can also participate in support provision. Some education systems emphasise the need for holistic support, with different specialists working together to support students with learning problems and difficulties.

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(242) Resolution of the Standing Conference of German Ministers of Education and Cultural Affairs on the support strategy for lower-achieving pupils, 4 March 2010 (*Förderstrategie für leistungsschwächere Schülerinnen und Schüler*).

(243) https://www.gov.ie/en/policy-information/4018ea-deis-delivering-equality-of-opportunity-in-schools/

In **Czechia**, schools are obliged to operate 'school guidance and counselling centres' (*školské poradenské zařízení*), which have the role of school failure prevention and provide counselling services. Low-achieving students can receive the support of school psychologists, school counsellors, school failure prevention specialists, special educational needs teachers, speech/language therapists and other similar professionals.

In **Liechtenstein**, the responsible class teachers can seek support or advice from school psychologists and school social workers to determine the appropriate support measures. There are also specialist/remedial teachers (*Ergänzungslehrer*) and school assistants (*Klassenhilfen*) in schools, who can also be involved in support. In addition, external experts such as occupational therapists or speech therapists can also be called upon.

In addition, as a form of digitalised support, France has introduced 'Jules', an online virtual assistant to support students in completing their homework in mathematics ([244]).

6.3.3. What impact has the COVID-19 pandemic had on learning support provision?

In 2020, the COVID-19 pandemic arrived in Europe and brought about extensive school closures and distance- and blended-learning periods for many children in the 2020/2021 school year (see Chapter 2, Figure 2.1). While data on the impact of such changes are still scarce, researchers have started to estimate the 'learning loss' experienced by children resulting from physical school closures, as well as the uneven impact of distance learning on students from different socioeconomic backgrounds or achievement levels (Blaskó, da Costa and Schnepf, 2021; Engzell, Frey and Verhagen, 2021; Grewenig et al., 2021). Students with existing learning difficulties have been facing additional hurdles in their learning experience (see also Chapter 2).

Despite the large impact the pandemic has had on schools, only about half of the education systems have put additional measures or support programmes in place, or have dedicated additional resources to learning support provision (Figure 6.6). Among them, the Netherlands adopted a new, comprehensive top-level framework programme on providing support.

In the **Netherlands**, the national education programme (*Nationaal Programma Onderwijs*) ([245]) was created with a focus on helping students catch up to prevent learning loss and low achievement. The programme started in the 2020/2021 school year with a budget of EUR 5.8 billion, evidence-based measures and a support structure.

The most common response to newly emerging learning difficulties as a result of school closures is to organise or offer students additional small-group tutoring or differentiated learning (on top of existing measures), typically taking place either during school holidays or after the formal school day, but in some cases also during the formal school day. Such measures were implemented and funded in Belgium (French and Flemish Communities), Czechia, Ireland, Spain (Castilla y León), France, Italy, Luxembourg, Austria, Poland, Romania and Slovakia.

Belgium (**French Community)** recommended the use of differentiated teaching and remedial support during the school day in both primary and secondary education ([246]) in order to provide additional support to students with difficulties after the school closures, and due to distance and blended learning.

Belgium (Flemish Community) organised summer, autumn and winter schools during the 2020/2021 school year for lower secondary students, as they were the most affected by school closures / hybrid-learning periods. Similarly, summer schools were offered to students with learning difficulties in **Czechia** and **Luxembourg**. In Luxembourg, pupils could go to school in smaller groups during 2 weeks in the summer to receive further educational support from teachers or other educational staff.

In **Italy**, in 2020, Ministerial Order 11 introduced extracurricular small-group tutoring for students at risk of school failure ([247]).

In **Austria**, the 'Corona support package' includes up to two additional support lessons per class in the main subjects.

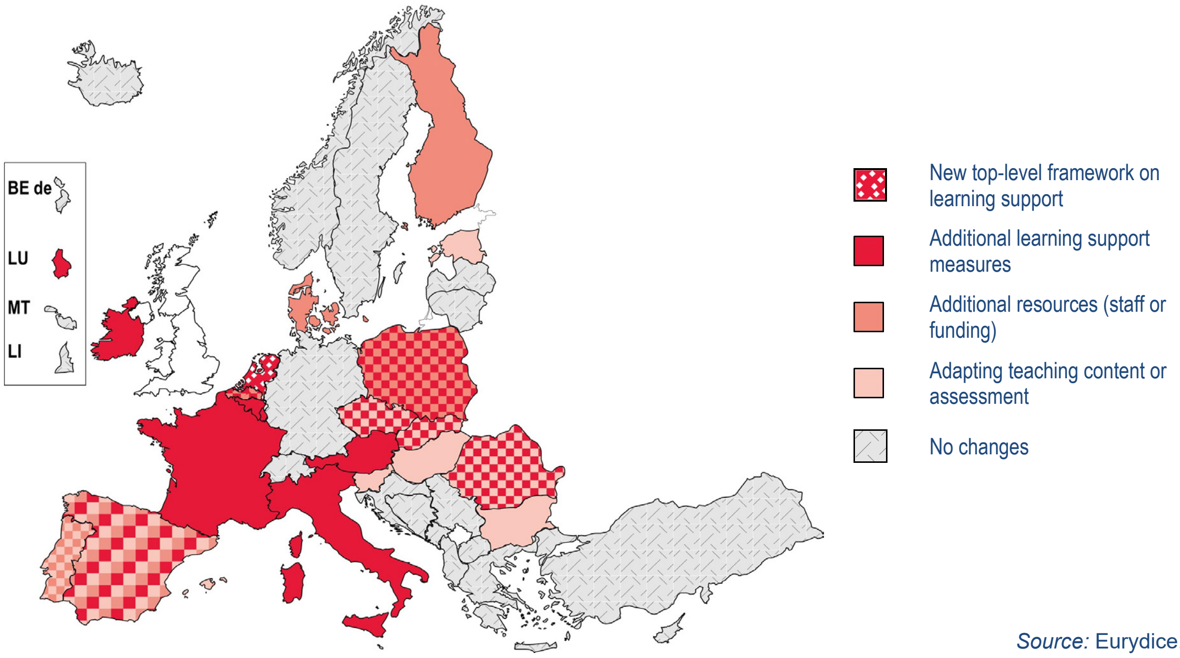
([244]) See: https://jules.cned.fr

([245]) https://www.nponderwijs.nl/

([246]) Ministerial circulars n°7704 of 25/08/2020 and n°8220 of 20/08/2021.

([247]) Italian Ministry of Education Ministerial Order 11 of 16 May 2020.

Figure 6.6: Additional learning support measures and dedicated resources due to the COVID-19 pandemic, ISCED 1-2, 2020/2021



Source: Eurydice.

Explanatory note

The category 'additional resources (funding)' refers to situations where schools had the autonomy to decide on the form of learning support, but top-level authorities provided additional funding to them to address low achievement.

In order to provide the adequate human resources for additional tutoring as well as reinforced counselling and psychological support, Belgium (Flemish Community), Spain (autonomous community of Andalucía), Poland and Portugal have made additional funding available for the temporary recruitment of supplementary staff – educators, psychologists, social workers, etc. – to enable schools to rapidly respond to students' needs.

> All educational centres in the autonomous community of Andalucía, **Spain**, have 'COVID-19 support teachers', who supported teaching work in schools as a reinforcement throughout the 2020/2021 school year (248).
>
> In **Poland**, a programme developed by the Ministry of Education and Science establishes rapid-response teams comprising counsellors, school psychologists, tutors, social workers, etc. The programme targets students severely affected by the COVID-19 crisis and aims to ensure a quick response to the deterioration of the mental health of students with learning difficulties (249).

Denmark and Finland have also distributed additional financial support to schools to address low achievement and learning loss as a result of the pandemic. In Finland, the additional funding targeted especially disadvantaged students (students not speaking the language of instruction at home, students from immigrant backgrounds and students with special educational needs) (250).

In Bulgaria, Czechia, Spain, Hungary, Portugal, Slovakia and Slovenia, top-level authorities issued new guidelines on adapting teaching content and/or the methods of assessment to the new reality. In Romania, guides have been created and made available for all teachers to help them address any

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(248) See https://www.adideandalucia.es/...

(249) See the website of the Polish Ministry of Education and Science for more details.

(250) See the website of the Finnish Ministry of Education and Culture for more details.

delays in their students' learning, for all subjects in primary and lower secondary education. In Estonia, new diagnostic tests were developed to identify learning gaps.

Summary

This chapter provided an overview of top-level learning support measures that education systems have identified to help students facing learning difficulties and to reduce the level of low achievement. Starting the analysis by examining assessment mechanisms through which European education systems identify students' learning needs, the chapter showed that the majority of education systems identify low achievers through ongoing evaluation, testing and grading. In this sense, teachers are in large part responsible for identifying students who need learning support.

In addition to ongoing classroom evaluation, a minority of education systems also rely on national competence-based tests to identify students' individual learning needs. These national tests can be compulsory or recommended. Where they are compulsory, top-level authorities specify the content and the frequency of the tests, and all students need to take them, irrespective of their achievement. Alternatively, top-level authorities can recommend the use of existing national tests when identifying students' learning needs, or can design competence-based tests that can be used by teachers for additional evaluation when they deem it necessary. Such tests are more common in mathematics than in science.

Top-level authorities can also take an active part in identifying the appropriate measures to support students with learning difficulties. In the large majority of education systems, top-level authorities oblige schools to provide learning support for low-achieving students. The majority of education systems also specify in more or less detail the kind of support measures schools can apply to help the students who need support. More frequently (in around half of European education systems), top-level regulations or recommendations are relatively broad, or contain various types of support measures that schools can freely choose from depending on the needs of the students. However, in around one quarter of education systems, the top-level authority provides a detailed framework that schools have to implement relatively thoroughly. Finally, in another quarter of education systems, top-level authorities do not specify learning support measures, and leave this task to local authorities or the schools themselves.

Top-level frameworks of learning support are rarely subject specific; they most often apply to learning difficulties in general. Nevertheless, a handful of education systems have specific provisions on supporting students in mathematics or numeracy. No such specific provisions address learning difficulties in science.

When it comes to determining how exactly schools should support low-achieving students, again slightly more education systems specify support measures in mathematics than in science. Nevertheless, differences are relatively small. The most common way of supporting students with learning difficulties is through additional one-to-one or small-group tutoring, which can take place either during the formal school day or outside it (or both). In addition, in some cases, top-level authorities oblige or advise schools to implement peer mentoring, summer schools or other forms of individualised support.

Differentiated teaching in mathematics and science classes may also serve as a way of supporting low-achieving students in the classroom. The TIMSS 2019 survey shows that differentiated teaching is fairly common in some countries but quite rare in others. However, the overarching pattern across Europe is of differentiated teaching being used more frequently in mathematics than in science.

Learning support provision is most commonly the responsibility of classroom teachers. They participate in supporting low-achieving students in all education systems with top-level regulations or recommendations on these issues. At the same time, around one third of education systems also involve teachers specialised in supporting low-achieving students (‘remedial teachers’) in learning support provision. Other participating staff include, for example, teaching assistants, student teachers and other professionals such as psychologists and social workers.

Finally, this chapter also examined European countries’ responses to the COVID-19 pandemic in terms of additional learning support provision, funding provided for the recruitment of additional teaching and support staff, and changes in teaching content and student assessment. Despite the large impact the COVID-19 pandemic has had on students’ learning experiences, only about half of education systems have put additional measures or support programmes in place, or have dedicated additional resources to learning support provision.

CHAPTER 7: TOWARDS A CONCLUSION: EXPLAINING DIFFERENCES IN LOW-ACHIEVEMENT RATES

After setting the scene by presenting the situation of European education systems in terms of low achievement rates in mathematics and science, and the challenges education systems faced during the COVID-19 pandemic, this report has provided a broad overview of mathematics and science teaching and learning. It examined how mathematics and science teaching and learning are organised in Europe, how learning outcomes are assessed, how instruction is contextualised and how students are supported when facing difficulties in the learning process.

This final chapter aims to bring together all this information by examining the common characteristics of education systems that have relatively low shares of low achievers. Combining qualitative and quantitative methods, the analysis aims to identify links between education structures and policies and percentages of low achievers in mathematics and science in European education systems.

The first section presents two 'path analysis' models (see, for example, Bryman and Cramer, 1990) – one for mathematics and one for science – which view low-achievement rates at the different educational levels as outcomes dependent on how mathematics and science education is organised in European education systems. The second section looks at additional factors that can be associated with lower percentages of underachieving students. Both sections aim to answer the same question: which types of education system tend to have higher shares of students with at least a basic knowledge of mathematics or science?

7.1. Modelling relationships between low-achievement rates

The percentage of low achievers can be measured at different educational levels. Chapter 1 presented low-achievement rates at two points in students' educational careers: in grade 4 (primary education), based on the 2019 Trends in International Mathematics and Science Study (TIMSS) survey administered by the International Association for the Evaluation of Educational Achievement (IEA), and at the age of 15 years (secondary education), based on the 2018 Programme for International Student Assessment (PISA) survey carried out by the Organisation for Economic Co-operation and Development (OECD). As Chapter 1 showed, low-achievement rates correlate strongly across educational levels. Nevertheless, differences remain: some education systems with relatively high percentages of low achievers in primary education have relatively low rates in secondary education and vice versa. Some of these differences can certainly be a result of dissimilarities in the design of the two international assessment surveys (see Chapter 1). Nevertheless, the way mathematics and science education is organised in European education systems can also contribute to these differences.

International student achievement surveys also established that achievement levels tend to correlate across subject areas (i.e. those education systems that do well in mathematics tend to also have good results in science) (see Chapter 1). However, there are some differences in how mathematics and science teaching and learning are organised. As Chapter 3 showed, the number of hours dedicated to mathematics exceeds the number allocated to science in all education systems in primary education, and in the majority of them at lower secondary level. In addition, it is more difficult to obtain clear information on science education than on mathematics education in this regard, as science is often taught together with other subject areas – such as social studies – especially in primary education (see Chapter 3). The organisation of science education can differ considerably between European education systems, as science subjects can be taught in an integrated way or separately. Even definitions of what constitutes 'natural sciences' differ; for example, geography is considered to be part of natural sciences in some education systems but not in others (see Chapter 4 and Annex I).

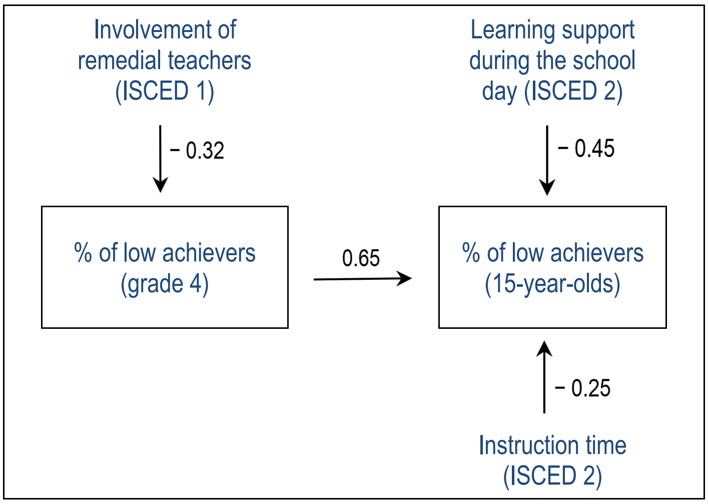
Chapter 4 pointed out that national tests and certified examinations are more commonly organised in mathematics than in science, especially when it comes to tests that are compulsory for all students. This is also true of national tests that aim to identify individual learning needs (Chapter 6). Chapter 5 revealed that, to increase interest and show the usefulness of mathematics, real-life applications in various contexts are part of almost all curricula in primary and lower secondary education. In contrast, history-of-science and especially socioscientific topics are not as common in science curricula at these educational levels. In addition, as Chapter 6 showed, while learning support measures are most often organised similarly for all subjects, subject-specific learning support is specified in steering documents only in mathematics, and not in science.

To analyse relationships between the characteristics of mathematics and science education and low achievement levels, this section uses the method of path analysis (see, for example, Bryman and Cramer, 1990). Path analysis allows for the modelling of complex patterns of relations, including indirect relationships between explanatory and outcome variables. Thus, path analysis models build on the assumption that certain combinations of factors could produce better results than a single policy measure.

To account for differences in the organisation of instruction between mathematics and science, two path analysis models were constructed: one for each subject. These models aim to explain the differences in percentages of low achievers between primary and secondary education levels. In other words, they show which characteristics of mathematics and science education could explain differences in low-achievement rates among 15-year-olds, controlling for the percentages of low achievers in grade 4.

Figures 7.1 and 7.2 illustrate the two path analysis models exploring this complex relationship between characteristics of education systems and low-achievement rates in mathematics and science. The analysis found some common characteristics that can ensure that more students have basic knowledge in both mathematics and science.

Figure 7.1: Model 1 on low achievement in mathematics



Explanatory notes

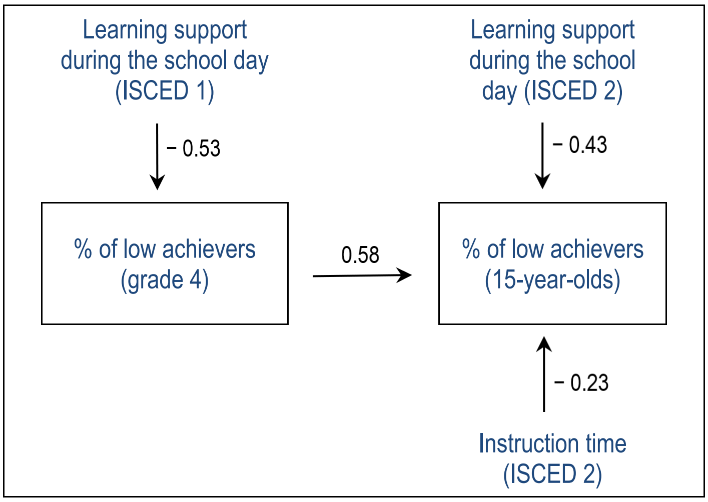
Parameter estimates are standardised and significant at the 5% level.

The R^2 values are 0.10 for the percentage of low achievers among grade 4 students and 0.79 for the percentage of low achievers among 15-year-olds. Fit indices for the model: chi-square = 3.491, degrees of freedom = 3, *p*-value = 0.32, comparative fit index = 0.990, Tucker–Lewis index = 0.977 and root mean square error of approximation = 0.066.

Due to the non-random sample, *p*-values should be interpreted with caution.

Source: Eurydice.

Figure 7.2: Model 2 on low achievement in science



Explanatory notes

Parameter estimates are standardised and significant at the 5% level.

The R^2 values are 0.28 for the percentage of low achievers among grade 4 students and 0.77 for the percentage of low achievers among 15-year-olds. Fit indices for the model: chi-square = 0.986, degrees of freedom = 3, *p*-value = 0.80, comparative fit index = 1.000, Tucker–Lewis index = 1.098 and root mean square error of approximation = 0.000.

Due to the non-random sample, *p*-values should be interpreted with caution.

Source: Eurydice.

Explaining the differences between low achievement rates across education levels

The models confirm the significant relationship between the percentage of low achievers at grade 4 and among 15-year-old students (i.e. the higher the share of underachieving students is in primary education, the higher it is in secondary education). This relationship holds for both mathematics and science. With the highest standardised regression coefficients in the path analysis models (0.65 in mathematics and 0.58 in science), low-achievement rates at primary level are the strongest predictors of the shares of underachieving students at secondary level.

Therefore, controlling for the percentages of low achievers in primary education allows for a better identification of measures that can contribute to the rate of low achievers specifically in secondary education. Two such characteristics of mathematics and science teaching are identified: (1) whether learning support provided to students with learning difficulties takes place during the formal school day (as opposed to only after formal the school day) and (2) how much time is dedicated to mathematics or science education at lower secondary level (per notional year). These factors can explain the differences between education levels in terms of the relative share of students who lack a basic understanding of mathematics or science. Education systems in which relatively more time is spent teaching mathematics or science and providing learning support during the formal school day have the potential to lower underachievement rates for 15-year-olds relative to their rates for primary education.

As Chapter 6 discussed, although the importance of learning support measures is widely accepted, there is little evidence on the relative effectiveness of the different ways of providing support to low-achieving students. Research has found positive effects on achievement levels of both within-class interventions (Montague, 2011; Moser Opitz et al., 2017) and after-school support (Ariyo and Adeleke, 2018; Laurer et al., 2006; Scheerens, 2014; Yin, 2020). However, research has not focused much on comparing the effectiveness of support organised during and after the school day, mostly due to the lack of reliable comparative research design in this area.

This report collected information on learning support measures as they are specified in top-level regulations, recommendations and guidelines. However, not all education systems have such top-level frameworks. Where local authorities or even schools are responsible for defining how learning support is provided, data on the actual support provided by the schools can be scarce. Nevertheless, the majority of education systems do provide definitions (with varying levels of detail) of support measures, including whether such support should be provided during the formal school day (i.e. during classes) or as a form of after-school support.

The present analysis therefore distinguished between education systems that organise learning support in mathematics and/or science during the formal school day and those that define learning support measures only as after-school activities. Education systems in which the top-level authority does not define support measures and in which there is no top-level information on when learning support takes place (251) are excluded from the analysis (considered missing). As there are more education systems that do not have a top-level framework for learning support in science than in mathematics, more education systems are regarded as missing in the analysis for science.

Concerning instruction time, as Chapter 3 explained, although research evidence points towards the positive effects of increased instruction time, most studies argue that instruction time alone cannot account for students' academic achievement. What happens during the lessons also matters: scholars investigating the relationships between instruction time and students' academic achievement emphasise the quality of teaching as a key factor in students' successful learning (Lavy, 2015; Meyer and Klaveren, 2013; Phelps et al., 2012; Prendergast and O'Meara, 2016).

Chapter 3 also showed that more instruction time is dedicated to mathematics at primary level than at lower secondary level in most education systems. In contrast, for science, data show that instruction time is greater at lower secondary level in nearly all education systems/tracks (252). In more than half of the education systems/tracks, the number of notional hours (253) per year in science at least doubles compared with primary education.

However, again some cases had to be excluded from the analysis due to high degrees of local or school autonomy. As Chapter 3 indicated, in some education systems, top-level education authorities set only a total number of teaching hours for a range of compulsory subjects within a given grade, and schools / local authorities have the autonomy to decide how much time to allocate to each subject. In addition, the number of hours dedicated to mathematics and/or science may also include the time to be spent on other subjects. The education systems concerned are excluded from the analysis (considered missing), together with systems in which instruction time has been considerably affected by school closures and distance learning (254). For education systems with multiple educational pathways/tracks at lower secondary level, the pathway/track with the smallest number of hours was taken into consideration.

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(251) In mathematics, these are Belgium (German-speaking Community), Denmark, Italy, Latvia, the Netherlands and Albania at both education levels, Belgium (French and Flemish Communities) at primary level and Norway at lower secondary level. In science, these are Belgium (German-speaking Community), Denmark, Italy, Latvia, Malta, the Netherlands, Austria, Albania and Switzerland at both levels, Belgium (French and Flemish Communities), Ireland and Greece at primary level and Norway at lower secondary level.

(252) Differentiated tracks are clearly distinct education pathways that students can follow during secondary education (see also the Glossary). Instruction time can differ between these tracks already at lower secondary level (see Chapter 3).

(253) Instruction time per notional year at a given education level corresponds to the total taught time in hours at that education level divided by the number of years of that education level.

(254) These education systems are as follows: Horizontal flexibility (see Chapter 3): Belgium (French Community at ISCED 1, German-speaking and Flemish Communities at both ISCED 1 and 2), Italy (ISCED 1), the Netherlands (ISCED 1 and 2) and Poland (ISCED 1). Time dedicated to mathematics includes taught time dedicated to other subjects: France (ISCED 1) and Italy (ISCED 2). Time dedicated to science includes taught time dedicated to other subjects: France (ISCED 2) and Italy (ISCED 2). Science is a compulsory flexible subject chosen by schools: Ireland (ISCED 2). Large impact of the COVID-19 pandemic on instruction time: North Macedonia (ISCED 1 and 2). The analysis does not include instruction time in science at primary level, as science education includes other knowledge areas in too many cases.

In accordance with the research literature, differences in instruction time alone cannot explain differences in low-achievement rates at either educational level ([255]). However, when controlling for the pre-existing level of low achievement and the type of learning support students receive, the conclusions are different: increasing the time spent on learning mathematics or science in lower secondary education together with support measures provided during the school day to students with learning difficulties has the potential to lower underachievement rates.

Explaining low achievement rates among grade 4 students

When it comes to explaining low achievement rates among grade 4 students, the models depicted on figures 7.1 and 7.2 highlight the role of two different factors in mathematics and science: (1) in mathematics, whether teachers with a specialisation in supporting low-achieving students ('remedial teachers') provide learning support, and (2) in science, whether learning support for students with learning difficulties is provided during the formal school day.

The involvement of different professionals in helping students with learning difficulties, as envisaged by top-level regulations, guidelines or recommendations, is another characteristic of learning support provision (see Chapter 6). Several studies emphasise the importance of adequate human resources and teacher training to ensure effective support within the classroom (Montague, 2011; Moser Opitz et al., 2017). Motiejunaite, Noorani and Monseur (2014) highlight the significant role of teachers specialised in supporting low-achieving students in reading literacy.

Whereas class teachers are intended to participate in learning support provision in all education systems with regulations or recommendations in this area, the involvement of remedial teachers is less commonly required (see Chapter 6, Figure 6.5). Nevertheless, according to Model 1, education systems in which remedial teachers are intended to provide learning support have, on average, lower percentages of low achievers. Thus, including such professionals in learning support provision in mathematics could increase its effectiveness. This relationship is not significant in science.

In science, according to Model 2, learning support provision during the formal school day is associated with lower percentages of low-achievers among fourth grade students. Thus, in this case, similar factors play a role in both primary and lower secondary education. The relationship shown in Model 2 could also apply to mathematics.

7.2. Other factors associated with lower percentages of low achievers in mathematics or science

The above models provide one explanation of the differences in low-achievement rates between primary and secondary education, focusing on the relationship between underachievement rates at primary and secondary levels. Although these models have a relatively high explanatory value, they can include only a limited number of explanatory factors due to the small number of education systems. However, other factors not included in the models may also be associated with higher percentages of students with at least a basic knowledge in mathematics or science. These characteristics of mathematics and science education are discussed in the following subsections. These subsections rely on bivariate analysis.

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[255] Spearman's rank correlation coefficients between the number of notional hours dedicated to mathematics in primary education and the percentage of low achievers among fourth grade students, and between the number of notional hours in lower secondary education in mathematics/science and the percentage of low achievers among 15-year-old students in mathematics/science are all negative but not statistically significant.

National tests in mathematics in primary education

National tests and certified examinations are generally regarded as important accountability tools in education systems (Allmendinger, 1989; Hooge et al., 2012; Horn, 2009). School accountability broadly refers to the practice of holding schools responsible for the results of their students, and national tests can serve as tools to monitor the performance of students, schools and the education system as a whole.

Previous analyses could not always draw firm conclusions about the impact of accountability policies on student performance due to the diversity of policy goals, designs and implementation methods, in addition to the complex interrelationship between accountability and other policies (Brill et al., 2018; Fahey and Köster, 2019; Faubert, 2009; Figlio and Loeb, 2011; Skrla and Scheurich, 2004). Chapter 4 discussed some potential adverse effects of national tests (e.g. lower student performance due to increased anxiety), especially concerning low achievers. Nevertheless, some research points towards the positive effects of national tests on average student performance, especially for low- and medium-performing countries (Bergbauer, Hanushek and Wößmann, 2018).

When examining data collected for this report, the analysis of 2018 PISA data shows that education systems organising certified examinations or national tests in mathematics at primary level tend to have lower percentages of low achievers among 15-year-olds. This remains true regardless of whether national tests are compulsory for all students or are sample-based, and whether or not they have the explicit aim of identifying individual learning needs. Having any kind of national examination or test in mathematics at primary level tends to go hand in hand with lower percentages of underachieving students in mathematics. The 10 education systems without certified examinations or national tests in mathematics have, on average, higher percentages of low-achieving 15-year-old students: 31.7% on average across these education systems. In comparison, the average low-achievement rate is 22.7% in the 28 education systems that organise certified examinations or national tests in mathematics. The difference between the two groups is statistically significant (256). However, this relationship is not present for certified examinations or national tests at lower secondary level.

This finding certainly does not mean that certified examinations or national tests guarantee higher achievement levels; neither does it suggest that examinations or tests are necessary for reducing the percentage of low achievers. There are education systems with relatively low percentages of low achievers that do not organise national tests in mathematics at primary level (e.g. Poland and Switzerland; see Chapter 1, Figure 1.2, for the percentages of low achievers, and Chapter 4, Figure 4.6, for information on certified examinations and national tests), and some education systems (most notably Bulgaria and Romania) have relatively high percentages of low achievers despite having such national tests. Nevertheless, there are important differences between the two groups in terms of the average percentage of low achievers.

Including socioscientific issues in science teaching

Chapter 5 of this report discussed certain aspects of mathematics and science curricula that relate to students' lives and give context for abstract concepts. Real-life applications of mathematics were included in the curricula of almost all education systems and thus provided no variation for exploring the relationship with low achievement. During the first eight grades of school, the curricula of every European education system included in this analysis either make some general statements about

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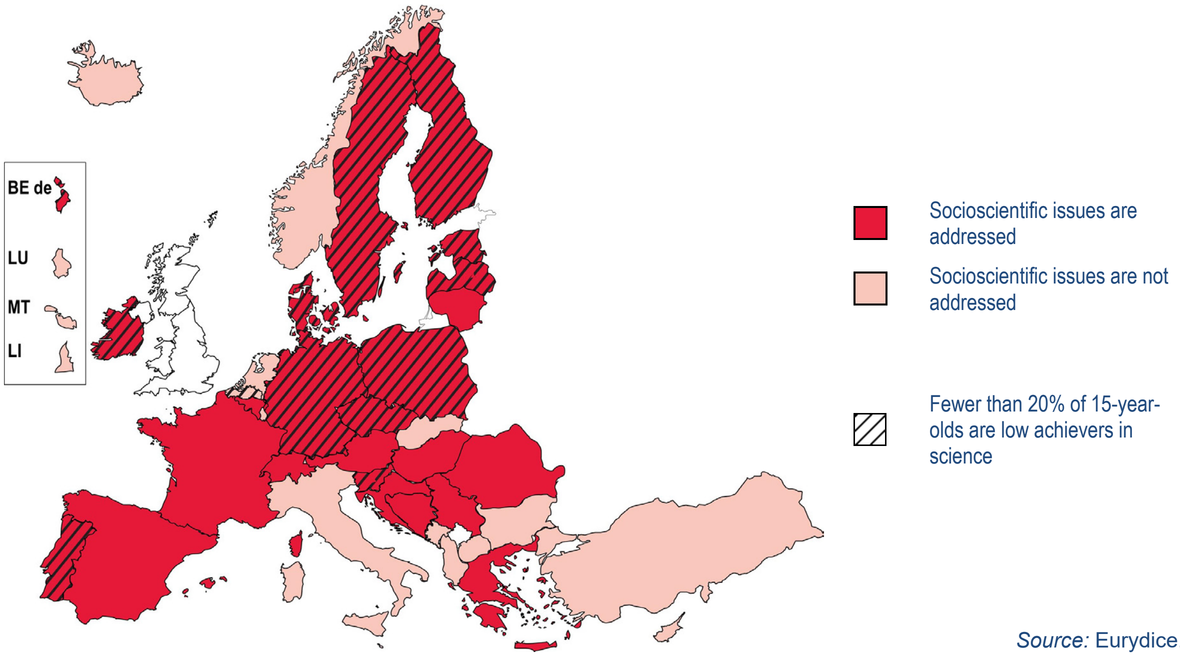
(256) The difference between the two averages is 8.97 percentage points, with a standard error of 0.63. This difference is significant at the 5% level (*t*-value: 12.93).

mathematics in functional contexts or provide concrete examples of how mathematical concepts should be applied in practice, through handling money, examples from architecture, cooking or do-it-yourself activities (see Annex II, Figure 5.1A). Similarly, learning for environmental sustainability forms a compulsory part of science curricula in all of the European education systems by the end of grade 8 (see Chapter 5, Figure 5.6) and thus was not suitable for explaining country-level variations in student achievement results.

However, emphasis on the philosophical, historical and societal aspects of science was not as evenly spread across Europe; therefore, it was applicable for the statistical analysis. When comparing the proportions of low achievers in science in countries that include certain aspects of contextualisation in their curricula and those that do not, certain aspects proved significant. Those education systems with curricula that mention socioscientific issues seem to have a higher proportion of 15-year-old students who achieve basic scientific literacy. The analysis of 2018 PISA data shows that the average proportion of low achievers in the 24 education systems that include some aspects of science and ethics in their curricula was 22.1%. The average share was 27.1% in the 14 education systems that did not refer to any of the analysed socioscientific questions in their national curricula. The difference between the two proportions is statistically significant ([257]). Figure 7.3 visually illustrates the relationship. Almost all education systems in which fewer than 20% of students are low achievers in science address socioscientific questions in their curricula by the end of grade 8. The only exception is Belgium (Flemish Community), where schools have autonomy over whether and to what extent to include such questions.

Figure 7.3: Inclusion of science and ethics issues in curricula during the grades 1-8, 2020/2021



Source: Eurydice.

Explanatory notes

The category 'socioscientific issues are addressed' refers to those countries that include in curricula any of the aspects mentioned in Annex II, Figure 5.4A, at grades 1–4 and/or grades 5–8.
The percentage of low achievers is based on OECD, 2018 PISA database. For the estimates of these percentages, see Chapter 1, Figure 1.2.

([257]) The difference between the two proportions is 5.0 percentage points, with a standard error of 0.71. This difference is significant at the 5% level (*t*-value: 7.15).

The results highlight the importance of including societal issues and the ethical consequences of scientific developments in lower secondary education. When students are invited to explore moral dilemmas in the field of biotechnology, explain their own opinions on animal testing or name risks to modern civilisation posed by technological progress, general levels of achievement improve. This supports the notion that critical analysis of the social effects of scientific developments forms an important part of scientific literacy (Pleasants et al., 2019; Sadler, 2011; Zeidler, 2015).

Interestingly, the inclusion in curricula of certain factual aspects of history of science did not yield a significant relationship with low achievement levels. This is in line with the studies that highlight the ‘affective’ rather than ‘cognitive’ effect of history-of-science themes. In other words, historical analysis of scientific events relates to students’ interest in and understanding of the nature of science rather than to achievement results (Abd-El-Khalick and Lederman, 2000, 2010; Wolfensberger and Canella, 2015). Moreover, such findings might be due to the factual nature of the curriculum analysis that was conducted. Merely positioning scientific discoveries in time or learning some facts about lives of scientists is not sufficient to raise achievement levels. To improve achievement, history of science should be treated in a way that illuminates particular characteristics of science rather than history (Abd-El-Khalick and Lederman, 2010). Proper integration of historical investigations when teaching modern science concepts is challenging (Henke and Höttecke, 2015). More research is needed to determine the extent to which the reflective aspects of history of science are included in European curricula. However, the analysis presented in this report suggests that reflection of ethics in scientific developments is an essential part of scientific thinking. The science curricula of lower secondary education may benefit from the inclusion of socioscientific questions.

Conclusion

When so many students in Europe lack basic literacy in mathematics and science, it is crucial to know what policies have the potential to influence student achievement. This chapter highlighted the top-level regulations shared by education systems with lower levels of low achievers in mathematics and science. The analysis put together qualitative data on regulations and measures and student achievement results gathered by comparative international surveys (TIMSS and PISA).

The results highlight the importance of timely and competent learning support for students who are falling behind. From the very first grades of school, every student should have the opportunity to receive additional help when needed. The models revealed the importance of this support being provided during school hours, and preferably by teachers who have specific training in remedial pedagogies.

In addition to professional learning support at every school grade, students can also benefit from more instruction time in mathematics or science in general. When controlling for low-achievement rates in early years, the analysis shows that the number of teaching hours in higher grades dedicated to these subjects matters. In addition to time, the learning content also makes a difference: in science, including socioscientific questions in curricula can raise students' motivation and thus can play a role in increasing the share of students achieving basic scientific literacy. Furthermore, national tests can be useful accountability tools contributing to high-quality education. Such standardised tests – especially in early grades – may also help to identify students who are falling behind and thus enable appropriate and timely support.

The analysis was based on top-level information: laws, regulations, recommendations and guidelines issued by the highest level of authority in education systems. This has both advantages and disadvantages. On the one hand, relationships between student achievement and top-level policy approaches could be explored, providing crucial insights for policymakers. On the other hand, top-level information is sometimes incomplete due to high degrees of local or school autonomy. Therefore, the availability of more information on how learning support measures are organised in schools could further enrich such enquiry. Moreover, there is a need for more comparative research to determine the most effective methods of organising learning support in schools.

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GLOSSARY

I. General terms

Biodiversity: The variety of life found in a given place on earth or, often, the total variety of life on earth. A common measure of this variety, called species richness, is the count of species in an area (Pimm, 2021).

Certified examinations: Formal examinations administered at the end of ISCED levels 1, 2 or 3. They are similar to other national tests (see **National tests**) in that they may be carried out under the responsibility of top-level authorities using standardised examination procedures. Passing these examinations results in the award of a certificate or other official proof of having successfully completed a particular level or full course of education.

Continuing professional development: The in-service training undertaken throughout a teacher's career that allows them to broaden, develop and update their knowledge, skills and attitudes.

Curriculum: An official steering document (see **Steering documents**) issued by top-level authorities detailing programmes of study and/or any of the following: learning content, learning objectives, attainment targets, guidelines on pupil assessment and syllabuses. More than one type of steering document may be in force at any one time in an education system, and these may impose different levels of obligation on schools to comply. They may, for example, contain advice, recommendations or regulations. Whatever the level of obligation, they all establish the basic framework in which schools develop their own teaching to meet their pupils' needs.

Differentiated tracks/pathways/streams: Clearly distinct education pathways that students can follow during secondary education. Typically, these pathways differ in their focus, offering general, vocational or technical education, and they often lead to a different type of certificate at the end of the programme. Different tracks/pathways/streams can be provided in the same school or by specific types of school.

Digital learning resources: Any digital technology resources that are designed and intended to be used by teachers and learners for learning. See also **Digital technology**.

Digital technology: Any product that can be used to electronically create, view, distribute, modify, store, retrieve, transmit or receive information in a digital form. This includes computer networks (e.g. the internet) and any online services supported by these (e.g. websites, online libraries); any kind of software (e.g. programmes, apps, virtual environments, games), whether on the network or installed locally; any kind of hardware or 'device' (e.g. personal computers, mobile devices, digital whiteboards); and any kind of digital content (e.g. files, information, data).

Generalist teacher: A teacher (usually in primary education) who is qualified to teach all (or almost all) subjects in the curriculum.

Greenhouse effect: A warming of the earth's surface and troposphere (the lowest layer of the atmosphere) caused by the presence of water vapour, carbon dioxide, methane and certain other gases in the air (Britannica, 2021a).

History of science: The development of science over time (Williams, 2021).

International Standard Classification of Education (ISCED): Developed to facilitate comparisons of education statistics and indicators across countries on the basis of uniform and internationally agreed definitions. The coverage of ISCED extends to all organised and sustained learning opportunities for children, young people and adults, including those with special educational needs, irrespective of the institutions or organisations providing them or the form in which they are delivered.

The current classification – ISCED 2011 (UNESCO UIS, 2012) – has the following levels of primary and secondary education.

ISCED 1: Primary education

> Primary education provides learning and educational activities typically designed to enable students to develop fundamental skills in reading, writing and mathematics (i.e. literacy and numeracy). It establishes a solid foundation for learning and a sound understanding of core areas of knowledge, and fosters personal development, thus preparing students for lower secondary education. It provides basic learning with little, if any, specialisation.
>
> This level begins at 5–7 years of age, is compulsory in all countries and generally lasts 4–6 years.

ISCED 2: Lower secondary education

> Programmes at ISCED level 2, or lower secondary education, typically build upon the fundamental teaching and learning processes that begin at ISCED level 1. Usually, the educational aim is to lay the foundation for lifelong learning and personal development, preparing students for further educational opportunities. Programmes at this level are usually organised around a more subject-oriented curriculum, introducing theoretical concepts across a broad range of subjects.
>
> This level typically begins around the age of 11 or 12 years and usually ends at the age of 15 or 16 years, often coinciding with the end of compulsory education.

ISCED 3: Upper secondary education

> Programmes at ISCED level 3, or upper secondary education, are typically designed for students completing secondary education in preparation for tertiary or higher education, or to provide skills relevant to employment, or both. Programmes at this level offer students more subject-based, specialist and in-depth programmes than in lower secondary education (ISCED level 2). They are more differentiated, with an increased range of options and streams available.
>
> This level generally begins at the end of compulsory education. The entry age is typically 15 or 16 years. Entry qualifications (e.g. completion of compulsory education) or other minimum requirements are usually needed. The duration of ISCED level 3 varies from 2 to 5 years.

Large-scale initiatives: Initiatives or policy measures that operate throughout the whole education system or a significant geographical area rather than those restricted to a particular institution or geographical location.

Learning outcomes/objectives: Statements of what a learner knows, understands and is able to do on completion of a learning process, defined in terms of knowledge, skills and competences. Learning outcomes indicate actual attainment levels whereas learning objectives define the competences to be developed in general terms.

Local authorities: Authorities responsible for territorial units below regional level. Local authorities may comprise elected representatives or they may be administrative divisions of central authorities.

Low-achieving students: Students performing below the expected level of attainment in one or more school subjects. Low achievement may be expressed in absolute terms (e.g. a low grade) or in relative terms (e.g. students who underperform compared with the majority of the class or, in other words, students whose results are significantly lower than the class average).

Mathematics: Covers all numeracy skills and subjects such as arithmetic, algebra, geometry and statistics.

National tests: Tests carried out under the responsibility of the top-level education authority during ISCED levels 1–3. The procedures for the administration and marking of these tests, the setting of content and the interpretation and use of results are decided at the top level. All students take the tests under similar conditions, and tests are marked in a consistent way. National tests are separate from and often additional to certified examinations (see **Certified examinations**) taken at the end of an ISCED level. Tests designed at school level on the basis of a centrally designed framework of reference are not considered national standardised tests. International surveys such as PISA are also not considered national tests, although the results may be used for national purposes.

One-to-one tuition: A form of individualised learning support in which one student is being taught or given learning support by one teacher (or teaching assistant).

Science (or natural sciences): Any system of knowledge that is concerned with the physical world and its phenomena, and entails unbiased observations and systematic experimentation. In general, science involves the pursuit of knowledge covering general truths or the operations of fundamental laws (Britannica, 2021b).

Science and ethics: Examining the ethical consequences brought by advances in science and technological innovations.

Science as an integrated subject: An umbrella subject encompassing the scientific subjects taught at school, such as physics, chemistry, biology, geology and geography. In some cases, particularly at primary level, science as an integrated subject includes other curriculum subjects, such as social studies.

Special educational needs: A range of needs, including physical and mental disabilities, and cognitive and educational impairments (UNESCO, 2021). A child is commonly recognised as having special educational needs if they are not able to benefit from the school education generally available to children of the same age without additional support or adaptations in the content of studies.

Specialist teacher: A teacher who is specifically qualified to teach one or two curriculum subjects.

Steering documents: Different kinds of official documents containing regulations, guidelines and/or recommendations for education institutions.

Sustainability: Prioritising the needs of all life forms and of the planet by ensuring that human activity does not exceed planetary boundaries (Bianchi, Pisiotis and Cabrera Giraldez, 2022).

Teachers with a specialisation in supporting low-achieving students: Teachers who have received special training – either during initial teacher education or as part of their continuing professional development (see **Continuing professional development**) – on the identification of and support for students facing difficulties. These teachers often, although not necessarily, teach only low-achieving students (i.e. serve as 'remedial teachers').

Teaching assistant: An individual who assists a teacher with instructional responsibilities. Teaching assistants may assist in the classroom, but may also serve as the sole instructor for a class or group of students. Teaching assistants may also be referred to as 'teachers' aides' or 'education assistants'.

Top level / top-level authority: The highest level of authority with responsibility for education in a given country, usually at national (state) level. However, for Belgium, Germany and Spain, the administrations of the communities, *Länder* and autonomous communities, respectively, either are wholly responsible or share responsibilities with the national level for all or most areas relating to education. Therefore, these administrations are considered the top-level authorities for the areas where they hold the responsibility, while, for those areas for which they share responsibility with the national level, both are considered to be top-level authorities.

II. Statistical terms

Correlation coefficient: An index that quantifies the linear relationship between a pair of variables. The coefficient takes values between – 1 and 1, with the sign indicating the direction of the relationship and the numerical magnitude indicating its strength. Values of – 1 or 1 indicate that the sample values fall on a straight line. A value of zero indicates a lack of any linear relationship between the two variables. Spearman's rank correlation coefficient is a coefficient that takes into account the ranks of the variables and not their observed values (Everitt and Skrondal, 2010).

Explanatory variables: Variables that seek to 'predict' or 'explain' the outcome variable.

Linear regression: A linear approach to modelling the relationship between an outcome variable and one or more explanatory variables. When a model has one explanatory variable, this is called simple or bivariate linear regression. For more than one explanatory variable, it is called multiple linear regression. In linear regression, the observations are assumed to be the result of random deviations from an underlying linear relationship (depicted as a straight line) between an outcome variable and an explanatory variable. The smaller the deviations from the underlying relationship (i.e. the smaller the distance of the observations from the line), the better the fit of the model to the observed values (see also ***R*-squared (*R^2*)**).

Outcome variable: A variable whose value depends on the value of one or more explanatory variables. In this report, the main outcome variable is percentage of low achievers.

Path analysis: A tool for evaluating the interrelationships among variables by analysing their correlational structure (Everitt and Skrondal, 2010). Path analysis allows the measurement of both direct and indirect effects on the main outcome variable. The relationships are modelled using a path diagram (see, for example, Bryman and Cramer, 1990).

Percentile: The value of the variable below which are a given percentage of the observations in the dataset. For example, a 25th percentile value (denoted P25) of EUR 1 000 for an income variable means that 25% of people in that sample earn less than EUR 1 000. P0 is the minimum and P100 is the maximum.

***R*-squared (R^2):** Also known as 'goodness of fit'. The R^2 is the proportion of the variance in the outcome variable that is predictable from the explanatory variable(s).

Significance level: The probability of wrongly rejecting the null hypothesis (the hypothesis that there is no difference or no association) when it is true. For example, a significance level of 0.05 indicates a 5% risk of concluding that a relationship exists when in reality there is no relationship.

ANNEXES

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

ISCED levels / Grades	Curriculum approaches	Subjects/Learning areas
Belgium (French Community)		
ISCED 1 / Grades 1-6	Science as an integrated subject	Scientific awakening
ISCED 2 / Grades 7-8	Science as an integrated subject	Scientific awakening
Belgium (German-speaking Community)		
ISCED 1 / Grades 1-6	Science as an integrated subject	Natural science (Biology, Chemistry and Physics)
ISCED 2 / Grades 7-8	Science as an integrated subject	Natural science (Biology, Chemistry and Physics)
Belgium (Flemish Community)		
ISCED 1 / Grades 1-6	Local/school autonomy	Local/school autonomy ('World orientation' is frequently used, covering Science, Technology, People and society)
ISCED 2 / Grades 7-8	Local/school autonomy	Local/school autonomy
Bulgaria		
ISCED 1 / Grades 1-2	Science as an integrated subject	Environment
ISCED 1 / Grades 3-4	Science as an integrated subject	Man and nature
ISCED 2 / Grades 5-6	Separate science subjects	Geography and economics, Man and nature
ISCED 2 / Grade 7	Separate science subjects	Geography and economics, Biology and health education, Physics and astronomy, Chemistry and environmental protection
ISCED 3 / Grade 8 (258)	Separate science subjects	Physics and astronomy, Geography and economics, Biology and health education, Chemistry and environmental protection
Czechia (259)		
ISCED 1 / Grades 1-5	Science as an integrated subject	People and their world
ISCED 2 / Grades 6-9	Separate science subjects	Physics, Chemistry, Biology, Geography
Denmark		
ISCED 1 / Grades 1-6	Science as an integrated subject	Nature and technology
ISCED 2 / Grades 7-9	Separate science subjects	Physics and chemistry, Biology, Geography
ISCED 2 / Grade 10 (optional year)	Separate science subjects	Physics and chemistry
Germany		
ISCED 1 / Grades 1-4	Science as an integrated subject	General science
ISCED 2 / Grades 5-9	Separate science subjects	Chemistry, Biology, Physics

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(258) Although grade 8 is part of upper secondary education (ISCED 3), it is included here as this grade is of particular interest for the analysis of the report.

(259) There is local/school autonomy regarding the teaching approaches for science education; however, in practice, integrated science education is more usual at ISCED 1, while at ISCED 2, instruction of separate science subjects prevails.

Estonia

ISCED 1 / Grades 1-6	Science as an integrated subject	Natural science
ISCED 2 / Grade 7	Separate science subjects	National science (laboratory and practical tasks), Biology, Geography
ISCED 2 / Grades 8-9	Separate science subjects	Biology, Geography, Chemistry, Physics

Ireland

ISCED 1 / Grades 1-6	Science as an integrated subject	Science
ISCED 2 / Grades 7-9	Science as an integrated subject	Science

Greece

ISCED 1 / Grades 1-4	Science as an integrated subject	Study of environment (Physics, Chemistry, Biology, Geology, Geography)
ISCED 1 / Grades 5-6	Separate as an integrated subject	Science-Research and discover (Physics, Chemistry, Biology), Geography (and Geology)
ISCED 2 / Grade 7	Separate science subjects	Physics, Biology, Geology-Geography
ISCED 2 / Grade 8	Separate science subjects	Physics, Chemistry, Biology, Geology-Geography
ISCED 2 / Grade 9	Separate science subjects	Physics, Chemistry, Biology

Spain

ISCED 1 / Grades 1-6	Science as an integrated subject	Natural sciences
ISCED 2 / Grade 7	Separate science subjects	Biology and geology, Technology
ISCED 2 / Grade 8	Separate science subjects	Physics and chemistry, Technology
ISCED 2 / Grade 9	Separate science subjects	Biology and geology, Physics and chemistry, Technology

France

ISCED 1 / Grades 1-3	Science as an integrated subject	Questioning the world
ISCED 1 / Grades 4-5	Science as an integrated subject	Science and technology
ISCED 2 / Grade 6	Science as an integrated subject	Science and technology
ISCED 2 / Grades 7-9	Separate science subjects	Physics-Chemistry, Life and earth sciences, Technology

Croatia

ISCED 1 / Grades 1-4	Science as an integrated subject	Nature and society
ISCED 2 / Grades 5-6	Separate science subjects	Nature, Geography, Technical education
ISCED 2 / Grades 7-8	Separate science subjects	Biology, Chemistry, Physics, Geography, Technical education

Italy

ISCED 1 / Grades 1-5	Science as an integrated subject	Science
ISCED 2 / Grades 6-8	Science as an integrated subject	Science

Cyprus

ISCED 1 / Grades 1-6	Separate science subjects	Natural sciences and technology (Physics, Chemistry, Biology, Design and technology), Geography
ISCED 1 / Grades 5-6	Separate science subjects	Natural sciences (Physics, Chemistry, Biology), Design and technology-digital technologies, Geography
ISCED 2 / Grades 7-9	Separate science subjects	Biology, Physics, Chemistry, Geography

Latvia

ISCED 1 / Grades 1-6	Science as an integrated subject	Science
ISCED 2 / Grade 7	Separate science subjects	Biology, Geography, Engineering
ISCED 2 / Grades 8-9	Separate science subjects	Biology, Geography, Chemistry, Physics

Lithuania

ISCED 1 / Grades 1-6	Science as an integrated subject	Science education
ISCED 2 / Grade 7	Separate science subjects	Biology, Physics
ISCED 2 / Grades 8-10	Separate science subjects	Biology, Physics, Chemistry

Luxembourg

ISCED 1 / Grades 1-4	Science as an integrated subject	Introduction to science (human, nature, technology, space and time)
ISCED 1 / Grades 5-6	Separate science subjects	Human and natural science (human, nature, space, time), Geography, History
ISCED 2 / Grades 7-9	Separate science subjects	Geography, Natural sciences (Biology, Physics, Chemistry)

Hungary (260)

ISCED 1 / Grades 1-2	NA	NA
ISCED 1 / Grades 3-4	Science as an integrated subject	Environmental knowledge
ISCED 2 / Grades 5-6	Science as an integrated subject	Science
ISCED 2 / Grades 7-8	Local/school autonomy	Biology, Chemistry, Physics, Geography or Science

Malta

ISCED 1 / Grades 1-6	Science as an integrated subject	Science
ISCED 2 / Grades 7-8	Science as an integrated subject	Science
ISCED 2 / Grades 9-11	Separate science subjects	Physics, Chemistry, Biology

Netherlands (261)

ISCED 1 / Grades 1-6	Local/school autonomy	Orientation on oneself and the world (People and society, Nature and technology, Space)
ISCED 2 / Grades 7-8	Local/school autonomy	Local/school autonomy
ISCED 2 / Grade 9-10	Separate science subjects	Biology, Physics/Chemistry 1, Physics/Chemistry 2

Austria

ISCED 1 / Grades 1-4	Science as an integrated subject	Elementary natural and social science (Biology, Chemistry and Physics; History, Geography, Social Science, Economics)
ISCED 2 / Grade 5	Separate science subject	Biology
ISCED 2 / Grade 6	Separate science subjects	Biology, Physics
ISCED 2 / Grades 7-8	Separate science subjects	Biology, Chemistry, Physics

Poland

ISCED 1 / Grades 1-3	Science as an integrated subject	Natural sciences
ISCED 1 / Grade 4	Science as an integrated subject	Science (Geography, Biology)
ISCED 2 / Grades 5-6	Separate science subjects	Biology, Geography
ISCED 2 / Grades 7-8	Separate science subjects	Biology, Geography, Chemistry, Physics

Portugal

ISCED 1 / Grades 1-4	Science as an integrated subject	Social and environmental studies (Biology, Physics, Chemistry, History, Geography, Social environment)
ISCED 2 / Grades 5-6	Science as an integrated subject	Natural sciences (Geology, Geography, Physics and Chemistry)
ISCED 2 / Grades 7-9	Separate science subjects	Natural sciences, Physics-Chemistry

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(260) The information reflects the new National Core Curriculum in all grades, although it is phased-in gradually and changes are implemented only in grades 1 and 5 in the school year 2020/2021.

(261) The information presented in this table refers to the VMBO track, as the majority of students frequents this track.

Romania

ISCED 1 / Preparatory grade-Grade 1 (262)	Science as an integrated subject	Mathematics and natural sciences
ISCED 1 / Grades 2-4	Science as an integrated subject	Natural sciences
ISCED 2 / Grade 5	Separate science subjects	Biology
ISCED 2 / Grade 6	Separate science subjects	Biology, Physics
ISCED 2 / Grades 7-8	Separate science subjects	Biology, Physics, Chemistry

Slovenia

ISCED 1 / Grades 1-3	Science as an integrated subject	Learning about the environment (Natural sciences, Social studies, Technology)
ISCED 1 / Grades 4-5	Science as an integrated subject	Natural sciences and technology
ISCED 1 / Grade 6	Science as an integrated subject	Natural sciences
ISCED 2 / Grade 7	Science as an integrated subject	Natural sciences
ISCED 2 / Grades 8-9	Separate science subjects	Biology, Chemistry, Physics

Slovakia

ISCED 1 / Grades 1-2	Science as an integrated subject	Local environment
ISCED 1 / Grades 3-4	Separate science subjects	Natural science, National history and geography
ISCED 2 / Grade 5	Separate science subject	Biology
ISCED 2 / Grade 6	Separate science subjects	Biology, Physics
ISCED 2 / Grades 7-9	Separate science subjects	Biology, Physics, Chemistry

Finland

ISCED 1 / Grades 1-6	Science as an integrated subject	Environmental studies
ISCED 2 / Grades 7-9	Separate science subjects	Biology and geography, Physics and chemistry, Health education

Sweden

ISCED 1 / Grades 1-3	Science as an integrated subject	Science studies
ISCED 1 / Grades 4-6	Separate science subjects	Biology, Chemistry, Physics
ISCED 2 / Grades 7-9	Separate science subjects	Biology, Chemistry, Physics

Albania

ISCED 1 / Grades 1-4	Science as an integrated subject	Mathematics and nature knowledge
ISCED 2 / Grades 5-9	Separate science subjects	Chemistry, Biology, Physics (263)

Bosnia and Herzegovina

ISCED 1 / Grade 1	Science as an integrated subject	My environment
ISCED 1 / Grades 2-4	Science as an integrated subject	Nature and society
ISCED 1 / Grade 5	Science as an integrated subject	Nature study
ISCED 2 / Grade 6	Separate science subjects	Geography, Biology
ISCED 2 / Grade 7	Separate science subjects	Geography, Biology, Physics
ISCED 2 / Grades 8-9	Separate science subjects	Geography, Biology, Physics, Chemistry

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(262) Primary education includes a preparatory grade followed by grades 1-4.

(263) In addition to the main science subjects presented here, the curriculum also defines mathematics as a science subject.

Switzerland (264)

ISCED 1 / Grades 1-6	Science as an integrated subject	Nature, man, society
ISCED 2 / Grades 7-9	Science as an integrated subject	Nature and technology (Physics, Chemistry, Biology)

Iceland

ISCED 1 / Grades 1-7	Science as an integrated subject	Natural sciences (Natural history, Physics and chemistry, Geology, Biology, Environmental education)
ISCED 2 / Grades 8-10	Science as an integrated subject	Natural sciences (Natural history, Physics and chemistry, Geology, Biology, Environmental education)

Liechtenstein

ISCED 1 / Grades 1-5	Science as an integrated subject	Nature, man, society
ISCED 2 / Grades 6-9	Separate science subjects	Nature and technology (Physics, Chemistry, Biology), spaces, times and society (History, Geography)

Montenegro

ISCED 1 / Grades 1-3	Science as an integrated subject	Nature and society
ISCED 1 / Grades 4-5	Science as an integrated subject	Knowledge of society, Nature
ISCED 2 / Grade 6	Separate science subject	Biology
ISCED 2 / Grades 7-9	Separate science subjects	Geography, Biology, Chemistry, Physics

North Macedonia

ISCED 1 / Grades 1-5	Science as an integrated subject	Science
ISCED 1 / Grade 6	Science as an integrated subject	Science
ISCED 2 / Grades 7-9	Separate science subjects	Biology, Physics, Chemistry, Geography

Norway

ISCED 1 / Grades 1-7	Science as an integrated subject	Natural science
ISCED 2 / Grades 8-10	Science as an integrated subject	Natural science

Serbia

ISCED 1 / Grades 1-2	Science as an integrated subject	World around us
ISCED 1 / Grades 3-4	Science as an integrated subject	Nature and society
ISCED 2 / Grade 5	Separate science subjects	Biology, Geography
ISCED 2 / Grade 6	Separate science subjects	Biology, Geography, Physics
ISCED 2 / Grades 7-8	Separate science subjects	Biology, Geography, Physics, Chemistry

Turkey

ISCED 1 / Grades 1-2	Science as an integrated subject	Life knowledge
ISCED 1 / Grades 3-4	Science as an integrated subject	Natural sciences
ISCED 2 / Grades 5-8	Science as an integrated subject	Natural sciences

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(264) The table presents the situation in the 21 German-speaking and bilingual Cantons (i.e. the most widespread approach).

Annex II: Additional information by education system

Chapter 2

Figure 2.1A: Data by country – Different forms of school organisation in the context of the COVID-19 pandemic, grades 4 and 8, 2020/2021

Source: Eurydice.

Country-specific notes

Belgium (BE fr, BE nl): Schools were closed for 4 extra days before the week of autumn holidays (in November) and for 1 week before the spring holidays (end of March to early April).

Belgium (BE de): Schools were closed for 1 week before the week of autumn holidays (in November). Before the spring holidays (end of March to early April), there was 1 week of full-time closure of primary schools and 1 week of full-time distance learning for lower secondary schools.

Bulgaria: In March, distance learning applied in grade 4 from 22 to 31 March. Grade 8 students attended classroom-based learning until 13 November, and then had distance learning.

Czechia: For students in grade 4, distance learning started on 14 October. From 12 April, blended learning was in place. In small schools, full classroom-based learning was allowed. Distance learning also started on 14 October for students in grade 8. Blended learning was used from 3 May in some regions and from 10 May in all regions. Full classroom-based learning for primary and lower secondary schools started on 17 May (and in some regions in grade 8 from 24 May).

Germany: School closures or suspensions of compulsory attendance are handled differently in the various *Länder*. Therefore, the data used are rough approximations

Estonia: Grades 1–4 had distance learning from 11 March until 2 May. Grade 8 had distance learning from 1 March until 16 May.

Ireland: In March, grade 4 students returned to school after the holidays on a phased basis.

Greece: The school year started on 14 September for all students of primary and lower secondary education (i.e. 1 week later than planned). Primary schools closed (and provided distance learning) from 16 November until the end of the month. They reopened in December, closed (with distance learning) again on 10 February and reopened on 10 May. Lower secondary schools closed (and provided distance learning) from 16 November until 10 May.

France: All primary schools were closed and provided distance learning from 6 to 9 April. For grade 8 students, distance learning was implemented from 6–9 April and 26–30 April.

Italy: The organisation of schooling (for all grades) was managed at national level, with regional differences based on the pandemic risk and, at the same time, on regional emergency legislation.

Latvia: In June, the school summer holidays started.

Lithuania: Primary education was classroom-based until 14 December. Between March and June, municipalities and primary schools could decide, based on the intensity of the COVID-19 pandemic and on parental agreement, how to organise learning (in person, distance or blended). In lower secondary education, classroom-based learning was encouraged in May and June; however, schools decided to finish the school year using distance learning, taking into account parents' opinions.

Luxembourg: From 4 to 8 January (immediately after the Christmas break) and from 8 to 12 February (the week before the February break), all schools and all education levels were using distance learning.

Hungary: Distance learning applied from 8 to 31 March. The school year ended on 15 June.

Malta: The school year started in October. All students in compulsory education experienced a period of distance learning between 15 and 30 March. Schools reopened for classroom-based learning on 12 April, after the Easter break (31 March to 11 April).

Netherlands: All schools closed on 16 December and switched to distance learning for the majority of students in primary and lower secondary education. From March, all lower secondary students had to physically attend school at least 1 day a week. From 7 June, all lower secondary schools were fully open to all students.

Austria: Students were generally in distance learning from 17 November to 6 December, and from 7 January to 7 February. Schools were open mainly for supervision and educational support. From 8 February to 16 May, lower secondary students were divided into groups, which took turns attending classroom-based learning. All Fridays were distance-learning days.

Poland: From 24 October, distance learning was used for students in grades 4–8. From 17 to 30 May, blended learning was used for students in those grades.

Portugal: Educational and teaching activities were suspended as of 22 January. They resumed from 8 February, on a distance-learning basis. Primary schools returned to face-to-face education on 15 March; lower secondary schools returned to face-to-face education on 5 April.

Romania: From 20 October, students moved from a blended to a distance-learning system. The Easter break (April 2021) was extended by 2 weeks to increase the possibility of in situ learning when students returned.

Slovenia: Students in grade 4 had distance learning from 9 November until 15 February. Students in grade 8 had distance learning from 19 October until 15 February. On 1 April, schools were closed again and all students had distance learning until 9 April.

Slovakia: At primary education level, distance learning applied from 11 January. From 8 March until 12 April, distance learning was again the norm. At lower secondary level, distance learning started on 26 October. From 7 December, in situ learning was allowed again, but depended on the local pandemic situation. From 17 May, in situ learning was allowed in all schools.

Finland: Schools have been mainly open; however, there have been occasional distance-learning periods in some regions. The summer holidays were in June.

Sweden: There were no national recommendations on school closures for grades 7–9, but in spring 2020 a new law and a temporary ordinance were passed enabling school organisers to close schools partially or entirely and switch to distance learning. A survey carried out by the Swedish National Agency for Education in mid-January shows that two thirds of all school organisers (municipal and independent schools) had partially or entirely changed to distance learning for grades 7–9.

Bosnia and Herzegovina: During January, schools were closed for winter holidays. In June, the summer holidays started.

Iceland: Apart from 2 school days before the Easter break in March 2021, compulsory schools were open.

Montenegro: From 15 March, primary school classes were held in a blended-learning format. From January, all lower secondary schools were able to organise in-school classes for grades 6–9 according to the school's capabilities. In March, classes in almost all municipalities were held online for grade 8 students.

North Macedonia: Teaching started on 1 October (i.e. with a 1-month delay). During the entire school year, most grade 4 and 8 students had distance learning. Exceptions were made upon the decision of the government and with the agreement of the parents; this applied to only a small number of schools in rural settings and schools with small numbers of students.

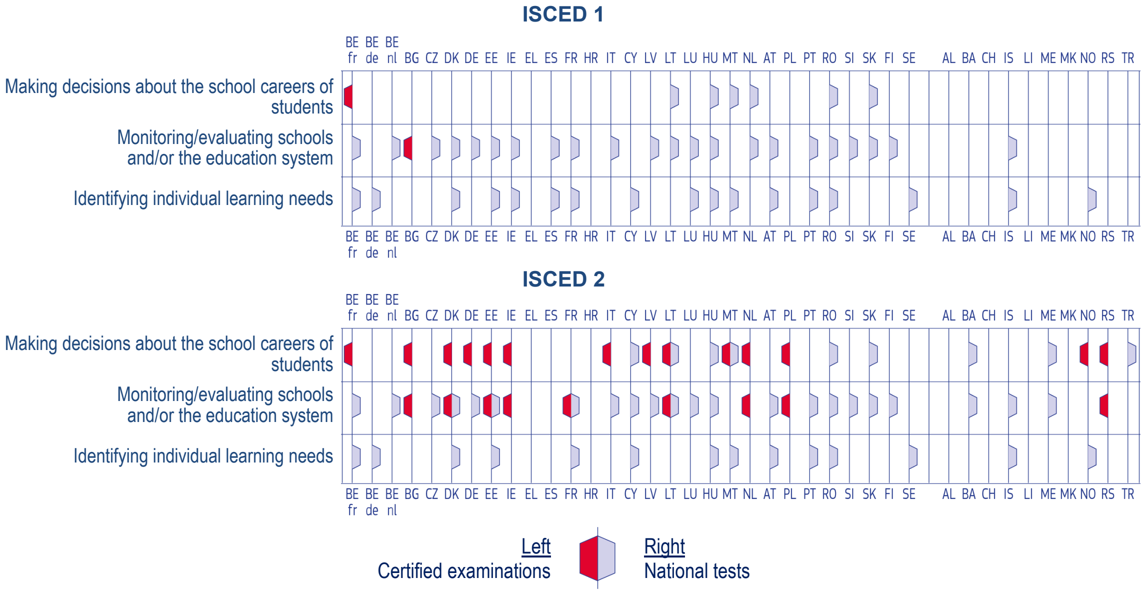
Norway: Top level regulations allowed the schools to be open, but may have been closed from 3 to 19 January.

Serbia: Primary schools generally remained open during the school year, but with adaptations. For example, every class was divided into two groups (with up to 15 students each), and classes lasted for 30 minutes instead of 45 minutes. Lower secondary schools mainly applied blended learning. During December and March, distance learning applied only in lower secondary education.

Turkey: From 20 November, grade 4 students had distance learning. Grade 8 students started school on 2 October. In February, school holidays were extended so that teaching took place for only half a month. All lower secondary schools began distance learning on 15 April.

Chapter 4

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



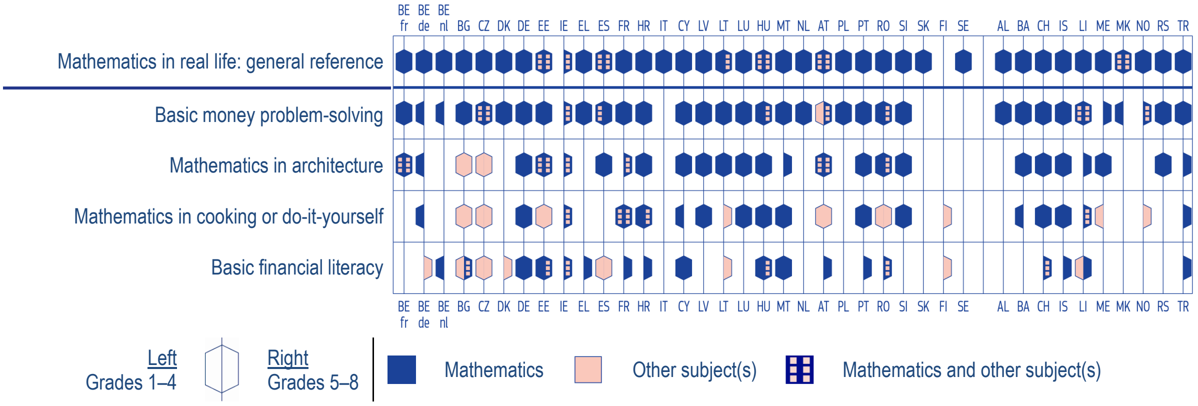
Source: Eurydice.

Country-specific notes

Slovenia: The main purpose of the national tests is to provide feedback on student knowledge, and to monitor and evaluate the education system, not schools.

Chapter 5

Figure 5.1A: Data by country – selected real-life applications of mathematical concepts mentioned in curricula, 2020/2021



Source: Eurydice.

Country-specific notes

Belgium (all Communities) and **Denmark**: The left refers to grades 1–6, the right to grades 7 and 8.
Czechia and **Italy**: The left corresponds to grades 1–5, the right to grades 6–9.
Germany: The right refers to grades 5–9.
Estonia: In the national curriculum for basic schools, learning objectives are organised according to grades 1–3 (school stage I), 4–6 (stage II) and 7–9 (stage III).
Ireland and **France**: The right refers to grades 7–9.
Latvia: Learning outcomes are described for grades 3, 6 and 9 for each learning area.
Sweden: The data cover grades 4–6 and 7–9, and learning outcomes are for grades 6 and 9.
Switzerland: The figure presents the situation in the 21 German-speaking and bilingual cantons (i.e. the most widespread approach).

Figure 5.3A: Data by country – selected aspects of history of science mentioned in curricula, 2020/2021

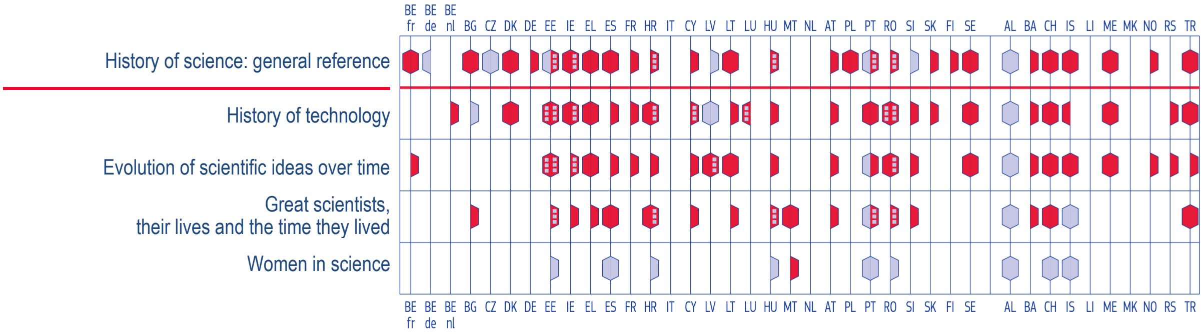
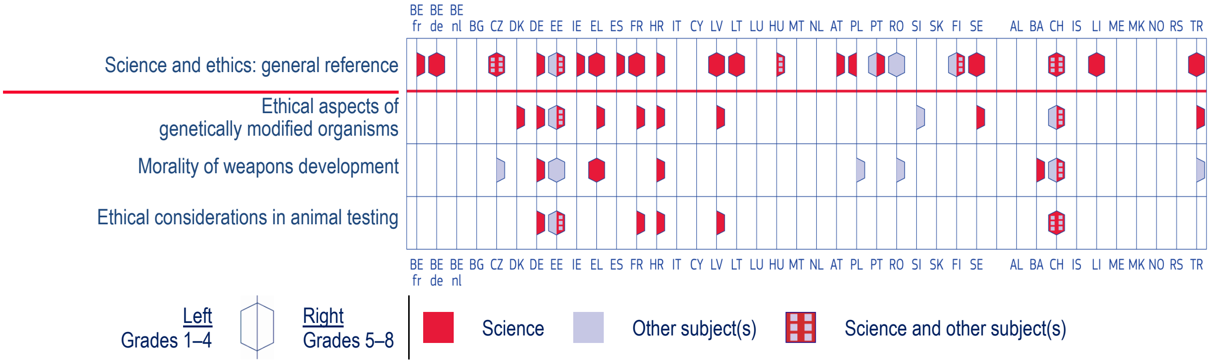


Figure 5.4A: Data by country – selected aspects of ethics in science mentioned in curricula, 2020/2021

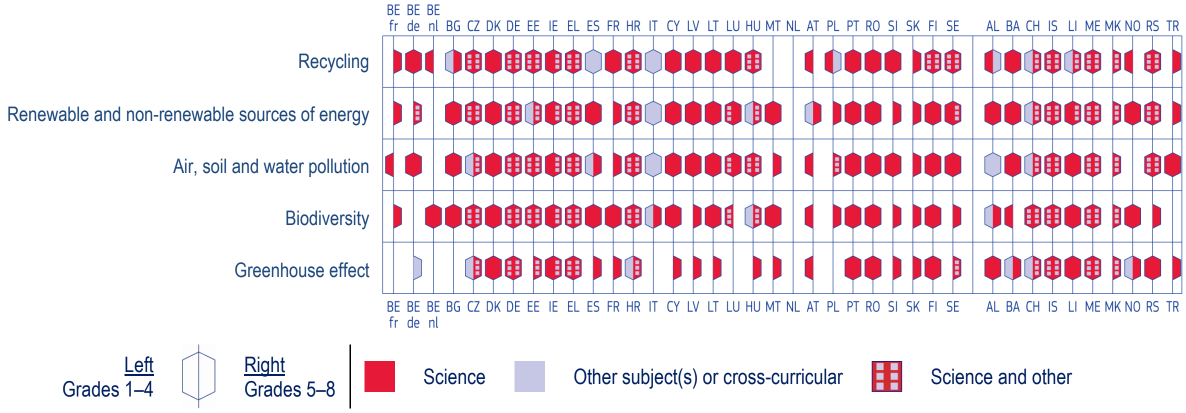


Source: Eurydice.

Country-specific notes

See Figure 5.1A.
Norway: The right refers to grades 5–7 and/or 8–10.

Figure 5.5A: Data by country – selected environmental sustainability topics mentioned in curricula, 2020/2021

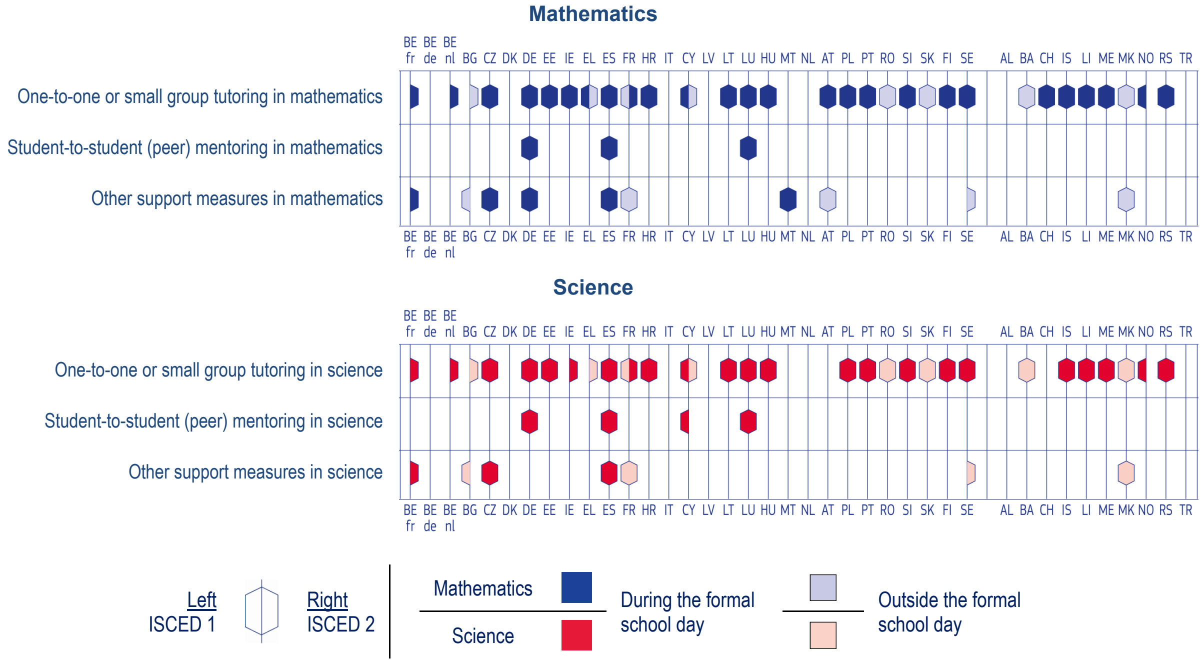


Source: Eurydice.

Country specific notes

See Figures 5.3A and 5.4A.
Belgium (German-speaking Community) and **Italy**: The other subject is geography.
Luxembourg: The other subject is 'Life and society' (VieSo).
Hungary: The other subject is ethics.
Netherlands: Schools have the autonomy to decide.
Poland: The other subject is technology.

Figure 6.3A: Data by country: top-level learning support measures in mathematics and science, ISCED 1-2, 2020/2021



Source: Eurydice.

Explanatory notes

Where learning support measures exist both during and outside the formal school day for the same subject and ISCED level, only the presence of support measures during the school day is shown in the figure.

Only long-term measures are taken into account; temporary measures due to the COVID-19 pandemic are not included in the figure.

Annex III: Statistical tables

Open the Excel file **Annex III:** https://eurydice.eacea.ec.europa.eu/sites/default/files/2022-06/Annex_III_Statistical_tables.xlsx

Table 1.1:	Percentage of low achievers in mathematics and science in the fourth grade, 2019
Table 1.2:	Percentage of low achievers among 15-year-old students in mathematics and science, 2018
Table 1.3:	Mean score and standard deviation in mathematics and science for fourth grade students, 2019
Table 1.4:	Mean score and standard deviation in mathematics and science for 15 year-old students, 2018
Table 1.5:	Percentage of low achievers in mathematics and science in the fourth grade, by the number of books at home, 2019
Table 1.6:	Percentage of low achievers in mathematics and science among 15-year-olds, by the number of books at home, 2018
Table 1.7:	Gender differences in the percentage of low achievers among fourth grade students in mathematics, 2019
Table 1.8:	Gender differences in the percentage of low achievers among 15-year-old students in mathematics and science, 2018
Table 2.2:	Percentage of fourth graders whose school used an online learning management system to support learning before the COVID-19 pandemic, 2019
Table 2.3:	Distribution of fourth graders per computer in schools before the COVID-19 pandemic, 2019
Table 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
Table 5.2:	Percentage of fourth graders whose mathematics teachers report relating lessons to students' daily lives, 2019
Table 6.4:	Percentage of fourth graders whose mathematics or science teachers report working in same-ability groups in the majority of lessons, 2019

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Increasing achievement and motivation in mathematics and science learning in schools

Eurydice report

In our fast-changing and technology-driven societies, education in mathematics and science is crucial for ensuring that children and young people have the necessary skills, knowledge and mindset to be responsible and active citizens. Despite the emphasis on the key competences of basic numeracy and scientific literacy in the European Education Area, the share of pupils not reaching basic achievement levels remains considerably above the agreed maximum of 15%.

This report investigates what education authorities across Europe do to strengthen student motivation, raise achievement and help those that are falling behind in mathematics and science. It brings together qualitative Eurydice data on national policies and legislation in 39 European education systems, and quantitative data from several student assessment surveys. The results highlight the importance of allocating sufficient instruction time, providing timely learning support, ensuring specialised teacher training and monitoring student achievement systematically. Ample examples are provided on how the mathematics and science curricula can foster reflection and relate to students' lives.

The information focuses on primary and lower secondary education, and it covers all the members of the Eurydice Network (the 27 EU Member States and Albania, Bosnia and Herzegovina, Switzerland, Iceland, Liechtenstein, Montenegro, North Macedonia, Norway, Serbia and Turkey).

The Eurydice Network's task is to understand and explain how Europe's different education systems are organised and how they work. The network provides descriptions of national education systems, comparative studies devoted to specific topics, indicators and statistics. All Eurydice publications are available free of charge on the Eurydice website or in print upon request. Through its work, Eurydice aims to promote understanding, cooperation, trust and mobility at European and international levels. The network consists of national units located in European countries and is coordinated by the European Education and Culture Executive Agency (EACEA).

For more information about Eurydice, see:
https://eacea.ec.europa.eu/national-policies/eurydice/

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