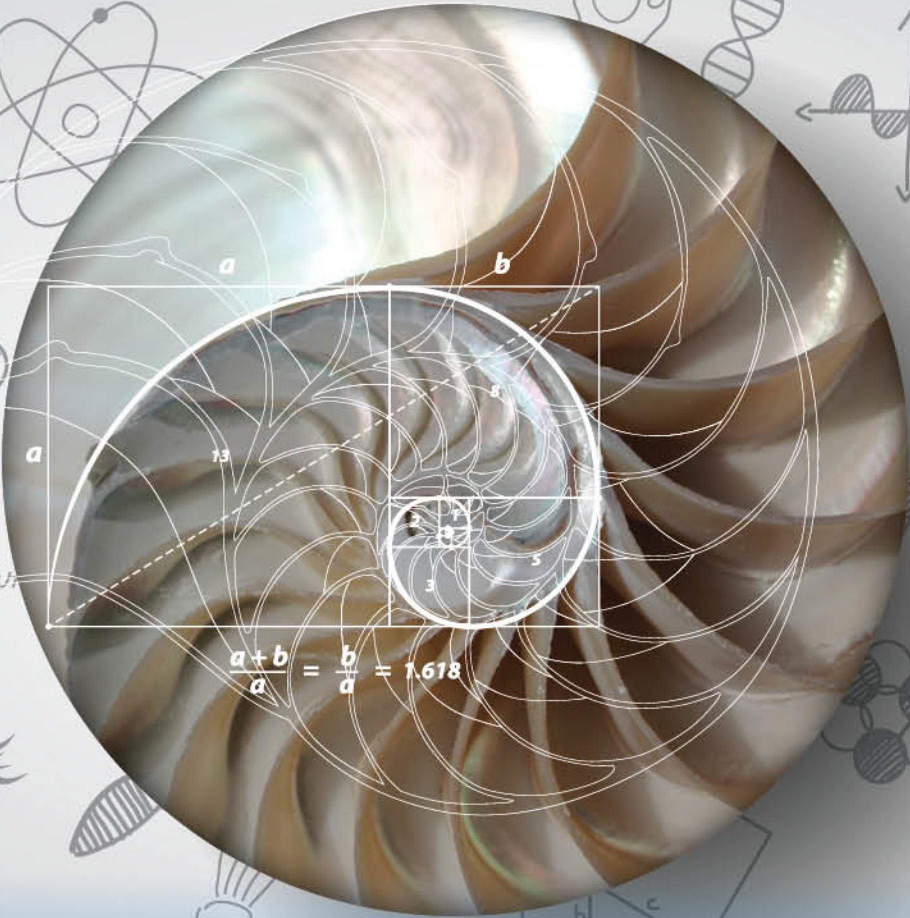
European Commission

Increasing achievement and motivation in mathematics and science learning in schools

Eurydice report



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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.

([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]).

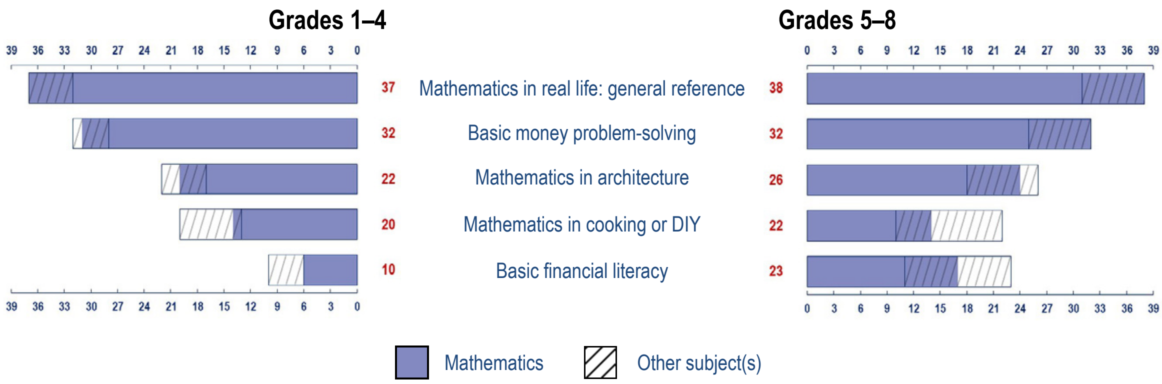
The mathematics curriculum for primary education in **Spain** sets out that the subject is to be learned by using it in functional contexts related to situations of daily life. In addition, it states that methodology in this area should be based on experience: the learning contents start from what is 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.

([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'.

([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.

([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]).

([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

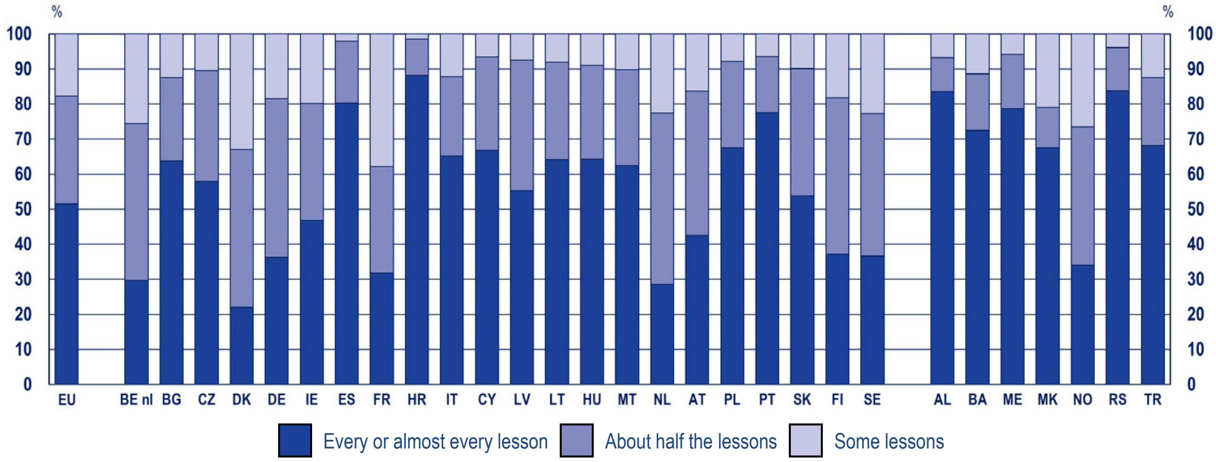
As this section reveals, curricula in Europe emphasise the importance of relating mathematics lessons to real-life examples and students' experiences. However, top-level documents cannot indicate the extent to which such practices are used in schools and classrooms. Instead, teachers' responses to international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

([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.

([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]).

([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]).

([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

([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,

([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/

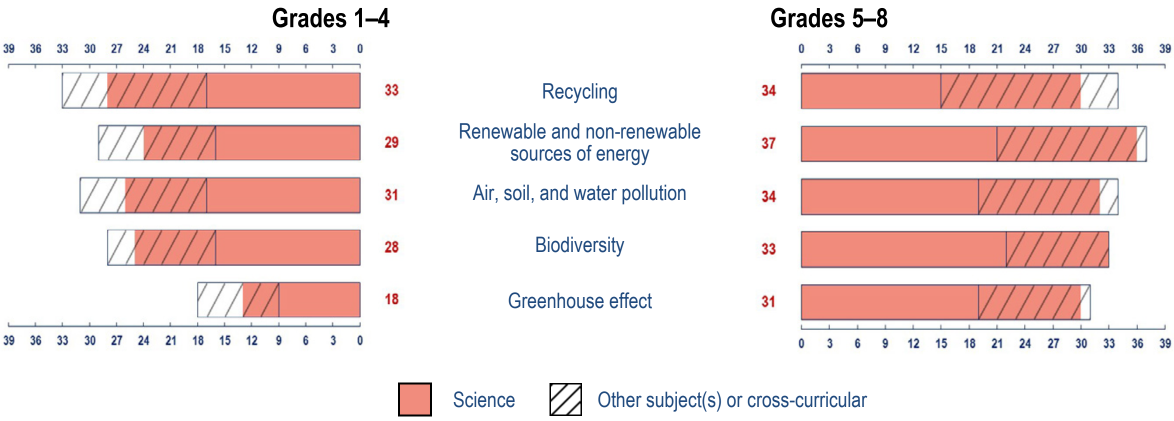
([145]) European Commission proposal for a Council recommendation on learning for environmental sustainability, COM(2022) 11 final, 2022/0004(NLE).

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.

([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

([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.

([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).

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 (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]).

([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.

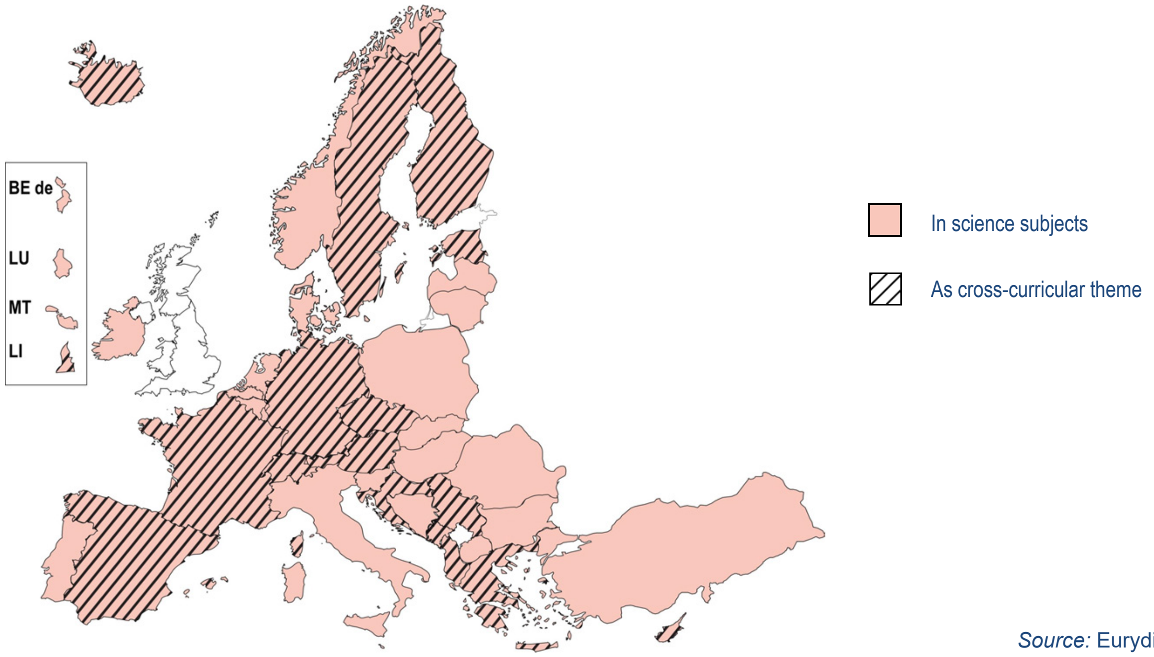
In **Germany**, education for sustainable development is a cross-curricular topic, as defined in the Standing Conference of the Ministers of Education and Cultural Affairs resolution on education for sustainable development ([180]) and in the orientation framework for the learning area of global development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

([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]).

([185]) Theoretical framework for curriculum 'environment and education for sustainable development'; Law 4547/2018 (G.G. 102/τ.A΄/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.

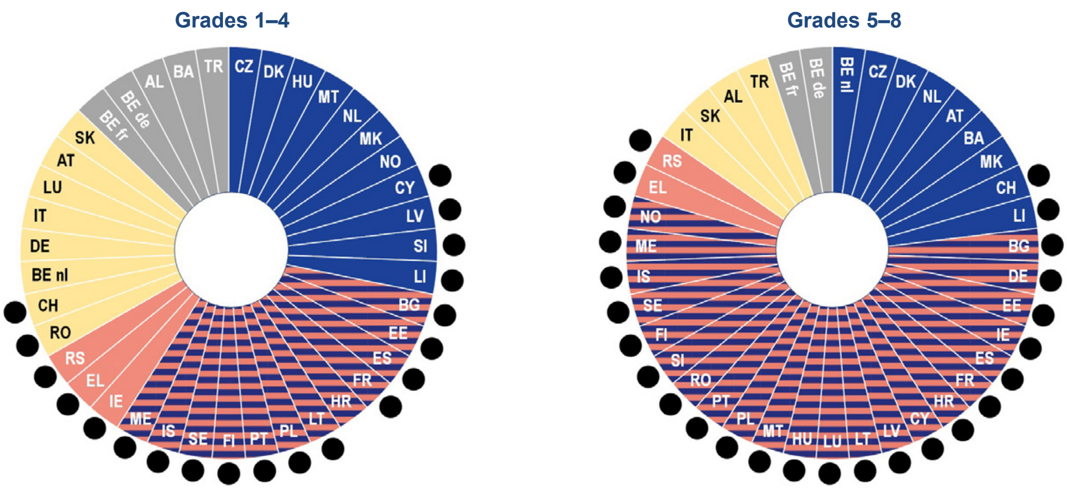
Figure 5.7 shows that learning outcomes related to the use of digital technologies in mathematics and science curricula are present in most of the European countries. By the end of grade 4, the use of digital technology in mathematics or science lessons is introduced in two thirds of countries. By the 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.

Digital literacy in science

Learning outcomes related to the use of digital technologies:

In mathematics | In science | Not in mathematics or science | Not included in the curriculum

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]).

([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, OG7/2019.

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.

([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.

([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.