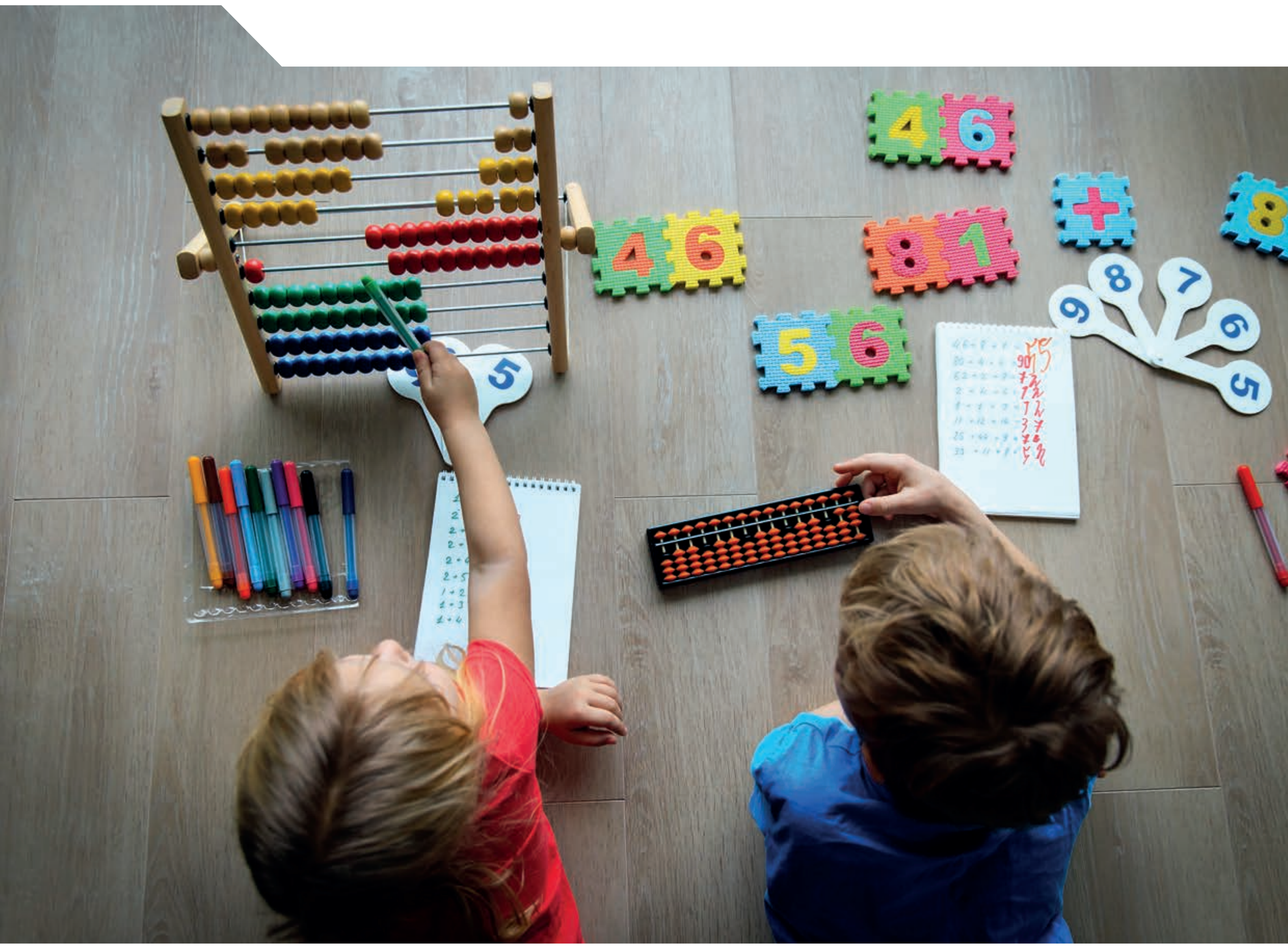
An Evolution of Mathematics Curriculum

WHERE IT WAS, WHERE IT STANDS AND WHERE IT IS GOING



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OECD
BETTER POLICIES FOR BETTER LIVES

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Foreword

International mathematics curriculum analysis as part of a broader reflection on future-oriented curriculum

This report is produced by the OECD's Future of Education and Skills 2030 (Education 2030) project. It presents an international analysis of mathematics curricula with the aim of supporting countries in their curriculum reform efforts.

Curriculum reform is pivotal in that it can act as a significant driver of student performance and well-being. A well-designed curriculum ensures consistent quality across different educational settings and age groups, contributing to equity in education. It provides a framework that supports teachers, facilitates parent-teacher interactions, and maintains educational continuity across various levels. Moreover, curriculum redesign is essential for keeping the educational content relevant and responsive to societal changes and innovations. Without periodic updates, a stagnant curriculum risks stifling creativity and misalignment with students' and society's evolving needs.

Any curriculum change has proven to be a real challenge for countries at different phases of its enactment, with unintended consequences experienced from design to implementation to evaluation. While remaining a domestic issue, policymakers have gradually come to realise that there is much to learn about how to successfully manage curriculum change from other countries' experiences. This realisation, coupled with the aspiration of governments to find some common language to articulate a broader vision of education to inform future-oriented curricula, provide the foundation for the Education 2030 project.

The project, which will evolve into Education 2040, was initiated in 2015 to help countries adapt their education systems to better meet the demands of the 21st Century. Specifically, the project aims to support countries in their efforts to respond to the following questions:

- What kinds of knowledge, skills, attitudes and values are necessary for students and teachers to understand, engage with and shape a changing world towards a better future in 2030?
- How can learning environments that can foster these competencies be designed, i.e. how can future-oriented curricula be designed and implemented?

As a response to the first question, a comprehensive future-oriented learning framework has been developed, the OECD Learning Compass 2030, which sets out an aspirational vision for the future of education grounded in the notions of **student agency**, **well-being and competencies** as powerful means for positive transformation in education and in society. The notion of student agency here refers to the belief that one can shape one's own future rather than being shaped by it.

The OECD Learning Compass is neither an assessment framework nor a curriculum framework. To successfully foster the competencies it sets out, education systems need to design future-oriented curricula that are appropriate and relevant to their local context. This is part of the "how" question, which the Education 2030 project addresses by conducting rigorous international curriculum analyses (i.e. descriptive, rather than prescriptive, with the goal of supporting curriculum change processes that are evidence-based). This has resulted in a series of six thematic reports exploring key policy challenges faced by governments related to curriculum reform:

1. *What Students Learn Matters: Towards a 21st Century Curriculum*: Managing time lag between today's curriculum and future needs. (OECD, 2020)
2. *Curriculum Overload: A Way Forward*: Addressing the pressures schools face to keep up with the pace of societal changes and issues related to overcrowded curriculum. (OECD, 2020)
3. *Adapting Curriculum to Bridge Equity Gaps: Towards an Inclusive Curriculum*: Confronts issues related to equality, equity and inclusion in curriculum innovation. (OECD, 2021)
4. *Embedding Values and Attitudes in Curriculum: Shaping a Better Future*: Incorporating values in curriculum as competencies for students' positive lifelong learning outcomes. (OECD, 2021)
5. Curriculum Flexibility and Autonomy: Promoting a Thriving Learning Environment: Discussing issues between curriculum prescription and autonomy in policy and practice. (OECD, 2024)
6. *Adopting an Ecosystem Approach to Curriculum Redesign and Implementation* (OECD, forthcoming).

The Education 2030 international curriculum analyses series also includes subject-specific reports. The first one focused on **physical education** and was published in 2019: Making Physical Education Dynamic and Inclusive for 2030**.** The present report focuses on **mathematics**. For more detailed information on the project and the reports outlined above, please refer to the Overview brochure of the series.

Redesigning mathematics curriculum for the 21st Century: Balancing innovation with curriculum depth

This report explores key considerations for modernising mathematics curricula to address the evolving societal, economic and technological demands of this century. Policymakers are confronted with the challenge of preparing students for a complex and dynamic future, where mathematical competencies are essential for personal and professional success. Mathematics has long been a cornerstone of human progress and continues to drive innovation in fields like technology and data science. Its influence is vital in shaping modern societies and economies across the globe.

To meet these demands, learners require a curriculum that not only emphasises the conceptual rigour and depth of mathematics but also supports its real-world applications. This entails equipping students with the competencies necessary to apply their mathematical knowledge in diverse contexts. However, policymakers face the challenge of incorporating new content and competencies, such as data literacy, computational thinking and problem-solving, without overloading students and educators.

This report highlights several key aspects for consideration in mathematics curriculum redesign, including catering to student diversity, content rebalancing, aligning curriculum implementation with design, the importance of adequate resourcing, embracing technological advancements, aligning high-stakes examinations with future-focused curriculum goals, and preparing and supporting teachers to effectively design and implement a future-oriented curriculum at the school level. By addressing these issues, policymakers can ensure that mathematics education remains relevant, equitable and capable of fostering the competencies students need for success in the rapidly changing world.

The report is structured into four chapters. Chapter 1 sets the scene for the report by highlighting the uniqueness of mathematics as a discipline and how mathematics curriculum accommodates 21st Century demands and competencies, such as problem-solving, critical thinking, computational thinking, and creativity, in comparison with other learning areas.

Chapter 2 focuses on the following aspects of curriculum development for which systematic comparative data are available: 1) how mathematics curricula are evolving in various countries, particularly on content coverage; 2) how countries are integrating future-oriented competencies in their mathematics curricula. The findings invite a reflection on some gaps identified between current curricula and aspirations for the future and that require further investigation.

Chapter 3 re-introduces five key priority issues in curriculum change, which were the focus of previously published Education 2030 thematic reports as general curriculum reform challenges. The five issues are: 1) keeping curriculum relevant for the future; 2) curriculum overload; 3) closing equity gaps in curriculum; 4) embedding attitudes and values in curriculum; and 5) curriculum flexibility and autonomy. This chapter discusses these issues in the context of mathematics teaching and learning.

Chapter 4 concludes by addressing some critical considerations for policymakers in redesigning mathematics curricula. It explores how general design principles apply to mathematics curriculum redesign, such as focus and rigour, authenticity, transferability, flexibility, and engagement (creating opportunities for student and teacher agency).

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Executive summary

As policymakers globally navigate the evolving societal, economic, and technological landscape, modernising mathematics curricula is crucial. A future-oriented curriculum equips learners with necessary competencies for both personal and professional realms without overloading students and educators. This report:

- introduces the current state of mathematics curriculum design, identifying transformation challenges and opportunities (Chapter 1);
- reviews the evolution of mathematics curricula over 25 years, highlighting competency integration and identifying curriculum gaps (Chapter 2);
- analyses findings from the OECD Future of Education and Skills 2030 project, exploring implications for mathematics curriculum development (Chapter 3);
- proposes principles for curriculum design to meet 21st-century needs, emphasising the integration of critical thinking, problem-solving, and digital literacy (Chapter 4).

Chapter 1 discusses the 21st-century needs driving transformation in mathematics curricula, drawing on findings from the E2030 Curriculum Content Mapping (CCM) exercise. It reveals how lower secondary mathematics curricula in various countries integrate competencies compared to other subjects. Core competencies like **numeracy, critical thinking, and problem-solving** are widely embedded in mathematics curricula, vital for cognitive development and real-world applications, while others, such as empathy, trust, responsibility, and co-agency are less emphasised. Chapter 1 also highlights challenges governments face reforming mathematics curricula, including the discipline's hierarchical and progressive nature.

Chapter 2 reviews the evolution of mathematics curricula in different countries over 25 years, using data from the E2030 Mathematics Curriculum Document Analysis (MCDA) study. It highlights the growing focus on **mathematical reasoning and statistics in modern curricula**, particularly in the first eight years of schooling. The data explores how countries structure and distribute content across grades, with some high-performing systems choosing a focused curriculum (fewer topics for deeper learning) while others adopt **broader curricula**. The chapter identifies **gaps between curriculum standards and textbooks**, especially regarding fostering higher-order thinking, which may undermine policy intentions.

Chapter 3 **exemplifies considerations for mathematics curricula** based on five thematic reports on curriculum analyses by the OECD Future of Education and Skills 2030 project, exploring:

- **What Students Learn Matters: Towards a 21st Century Curriculum:** Emphasising future-oriented competencies such as critical thinking, creativity, and student agency in mathematics, and the potential of digital curricula for personalised learning.
- **Curriculum Overload: A Way Forward:** Addressing curriculum overload through principles of focus, rigour, and coherence, ensuring that students are not overwhelmed while reinforcing key mathematical concepts.

- **Adapting Curriculum to Bridge Equity Gaps:** Exploring inclusive pedagogies to support students struggling with mathematics, promoting teaching methods that enhance engagement.
- **Embedding Values and Attitudes in Curriculum:** Highlighting the role of values such as respect, collaboration, and persistence in reducing mathematics anxiety and fostering a growth mindset.
- **Curriculum Flexibility and Autonomy:** Examining how pedagogies can be adapted to diverse student needs, ensuring instruction remains flexible and responsive.

Chapter 4 concludes with 12 principles for redesigning mathematics curricula to help policymakers and designers meet emerging societal and technological demands. It highlights strategies for **balancing content depth and rigour** without overloading students and educators**, resourcing teachers' professional development**, and **methods for catering to student diversity**. It also addresses the importance of aligning high-stakes assessments with redesigned curricula to ensure assessment reflects content mastery and new competencies.

Key messages

- Mathematics is central to **technological innovation**, **economic growth**, and **social cohesion**. It is essential in fields like data science and artificial intelligence for developing algorithms, statistics, and pattern recognition. Additionally, the modern mathematics curriculum is increasingly emphasising **statistics**, **data literacy**, and **digital literacy**, reflecting their importance in our data-driven and technologically rich societies.
- **Modernising mathematics curricula** is critical for preparing students for a dynamic future, balancing a strong foundational understanding with the introduction of new competencies like data literacy and computational thinking.
- Mathematics, often considered a "hard to change" discipline, is undergoing transformation. In addition to traditional content areas, such as quantity/operations, geometry, and measurement, developing students' **mathematical reasoning** has become a key goal for many education systems.
- The emphasis on core cognitive and meta-cognitive foundations - such as **numeracy, problem-solving, critical thinking, and literacy** – in lower secondary curricula is evident, with a notable focus on **data and digital literacy**, reflecting the importance of helping students navigate a technologically rich environment.
- Some so-called 21st century competencies – e.g. **empathy, trust, responsibility, and co-agency** - are often less emphasised in lower secondary mathematics curricula and more integrated into humanities, national language, and physical education curricula.
- Design choices differ across education systems: some high-performing countries and jurisdictions focus **on fewer topics** to allow for deeper learning, while others adopt **a broader curriculum** leaving space for greater teacher autonomy.
- Curriculum design must ensure that mathematics remains **focused, challenging, and aligned with real-world applications** to meet the evolving demands of the workforce and society.
- Curriculum reform in mathematics requires **alignment across designed, implemented, and achieved curricula**. Disparities between policy intent and classroom implementation—such as gaps between curriculum goals and textbook content—must be addressed to ensure effective reform.
- **Holistic curriculum design** should integrate digital tools, cross-curricular themes, and student agency, equipping learners with the skills to navigate a rapidly changing world.
- **Curriculum, pedagogies, the learning environment, teacher training and assessment are all essential to promoting equity**, ensuring that all students, including those struggling with

mathematics, have opportunities to engage meaningfully with mathematical concepts, in particular, addressing math anxiety, nurturing persistence and an exploratory mindset, and fostering confidence and resilience. Integrating Universal Design for Learning (UDL) principles in math curriculum supports this goal by providing varied and flexible ways for students to access, interact with, and demonstrate their understanding of mathematical ideas. Balancing **content depth with avoiding overload** is a significant challenge for policymakers, who wish to ensure students' thorough understanding of essential mathematical concepts without feeling overwhelmed.

- **Resourcing is critical to successful curriculum reform** - teachers need ongoing professional development, curated resources, and appropriate tools to deliver high-quality mathematics education.
- **Assessments, and high-stakes exams in particular, should align with future-focused curriculum goals**, ensuring that exams not only reflect content mastery but also the emerging competencies required for success in the 21st century.

1 How does mathematics curriculum respond to 21st century demands, and how does it compare with other subjects?

This chapter outlines key drivers for change in mathematics curriculum and how mathematics curriculum is adapting in response to societal and technological demands. It shows findings from comparative analyses about how curricula accommodate 21st century demands, in comparison with other learning areas. It also discusses the uniqueness of mathematics as a school discipline.

In today's fast-changing world, education systems are under increasing pressure to adapt. Young people need to be equipped with the necessary competencies to thrive as active and responsible citizens in an uncertain and imbalanced world, and to be prepared to enter a rapidly changing workforce. To help them thrive as they navigate through uncertainty and change, students need an education that equips them with adequate knowledge, skills, attitudes and values to ensure individual, collective and planetary well-being (OECD, 2020[1]). Mathematical knowledge and the ability to apply that knowledge across the changing contexts encountered in daily life and work are a critical part of that education.

What are 21st century demands on mathematics education?

Mathematics knowledge and related competencies are essential to economic growth, social well-being and equity. As societies continue to change, rapidly, profoundly and often unpredictably, students need to be equipped with the necessary skills to navigate this evolving landscape. A strong foundation in mathematics and its applications will empower students to confidently tackle challenges in both work and life. The ability to understand and apply mathematical concepts will help individuals navigate the changing landscape of work and develop adaptable and transferable skills to remain competitive and innovative.

The changing world of work

Rapid technological advancements are reshaping the landscape of work, requiring a new range of mathematical knowledge, skills, attitudes and values. The shift from traditional manufacturing to automation and artificial intelligence (AI) has already revolutionised industries worldwide. Jobs centred on routine and repetitive tasks have increasingly been taken over by machines, pushing human workers to adapt to more complex, analytical roles. As we move deeper into the digital age, even professional sectors such as accounting, law and finance – historically reliant on human expertise – are being disrupted by automation, artificial intelligence and machine learning (OECD, 2023[2]; Lassébie and Quintini, 2022[3]). Some examples of current trends across various industries and fields include the following:

- For workers in industries that were once reliant on manual labour or repetitive tasks, the need to develop new competencies is now critical.
- Many jobs, such as those in programming, robotics and systems management, now require employees to understand and manage digital tools that perform complex processes. Fields like data science, artificial intelligence (AI) and machine learning are driving this change by automating analysis and decision-making processes. For instance, data science underpins much of the decision making across sectors, from optimising supply chains in logistics to personalising user experiences in e-commerce and media (Jahani, Jain and Ivanov, 2023[4]; Nadikattu, 2020[5]). Also, in finance, AI-driven algorithms now handle tasks like predictive modelling for investment strategies and real-time fraud detection (Javaid, 2024[6]; Bello and Olufemi, 2024[7]), while AI in healthcare uses machine learning to diagnose diseases and personalise treatment plans (Johnson et al., 2020[8]).
- Cybersecurity is emerging as a critical area where mathematical models, statistical algorithms and encryption techniques are used to safeguard data, detect breaches and protect digital infrastructures from increasingly sophisticated threats (Shah, 2022[9]).
- In industries like renewable energy, mathematical models help improve the efficiency of energy grids and forecast energy consumption, while in autonomous vehicles, algorithms relying on geometry, calculus and probability drive innovation (Ahmad, Zhang and Yan, 2020[10]; Mostafa, Ramadan and Elfarouk, 2022[11]; Wu, Bayen and Mehta, 2018[12]).

Today, workers are expected to have **competencies in data analysis, problem solving and technical literacy** to thrive in increasingly automated environments (OECD, 2022[13]). **Mathematical and statistical**

literacy not only support the advancement of digital technologies but are also instrumental for the end-users in many fields, equipping workers to navigate and shape the future of highly complex, technology-driven industries.

Demographic challenges

Projected population ageing across OECD countries is expected to have far-reaching implications for economic growth, productivity, inequality within and between generations, and the sustainability of public finances. Mathematic competencies are critical to navigating challenges related to demographic change:

- Health care is increasingly moving towards a digital platform to increase capacity of care as well as control costs.
- Medical diagnoses are being driven by algorithms, especially in emergency centres and hospitals. The algorithms are founded on interrogation of large data sets and calculation of probabilities for relative risk.
- Drug efficacy is researched using randomised control trials that employ statistical procedures to establish the benefits of treatments, and the risks of side effects.

Citizens increasingly need to be **digitally literate** to effectively navigate healthcare systems. Individuals are now more responsible than in past for evaluating their own health data to make informed decisions about treatments, medications and surgeries. This **self-evaluation** requires an ability to assess probabilities, determine medication dosages, consider potential side effects, and weigh the likelihood of improved quality of life outcomes from treatments. Essential competencies, such as **problem solving, decision-making in uncertain or probabilistic contexts, understanding the limitations of real-world data,** and **critical thinking**, are crucial for all citizens to manage their healthcare.

Environmental challenges

The OECD Future of Education and Skills 2030 position paper sets out that the foremost challenge brought about by rapidly and profoundly changing societies is environmental, calling for urgent action and adaptation to address the issue of climate change and the depletion of natural resources (OECD, 2018[14]). Mathematics plays a crucial role in addressing complex environmental challenges:

- Increasingly, data-based information featuring statistics constructed using mathematical tools (e.g. algorithms) is used to inform people about issues such as climate change or pandemics.
- Mathematical models, or representations of real-world phenomena using mathematical and statistical frameworks, are instrumental in predicting societal and environmental outcomes and evaluating potential consequences without the need for real-world experimentation. For example, stochastic modelling has been used to predict the spread of infectious diseases, such as COVID-19, and to assess the impact of various policy interventions prior to their implementation (He, Tang and Rong, 2020[15]).
- Similarly, calculus models are applied in engineering to solve problems such as temperature regulation, structural design and satellite trajectory prediction. Such use of mathematics offers critical insight into how societies can mitigate environmental and technological challenges.

Beyond basic calculations and computations, mathematics literacy is **fundamental in analysing and solving issues** like population growth, waste production, resource scarcity and pollution. Skills like **understanding percentages and ratios, and interpreting data in tables, charts and graphs** are crucial for quantifying these problems and enabling informed action (Schwartz, 2010[16]).

Challenges of growing inequality

Inequity is not a new phenomenon, but the challenge today and for the future is that it is growing in many OECD countries. (United Nations, 2015[17]). Rapid advancements in science and technology may exacerbate social and economic inequalities if not carefully managed.

- Highly skilled workers with transversal skills benefit from technological advances, while low-skilled workers face job displacement and stagnant wages, exacerbating income inequality. For instance, automation disproportionately affects sectors like manufacturing, widening the wage gap (World Economic Forum, 2020[18]; World Economic Forum, 2020[19]).
- Access to quality education is increasingly determined by economic and social status. In many OECD countries, the digital divide, i.e. unequal access to technology and the internet, limits learning opportunities for disadvantaged students, further entrenching educational inequalities. The COVID-19 pandemic highlighted how remote learning disproportionately affected students from low-income households (OECD, 2020[20]).
- In many OECD countries, individuals with higher incomes benefit more from cutting-edge treatments, while lower-income populations continue to face barriers to quality healthcare (World Health Organization, 2021[21]; OECD, 2021[22]).
- The effects of climate change disproportionately impact poorer communities and nations, both within OECD countries and globally. Wealthier populations have more resources to mitigate the impacts of climate change, while vulnerable groups bear the brunt of extreme weather events, food insecurity and health risks. This growing environmental inequity highlights the need for inclusive policies ((United Nations Department of Economic and Social Affairs, 2017[23]; United Nations Development Programme, 2021[24]; United Nations Framework Convention on Climate Change, 2021[25])).

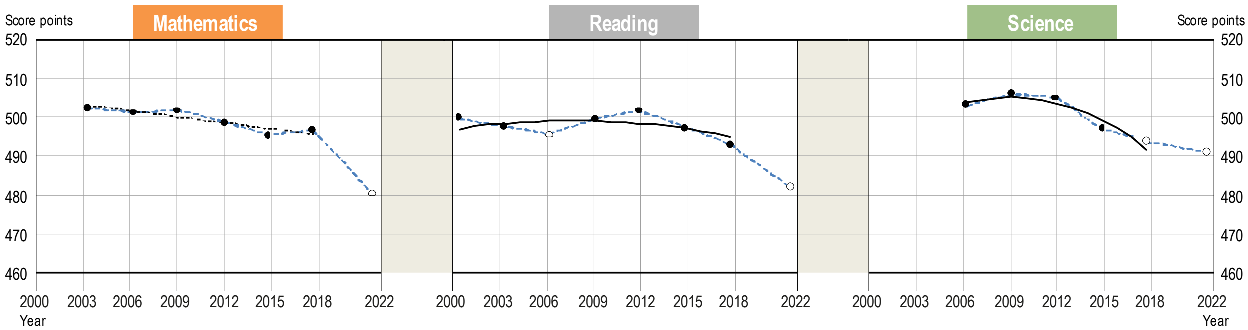
Mathematics is crucial for understanding global issues, such as the unequal distribution of resources and wealth both within and across countries, as well as the broader impacts, both positive and negative, of a global economic environment. To address disparities in economic, social and educational opportunities, building **strong mathematical foundations** for all children from the early years is essential. This foundation equips individuals with the skills needed to improve outcomes and life skills, particularly in a world where automation and big data are increasingly integrated into in daily life (Alvaredo et al., 2021[26]; The Royal Society, 2020[27]; Harvard University, n.d.[28]).

How well are today's students responding to 21st century demands in math?

The results of the OECD Programme for International Student Assessment (PISA) highlight strengths and critical concerns regarding student performance, particularly in mathematics. While some countries have shown improved outcomes over time, the overall trends raise significant questions. One alarming finding is the "unprecedented drop" in mathematics performance across OECD countries between 2018 and 2022, equivalent to a loss of three-quarters of a school year's learning (OECD, 2023[29])

While this decline is likely linked in part to the disruptions caused by the COVID-19 pandemic, it is important to note that student performance had already been gradually declining prior to the pandemic, as can be observed in Figure 1.1. This suggests that it is important for policymakers, educators and other education stakeholders to consider possible reasons for deeper, long-term challenges in education systems, and not only changes due to the pandemic.

Figure 1.1. PISA trends in mathematics, reading and science performance



Note: White dots indicate mean-performance estimates that are not statistically significantly above/below PISA 2022 estimates. Black lines indicate the best-fitting trend lines; a dotted black line indicates a non-significant (flat) trend (see Annex A3).
Source: OECD (2023[30]), PISA 2022 Results (Volume I): The State of Learning and Equity in Education, PISA, OECD Publishing, Paris, https://doi.org/10.1787/53f23881-en.

Researchers argue that the downward trend in student performance observed prior to the COVID-19 pandemic in several countries can be attributed to several interrelated systemic issues (OECD, 2023[29]), such as:

- **Gaps between curriculum content and real-world applications.** One issue is a slow adaptation of curriculum, in particular in mathematics, to shift from routine calculations to incorporate problem solving and real-world application. Traditional teaching methods that emphasise rote learning may not be preparing students adequately for higher-order skills, leading to declining performance.
- **Teacher shortages, teacher education and professional development**. Research has shown a lack of well-trained teachers and insufficient professional development opportunities as critical issues. In some countries, the recruitment and retention of qualified mathematics teachers have become more challenging, affecting the quality of instruction. Even when curriculum content is updated, inadequate training on new pedagogical approaches can leave teachers unprepared to successfully implement the new content.
- **Technological disruptions**. Another issue is the extent of technological tool use in mathematics classes. While technology has the potential to enhance learning, it can lead to disengagement and distraction when poorly implemented; unequal access to such tools can also be an issue.
- **Student perceptions about math**. Another cause could be that students often perceive mathematics as a difficult or irrelevant subject to their future lives; this lack of motivation can lead to lower effort and achievement. Research has shown that student engagement with subjects like mathematics has been declining.
- **Inequity in education**. Inequity performance gap trends have been exacerbated, where wealthier students have more opportunities to succeed academically while disadvantaged students struggle in math.

Furthermore, in low-performing countries, there is widespread disappointment in student outcomes, despite considerable public investment in education. For example, 35 education systems participating in the last round of PISA underperformed in mathematics proficiency, with over 50% of 15-year-old students failing to meet **basic competency levels,** i.e. being able to solve simple problems in mathematics (OECD, 2023[29]). In 12 of these systems, over 80% of students scored below basic proficiency levels. This is a serious concern, as mathematical literacy is a critical skill for participation in modern societies. Students without these basic competencies are at a disadvantage in the workforce, limiting their ability to contribute to national economies (OECD, 2019[31])

In various high-performing countries, a different concern exists. Despite having a good share of top performers in mathematics and/or science, these countries face a paradox: a significant proportion of these high achievers are not interested in pursuing careers in STEM-related fields. For example, in Estonia, Finland, Hong Kong (China), Japan, Korea and the Netherlands, fewer than 20% of top performers express an interest in related careers, such as science and engineering, a concerning figure for policymakers, given the critical role these fields play in driving innovation and economic growth (OECD, 2019[32]). The decreasing interest in STEM professions has implications for national competitiveness and innovation capacity (OECD, 2021[33]).

PISA 2022 results have also shown that in many school systems, including all EU countries, students' confidence about **motivating themselves to do schoolwork is weaker than their confidence about using digital technology for learning remotely.** On average, around 75% of students felt confident using digital tools like learning management systems or video communication platforms. However, only about 60% felt equally confident about self-motivating and staying focused on schoolwork without reminders. This suggests that students often struggle with **self-motivation, self-control** and **self-discipline needed for autonomous learning**. This has an important policy implication, as this means teaching students how to use digital devices is not enough – students also need to develop strategies on how to motivate themselves to effectively navigate their own learning.

Autonomous learning does not mean that teachers are not necessary; on the contrary, teachers' support matters even more. Indeed, students whose teachers were available when schools were closed scored higher in mathematics and were more confident about self-directed learning. Self-motivation is necessary not just during school but throughout life for upskilling and reskilling. It is important for teachers to better understand that instilling students with **self-motivation** for lifelong learning requires a highly complex developmental trajectory; for example, teachers may need pedagogical knowledge such as intrinsic and extrinsic motivation theories, for example, Deci and Ryan's self-determination theory, which stresses **autonomy, competence and relatedness as key factors of self-motivation** (2008[34]).

Beyond self-motivation, autonomous learners also need **digital navigation skills** (OECD, 2023[29]). Teachers need a combination of knowledge about their students' prior skills and awareness about digital literacy, critical thinking skills, and a supportive, responsible and empowering attitude. Teachers should be able to guide their students in recognising reliable sources, identifying biases, conducting research online, and understanding how digital content is curated and influenced by algorithms. In addition to technical proficiency, teachers can empower students to become discerning, responsible digital citizens by instilling certain attitudes and values e.g. respect for intellectual property, data privacy, digital safety, inclusivity, and balanced digital habits for well-being.

These realities, coupled with the growing pressures on education systems to equip young people with the agency, well-being and competencies necessary for success in a rapidly evolving world, highlight some of the reasons behind the push for curriculum reform in mathematics in various countries. For example, the demand for 21st century competencies such as digital literacy, data literacy, computational thinking, critical thinking, self-directed and autonomous learning, collaboration and problem solving is rising, and mathematics curricula is increasingly expected to adapt and help prepare students for the future, as outlined in the OECD Learning Compass for Mathematics 2030 (OECD, 2023[35]).

How well does today's mathematics curriculum accommodate new demands for 21st century competencies? And how does it differ from other subjects?

OECD Learning Compass for Mathematics and OECD E2030 curriculum analyses: Closing gaps between curriculum content and real-world applications

Recognition that mathematics education must do more than teach disciplinary knowledge has been a significant factor in discussions about mathematics curriculum, assessment and pedagogy for many decades. The importance of mathematical literacy has been part of policy discussions since the mid-1940s. For example, in 1989, the National Council of Teachers of Mathematics in the United States identified five goals relating to mathematical literacy for all students (National Council of Teachers of Mathematics (NCTM), 1989[36]). These goals focused on helping students:

1. value mathematics;
2. gain confidence in their mathematical ability;
3. become mathematical problem solvers;
4. learn to communicate mathematically;
5. develop mathematical reasoning skills.

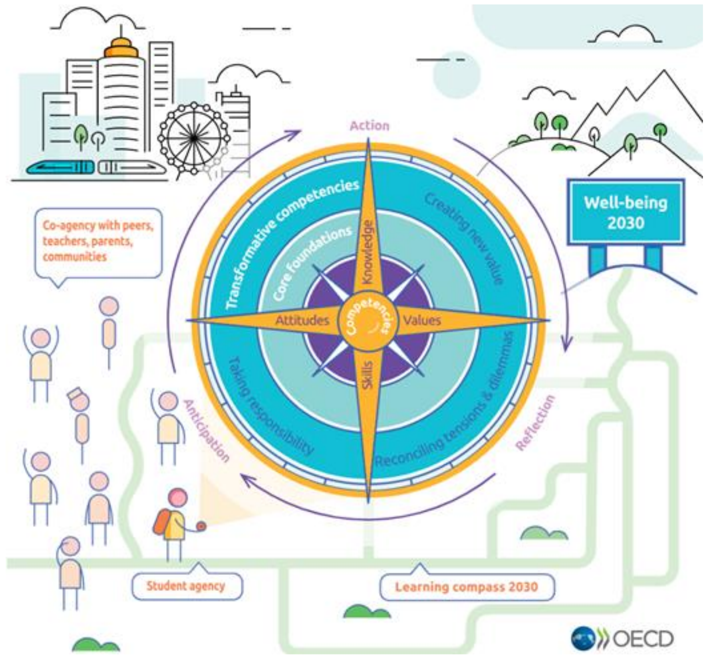
As educators and policymakers seek to redesign mathematics curricula for the future, it is essential to bridge the gap between the theoretical foundations of mathematics and its practical applications. Students must be provided with opportunities to engage with mathematics in ways that reflect its real-world relevance and utility, ensuring that they leave school not only with an understanding of mathematical concepts but also with the confidence and capability to apply them effectively in everyday life and the workplace.

It is in this context that a number of mathematics-related competencies have gained increased importance in curriculum reform circles. As a response, the OECD Future of Education and Skills 2030 (E2030) project has embarked on a series of mathematics-specific curriculum analyses.

OECD Learning Compass for Mathematics 2030

The new demands on mathematics education are synthesised in the **OECD Learning Compass** (LC) for Mathematics (Figure 1.2 below). The framework sets out the key concepts and types of mathematical competencies today's students need to thrive in math and apply the math knowledge and skills to shape a better future.

Figure 1.2. OECD Learning Compass



The key concepts and constructs included in the LC include: **student agency, co-agency, collective agency, literacy, numeracy, digital literacy, data literacy (including information use), physical and mental health literacy, creativity, conflict resolution, responsibility, computational thinking/programming/coding, literacy for sustainable development/environmental literacy, financial literacy, problem solving, critical thinking, communication, self-direction/learning to learn, persistence,** and **resilience**.

OECD E2030 Curriculum Content Mapping

In order to support countries to redesign their curriculum by embedding so-called 21st century competencies, the OECD E2030 project developed a **Curriculum Content Mapping** (CCM) exercise. It supported countries to better understand how well their curricula are intended, by design, to develop competencies essential for the future in major subjects, including mathematics. The curriculum experts coded their curriculum documents and mapped how well the types of knowledge, skills, attitudes and values implicated in the OECD Learning Compass are explicitly intended in their curriculum.[1] The key constructs included in CCM include: **student agency, co-agency, literacy, numeracy, Information and Communications Technology (ICT)/digital literacy, data literacy, physical/health literacy, creativity, responsibility, conflict resolution, critical thinking, problem solving, co-operation/collaboration, self-regulation/self-control, empathy, respect, persistence/resilience, trust, learning to learn, global competency, media literacy, literacy for sustainable development, computational thinking/programming/coding, financial literacy,** and **entrepreneurship**.

The exercise supported countries to recognise gaps between current curricula and future needs, offering insights for curriculum redesign and helping countries avoid overloading their curricula by adding too many new topics without careful integration. Participating countries use CCM as a tool for both self-reflection and peer learning, allowing them to track their progress in curriculum reform and make evidence-based adjustments. Ultimately, the CCM helps ensure that education systems align with the evolving demands of the 21st Century, emphasising interdisciplinary and holistic competency-based learning approaches.

OECD E2030 Mathematics Curriculum Document Analysis

The E2030 project also conducted a mathematics-specific curriculum analysis, the **Mathematics Curriculum Document Analysis** (MCDA), modelled after the Trends in International Mathematics and Science Study (TIMSS-95).[2] The analysis focused on: i) curriculum changes, investigating how the content and focus on mathematics curricula have evolved, particularly looking at new topics that have emerged in recent decades, such as statistics, algorithmic reasoning and nonlinear models; ii) mathematics literacy, assessing how countries are incorporating mathematic competencies, e.g. quantitative reasoning, data interpretation and real-world problem solving, into their curriculum; iii) textbook analysis, reviewing the consistency between national curriculum standards and the textbooks used in classrooms, ensuring that students have opportunities to develop both traditional and modern mathematical competencies; and iv) decision making, exploring who holds decision-making power in mathematics curricular reforms and, analysing how decisions regarding mathematics education are made and implemented. The key constructs of 21st century competencies included in MCDA include: **communication, creativity, critical thinking, information use, reflection and resistance/ resilience,** and **systems thinking**.

The MCDA project aimed to ensure conceptual coherence with the PISA 2022 mathematics assessment framework through having the same expert sitting in both of the technical groups. As a result, the key constructs included in the PISA 2022 assessment are highly consistent: **communication, critical thinking, creativity, research and inquiry, self-direction/initiative/persistence, information use, system thinking,** and **reflection**.

For a comparative table of key constructs, please see Table 1.1.

OECD E2030 Policy Questionnaire on Curriculum

In order to contextualise all the above technical analyses in a real policy context, the project also conducted a **Policy Questionnaire on Curriculum (PQC)**[3] (OECD, 2020[20])**.** The aim of the PQC was twofold: to give countries/jurisdictions the opportunity to learn from peers about good practices in and challenges faced in the curriculum redesign process and to provide countries/jurisdictions with an opportunity for self-reflection to position their curriculum (e.g. visions, educational goals and expected student outcomes).

Notions of curriculum and approaches to curriculum redesign are particularly diverse across countries and jurisdictions. To capture this diversity, the PQC questionnaire was designed with an exploratory approach, covering key policy issues in curriculum design: 1) contextual information necessary to better understand country-specific circumstances regarding curriculum, e.g. major government visionary policies, legal regulation/s, education courses and curricula, teachers' and students' autonomy in curricula, extra-curricular activities; 2) curriculum-specific information, e.g. curricular goals, values, coverage, textbooks, instruction time and transition; 3) trends in curriculum redesign e.g. trends in the frequency of changes, stakeholder management, lessons learned from the previous curriculum reform, plan for the next curriculum, etc. For more information on the methodology of the PQC please refer to the technical report (OECD, 2020[20]).

Findings of the OECD Curriculum Content Mapping exercise

This section details specific findings from the CCM exercise, highlighting how countries integrate 21st century competencies into mathematics curricula compared to other subjects. To ensure a valid and reliable analysis, definitions were carefully developed for this CCM exercise, with particular attention to the language variations in curriculum documents among participating countries.

Overall, mathematics curricula across countries/jurisdictions vary significantly in how they integrate 21st century competencies. Some obvious foundational competencies, such as numeracy, critical thinking and problem solving, are extensively embedded and highly emphasised within mathematics education. These reflect the foundational skills necessary for cognitive development and the application of mathematical reasoning to real-world situations. Interestingly, some competencies that might not traditionally be associated with mathematics, like literacy, are also embedded into mathematics in some countries/jurisdictions, reflecting a broader shift towards making mathematics more interdisciplinary and relevant to diverse contexts.

Table 1.1. Examples of 21st century competencies/constructs deemed relevant for inclusion in future-oriented mathematics curriculum

OECD Learning Compass for Mathematics 2030	E2030 Curriculum Content Mapping (CCM) Exercise	E2030 Mathematics Curriculum Document Analysis (MCDA)	PISA 2022 Mathematics Framework
• Student agency, co-agency and collective agency • Core foundations: ○ cognitive foundations, i.e. literacy, numeracy, digital literacy, data literacy (including information use) ○ health foundations, i.e. physical and mental health literacy (to overcome math-related anxiety and "fear of failure"), well-being ○ social and emotional foundations, including morals and ethics. • Knowledge (disciplinary, interdisciplinary, epistemic, procedural) • Skills (including cognitive/ meta-cognitive skills, social and emotional skills, and practical and physical skills, e.g. problem solving, critical thinking, communication, self-direction/learning to learn) • Attitudes and values (e.g. persistence, resilience, ethical understanding, e.g. of opportunities and risks of AI) • Transformative competencies (creating new value, reconciling tensions and dilemmas, taking responsibility) • Compound competencies: ○ computational thinking/programming/ coding ○ literacy for sustainable development/environmental literacy ○ financial literacy • Anticipation-Action-Reflection cycle	Key concepts: • Student agency • Co-agency Core foundations – cognitive and meta-cognitive: • Literacy • Numeracy • Data literacy • ICT/digital literacy • Critical thinking • Problem solving • Learning to learn Core foundations – health: • Physical/health literacy Core foundations – social and emotional skills: • Co-operation/ collaboration • Self-control/self-regulation • Persistence/resilience • Empathy • Trust • Respect Transformative competencies: • Creativity • Conflict resolution • Responsibility Compound competencies: • Computational thinking/programming/ coding • Financial literacy • Entrepreneurship • Media literacy • Global competency • Literacy for sustainable development AAR Cycle: • Anticipation • Action • Reflection	Quantitative reasoning: • Algorithmic • Geometric • Mathematics • Statistical Higher order thinking: • Real-world applications • Mathematics higher order applications 21st century competencies: • Communication • Creativity • Critical thinking • Information use • Reflection • Resistance/resilience • Systems thinking	• Communication • Critical thinking • Creativity • Research and inquiry • Self-direction, initiative and persistence • Information use • Systems thinking • Reflection • Mathematical reasoning

However, emerging competencies like social and emotional skills, transformative competencies (e.g. responsibility, trust and empathy) and co-agency, are generally less embedded in mathematics compared to other subjects like humanities, national language or physical education. For example, empathy, trust and respect are more commonly found in subjects that foster social interactions and collaborative learning, such as national language or arts, and are rarely incorporated explicitly into mathematics.

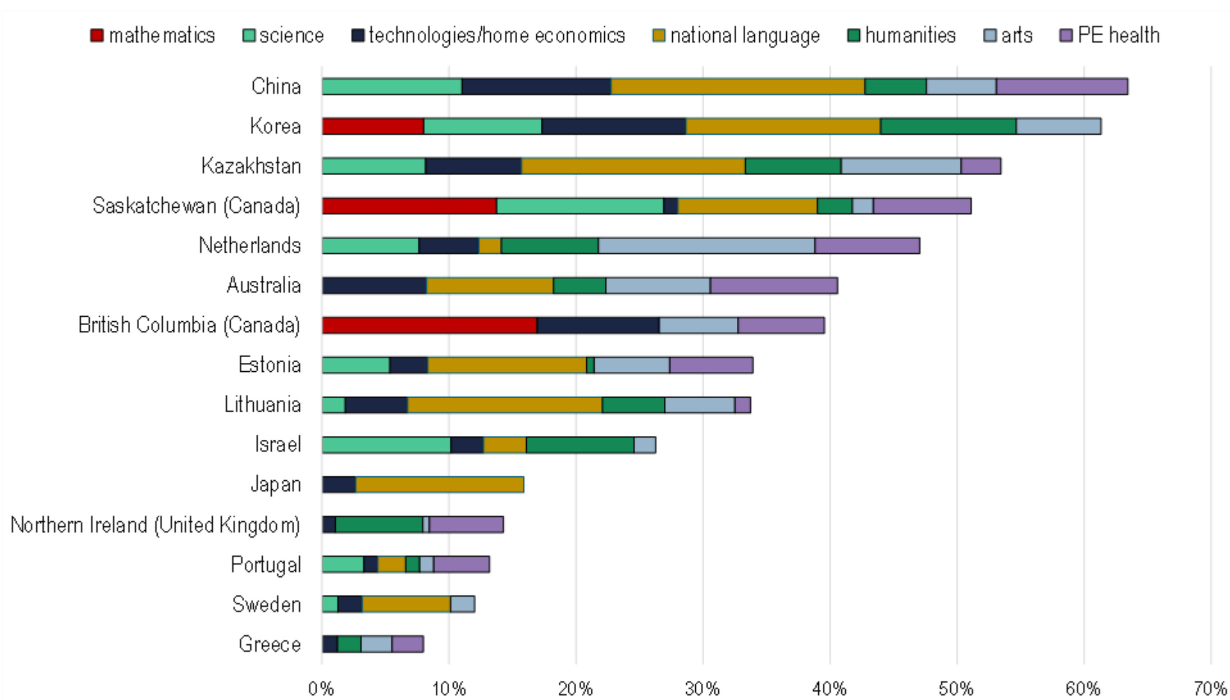
It is important to clarify that CCM findings reflect what is outlined in curriculum documents (i.e. the *intended curriculum*), not necessarily what teachers implement in classrooms (i.e. the *taught curriculum*) or the learning outcomes students actually achieve (i.e. the *achieved curriculum*). It is also important to note that the CCM findings illustrate how countries make different choices, prioritising their own unique cultural and context.

Key concept: Student agency

Student agency is defined as "the capacity and propensity to take purposeful initiative – the opposite of helplessness. Young people with high levels of agency do not respond passively to their circumstances; they tend to seek meaning and act with purpose to achieve the conditions they desire in their own and others' lives. They have the belief that they can have impact and influence over their learning and future." (OECD, 2020[20]). The extent to which countries/jurisdictions explicitly incorporate student agency in their curricula varies considerably (Figure 1.3).

Figure 1.3. Student agency in curricula

Distribution of content items in the mapped curricula targeting student agency (as main or sub target), by learning area



Notes:
1. Year of reference for data collection is 2018.
2. The findings from the CCM analysis in the Netherlands are included here for their research interest. The country did not participate in the CCM main study. The curriculum mapping was conducted on a proposed revision to their curriculum, which was ultimately not approved by the Dutch Parliament and never implemented. OECD (2019[37]), Education 2030 Curriculum Content Mapping: An Analysis of the Netherlands Curriculum Proposal, OECD Publishing, Paris, https://www.oecd.org/content/dam/oecd/en/about/projects/edu/education-2040/6-bilateral-support/E2030_CCM_analysis_NLD_curriculum_proposal.pdf.
Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

StatLink https://stat.link/ndrs0o

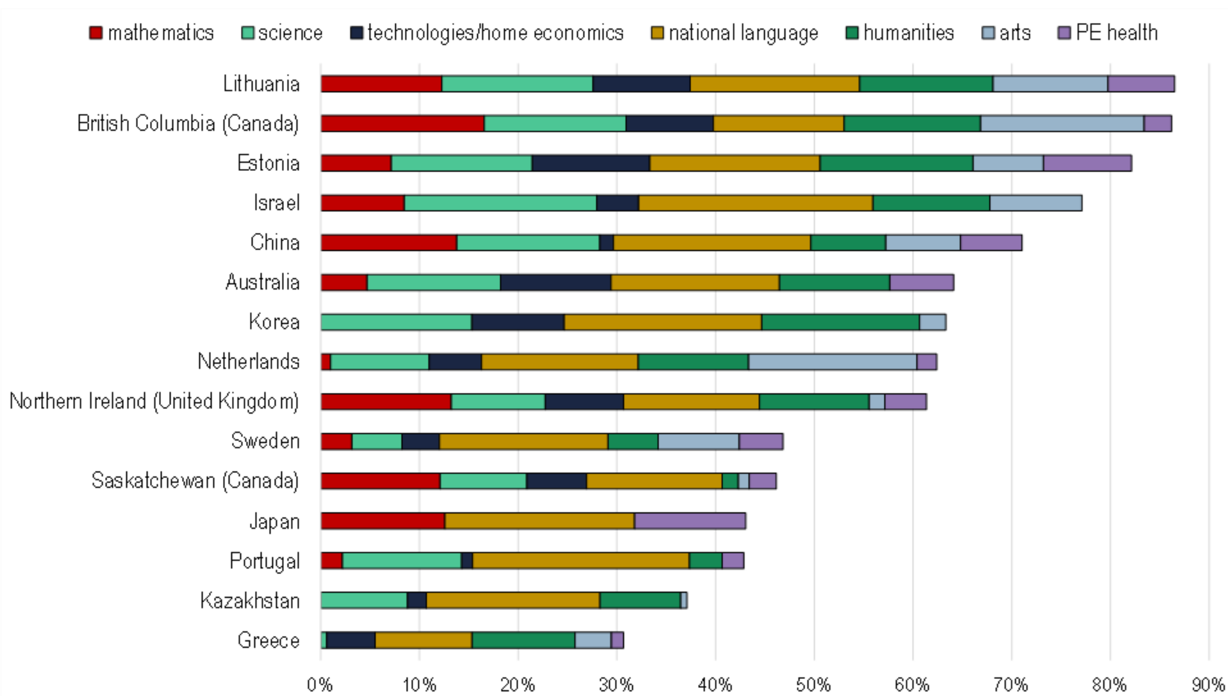
Supporting student agency in mathematics will empower students to approach problems with confidence and creativity, develop perseverance when tackling difficult tasks, and apply mathematical reasoning independently and collaboratively. However, while mathematics is a key subject, it is often less emphasised in a math curriculum document, compared to other subjects in fostering student agency. Only a few countries/jurisdictions embed student agency in mathematics curriculum, i.e., **British Columbia (Canada)** (17%) and **Saskatchewan (Canada) (14%)** and **Korea** (8%). In other countries, other subjects, such as **national language**, **science, and arts**. receive greater focus. Additionally, **technologies/home economics** and **PE/health** also show, to some extent, a representation in certain countries.

Cognitive foundation: Literacy

Literacy is defined as “the ability to evaluate, use and engage with written, spoken, visual and multi-modal texts” (OECD, 2020[20]). It is a cornerstone of success in the 21st century, enabling students to access and interpret information, make informed decisions, and fully participate in a globally connected world.

Figure 1.4. Literacy in curricula

Distribution of content items in the mapped curricula targeting literacy (as main or sub target), by learning area



Notes:
1. Year of reference for data collection is 2018.
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Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

StatLink https://stat.link/dcw1ra

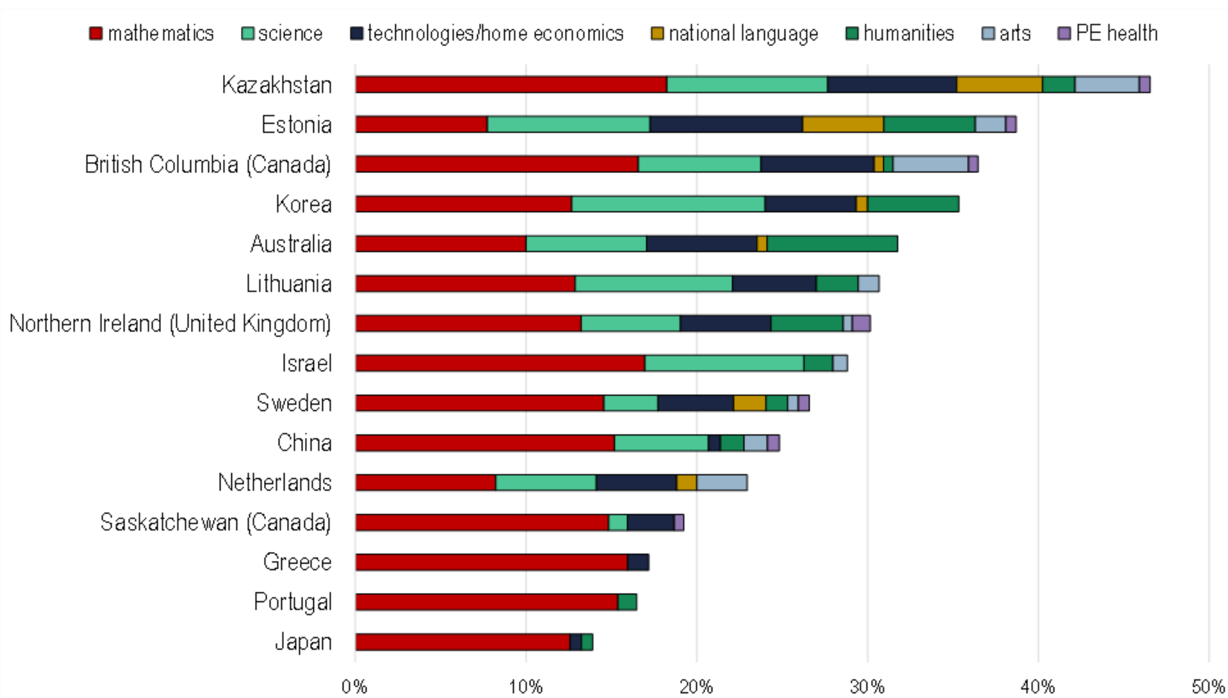
Literacy also plays a pivotal role in mathematics, helping students to solve word problems, comprehend complex instructions, and understand mathematical proofs. Without strong literacy skills, students may struggle to interpret the meaning behind numbers and symbols, which limits their problem-solving ability. Acknowledging the vital connection between literacy and mathematical understanding, several countries have integrated more than 10% of literacy-focused items in their mathematics curriculum, e.g. **British Columbia (Canada)** (**17%), China** (**14%), Japan** and **Northern Ireland (United Kingdom)** (13%), and **Lithuania** and **Saskatchewan (Canada)** (12%). Similarly, literacy is considered as the core foundation for other subjects and thus is embedded in almost all other subjects (such as science, technology, national language, humanity, arts and even physical education/health), of course with varying degrees across countries.

Core foundation: Numeracy

Numeracy is defined in the CCM exercise as "the ability to access, use, interpret and communicate mathematical information and ideas" (OECD, 2020[20]).This includes applying the knowledge and skills acquired in mathematics when engaging with subject-specific content in other subject areas, where appropriate. Numerate students can apply mathematical understanding and skills effectively in both school settings and everyday life. Numeracy is embedded, with significant variation, in the mapped curricula of participating countries (Figure 1.5).

Figure 1.5. Numeracy in curricula

Distribution of content items in the mapped curricula targeting numeracy (as main or sub target), by learning area



Notes:
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Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

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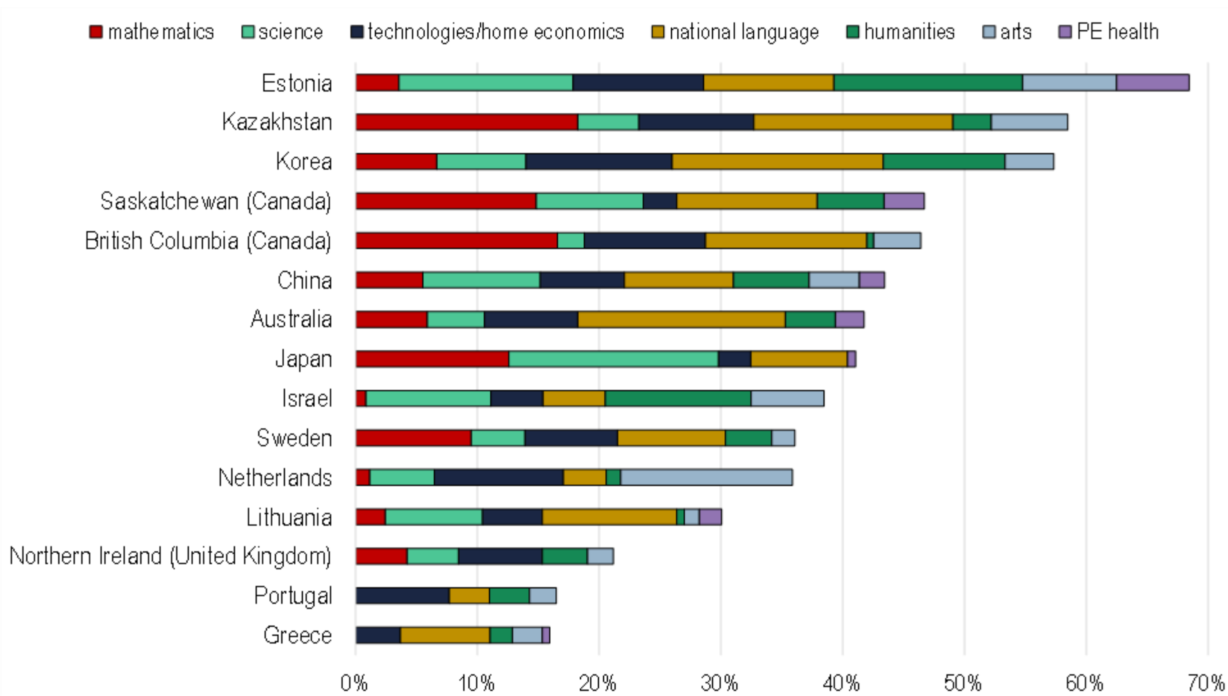
Not surprisingly, numeracy is primarily embedded within mathematics in most countries/jurisdictions. However, among top PISA performing countries, patterns vary. For example, **Estonia** shows significant integration of numeracy (39%) across a wide range of subjects, including mathematics **(8%),** science (10%), technologies/home economics (9%), national language (5%), humanities (5%), and even arts (2%) and physical education (1%), whereas **Japan** shows a more concentrated pattern with numeracy-related content items embedded mostly in mathematics **(12.6%),** and some in technologies/home economics (0.7%) and humanities (0.7%).

Cognitive foundation: ICT/digital literacy

Digital literacy is defined in the CCM exercise as the "ability to use information and communications technology (ICT) effectively and appropriately in school and beyond school". Digitally literate students are able to access, create and communicate information and concepts, and adapt to changing technologies. They are also able to use ICT[4] to achieve a purpose and to communicate with others using devices in an ethical and responsible way (OECD, 2020[20]). ICT/digital literacy is strongly emphasised within the content of mapped curricula, ranging from 16% to nearly 70% of curriculum content items (Figure 1.6).

Figure 1.6. ICT/digital literacy in curricula

Distribution of content items in the mapped curricula targeting ICT/digital literacy (as main or sub target), by learning area



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Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

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Embedding digital literacy into the mathematics curricula ensures that students are not only proficient in mathematical concepts but also able to leverage digital tools to solve complex problems. Digital literacy enables students to handle data, create models and use simulations, which are increasingly relevant in various sectors such as engineering, finance and technology.

Estonia stands out, with nearly 70% of its curriculum embedding ICT/digital literacy – mathematics (4%), however, is not the subject in which ICT/digital literacy is embedded most, with humanities (15%) and science (14%) as the two most highlighted learning areas for the development of this competency. **Kazakhstan and Korea** also feature this competency prominently, with close to 60% of their curricula embedding ICT/digital literacy, with a notable emphasis in **Kazakhstan** on integration into mathematics (18%). **British Columbia** (17%) and **Saskatchewan** (15%) **(both Canada),** as well as **Japan (13%)** feature ICT/digital literacy to a greater extent in mathematics specifically.

A noticeable trend across the countries and jurisdictions is the consistent integration of ICT/digital literacy across the seven mapped learning areas. This competency is frequently embedded in both STEM subjects and social sciences, such as humanities and national language. Although ICT/digital literacy is less prevalent in areas like physical education/health and arts, most countries take advantage of multiple opportunities to foster ICT/digital literacy across their curricula.

Cognitive foundation: Data literacy

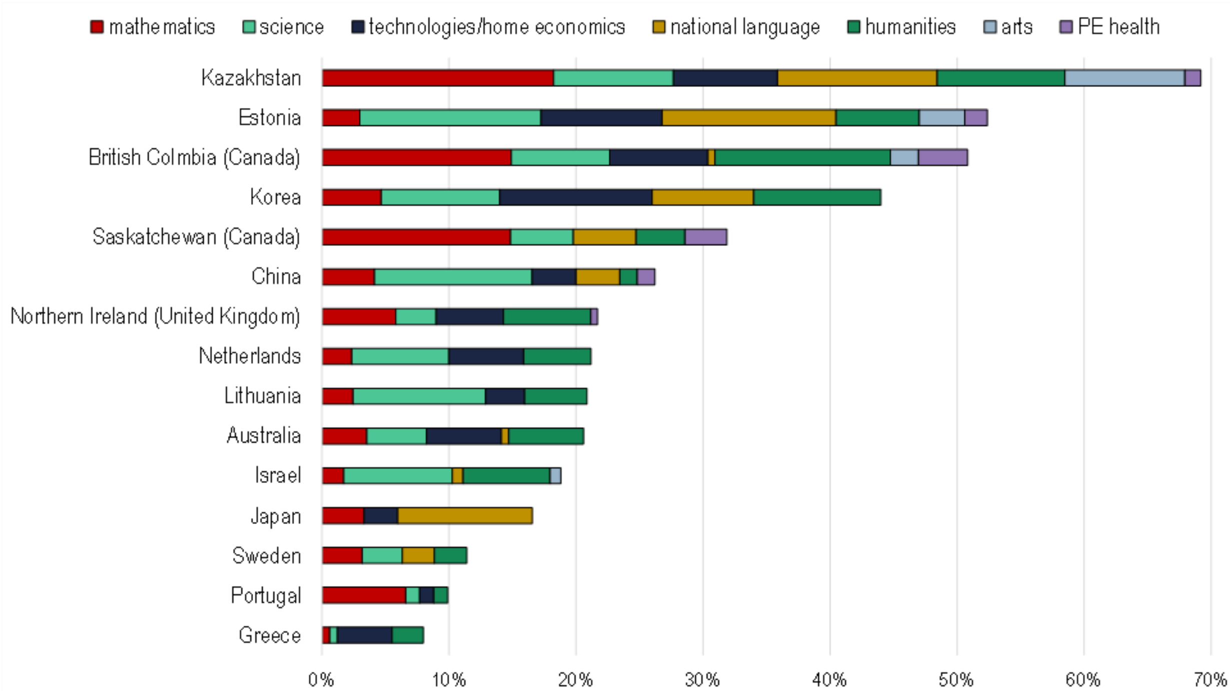
Data literacy is increasingly considered as one of the foundational literacies essential for future success, as it enables students to navigate and interpret the vast amounts of data they encounter in today's information-rich world. It is defined as the ability to acquire meaningful information from data, and create and communicate using data, based on mathematical understanding and skills (particularly in relation to statistics). It includes thinking critically about information presented in statistical or visual formats, analysing the data and determining the accuracy of claims and objective interpretations made in relation to the data (OECD, 2020[20]). Data literacy is embedded within the curricula of various countries and jurisdictions, with significant variation in coverage (Figure 1.7).

Mathematics provides the necessary foundation for understanding data; data literacy enables students to apply mathematical concepts to real-world scenarios and enhances computational thinking, fostering skills like pattern recognition and abstraction to develop solutions that can be automated and scaled using computer-based technologies.

The distribution of data literacy across different subject areas reflects the interdisciplinary nature of this competency. For instance, **Kazakhstan** incorporates data literacy into 69% of its curriculum, with **18%** in mathematics, while **Greece** includes it in only 8% (with only **1%** in mathematics). Kazakhstan is closely followed by **Saskatchewan** and **British Columbia (both Canada),** embedding data literacy in **15%** of their mathematics curriculum, while in contrast, countries such as **Estonia (14%), China (12%)** and **Lithuania (10%)** focus primarily on embedding data literacy within **science** subjects. **Japan,** on the other hand, places a strong emphasis on data literacy in the **national language** curriculum (11%).

Figure 1.7. Data literacy in curricula

Distribution of content items in the mapped curricula targeting data literacy (as main or sub target), by learning area



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Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

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Cognitive foundation: Critical thinking

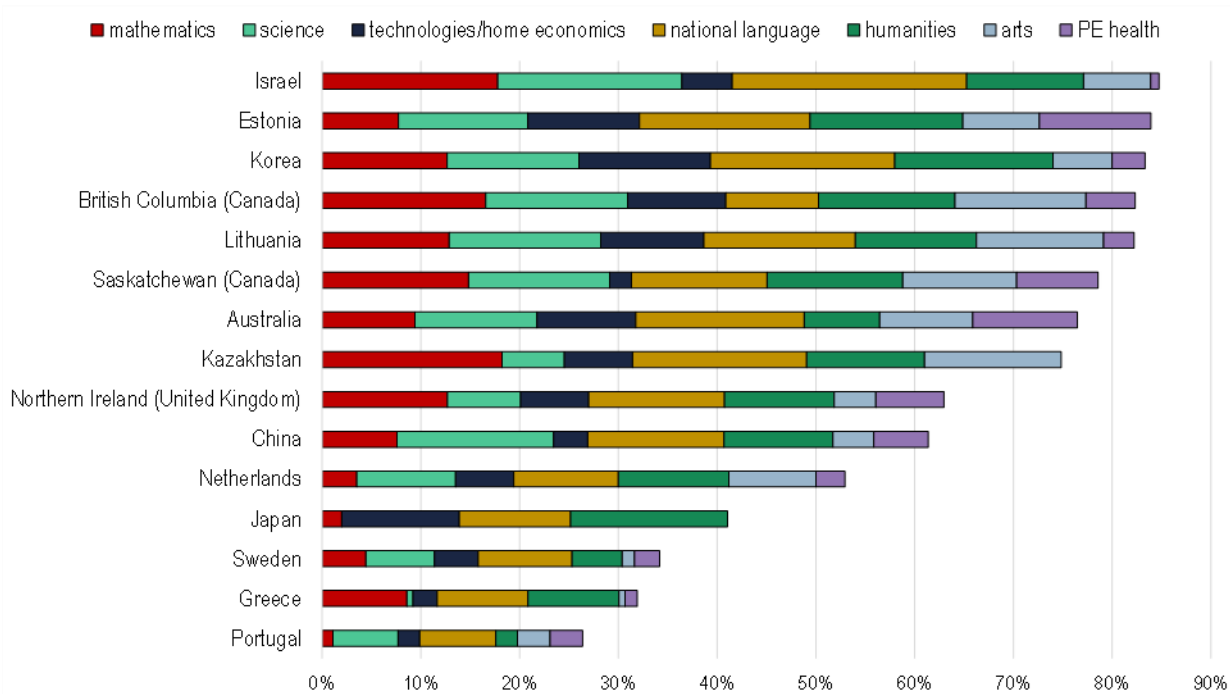
Critical thinking is defined in the CCM exercise as questioning and evaluating ideas and solutions. This definition embodies components of metacognition, social and emotional skills (reflection and evaluation within a cultural context), attitudes and values (moral judgment and integration with one's own values), as well as a combination of many cognitive skills including experiencing, observing, analysing, conceptualising, synthesising, evaluating, reflecting and communicating. Critical thinking is a higher-order cognitive skill and includes inductive and deductive reasoning, making correct analyses, inferences and evaluations (OECD, 2020[20]). Critical thinking is one of the most frequently embedded cross-curricular competencies, found in various learning areas in curriculum, including mathematics (Figure 1.8).

It is essential in mathematics, as it allows students to engage deeply with concepts, evaluate solutions and approach problems methodically and logically, building a robust foundation for effective decision making, logic and adaptability – all essential qualities in personal and professional contexts.

In most countries/jurisdictions, critical thinking is embedded across all seven mapped learning areas. Israel, Estonia, Korea, Lithuania and British Columbia (Canada) feature critical thinking in over 80% of their mapped content items. Out of those, **Israel (18%)** and **British Columbia (Canada) (17%)** embed critical thinking to a greater extent in mathematics, closely followed by **Kazakhstan (18%), Saskatchewan (Canada) (15%), Korea, Lithuania** and **Northern Ireland (United Kingdom) (all three at 13%).** The presence of critical thinking in particular subjects varies significantly between countries. For example, in **Greece and Japan**, critical thinking is emphasised in a substantial proportion of the curriculum in humanities and national language, not only in mathematics and technologies/home economics.

Figure 1.8. Critical thinking in curricula

Distribution of content items in the mapped curricula targeting critical thinking (as main or sub target), by learning area



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Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

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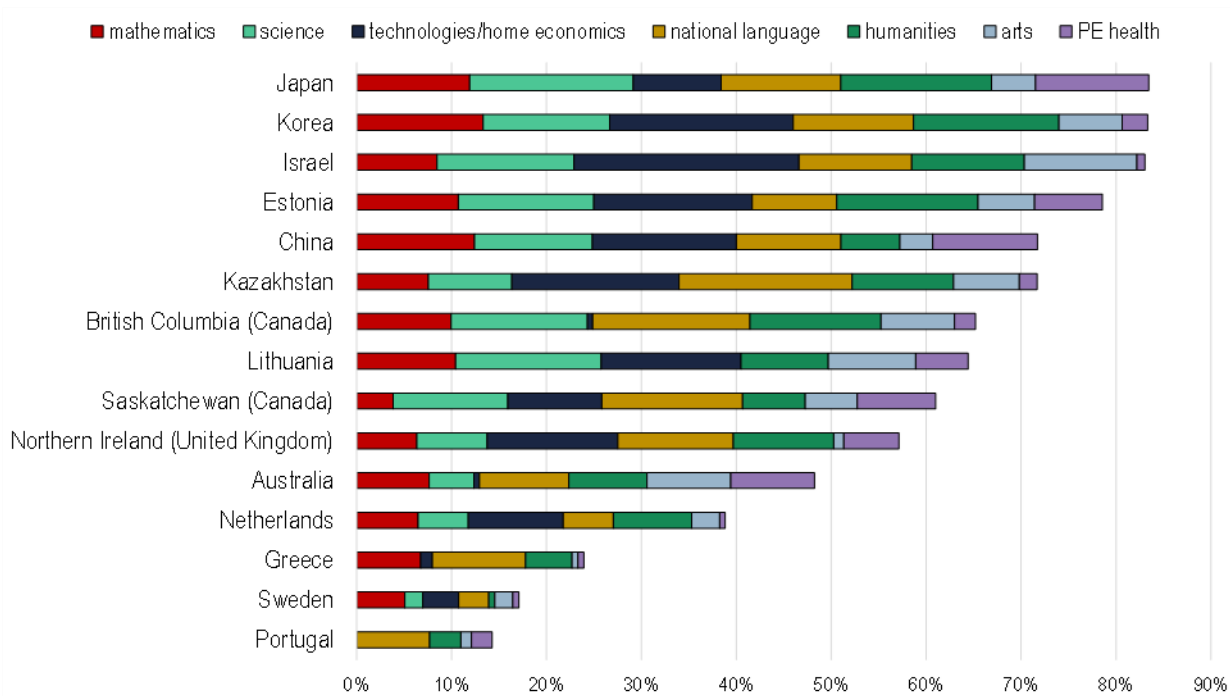
Cognitive foundation: Problem solving

Problem solving is defined as the process of finding solutions to difficult or complex issues, and involves engaging in cognitive processes to resolve situations where a clear solution is not immediately available. The OECD further emphasises problem solving as a multi-faceted skill, which can take various forms, including interpersonal, intrapersonal and social problem solving, as well as within specific disciplines like mathematics and science (OECD, 2020[20]). Since the 1990s, curriculum designers have increasingly recognised the importance of students engaging in problem solving and investigative activities as part of their development as emerging mathematicians and statisticians. Since then, problem solving has become another widely embedded concept in curricula across the world (Figure 1.9). It is fundamental in mathematics, as it represents the process of applying mathematical concepts to finding solutions, fostering logical thinking and creativity, thus cultivating critical skills that shape analytical, resilient and adaptable thinkers.

Countries/jurisdictions such as Israel, Korea, Japan, Estonia, Kazakhstan, China, British Columbia (Canada), Lithuania and Saskatchewan (Canada) embed problem solving in over 60% of their mapped curricula. However, mathematics is not the first subject choice for embedding this concept: only **Korea (13%), Japan (12%), China (12%)** and **Estonia (11%)** are beyond 10%, while other countries prefer giving precedence to subjects such as science, technologies/home economics, national language and humanities to target problem solving.

Figure 1.9. Problem solving in curricula

Distribution of content items in the mapped curricula targeting problem solving (as main or sub target), by learning area



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Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

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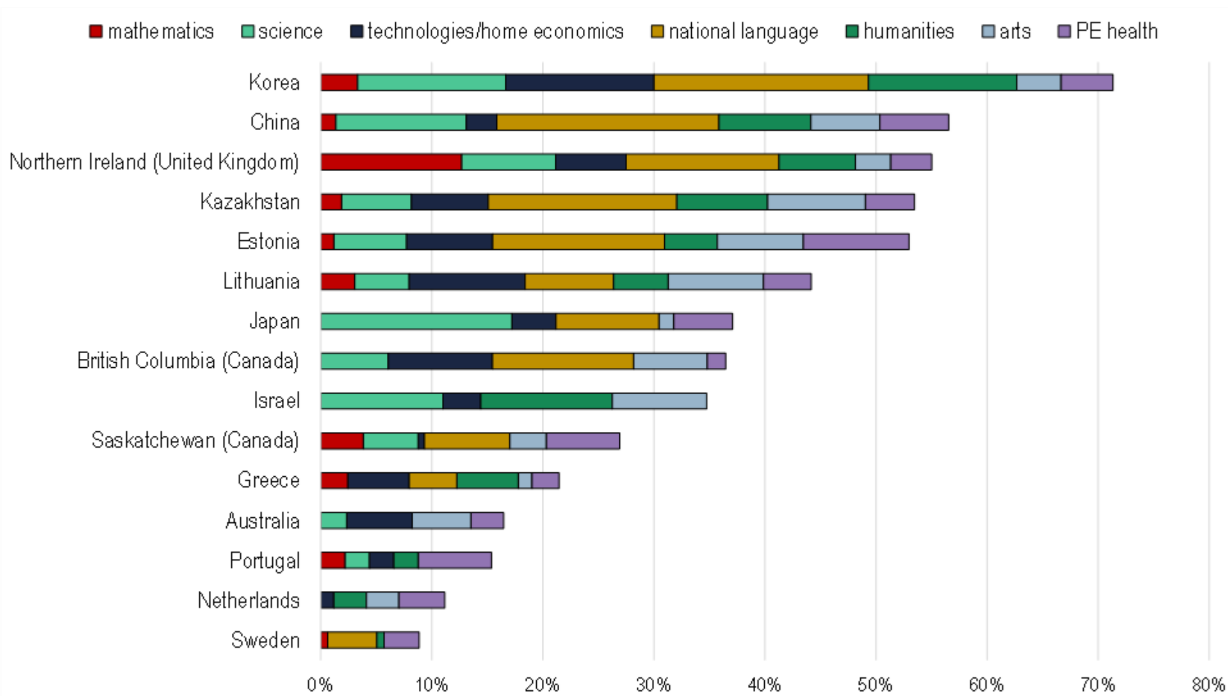
Social and emotional foundation: Co-operation/collaboration

Co-operation/ collaboration refers to the ability to work well as member of a group or team, being loyal to the group, doing one's share. Teamwork is a strong predictor of well-being and of a fulfilled and successful life. Collaboration skills are character traits and skills (rather than moral values or attitudes) (OECD, 2020[20]). Co-operation/collaboration in mathematics is essential as it transforms the traditionally individual learning process into a dynamic, interactive experience, making the subject more approachable, all while cultivating empathy and respect for others' perspectives – thus building strong socio-emotional foundations. Moreover, co-operative learning methods have been shown to improve students' achievement in mathematics and their attitude towards mathematics (Zakaria, Chin and Daud, 2010[38]; Hossain and Tarmizi, 2013[39]).

Figure 1.10. Co-operation/collaboration in curricula

Distribution of content items in the mapped curricula targeting co-operation/collaboration (as main or sub target), by learning area



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Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

StatLink https://stat.link/1wq7zn

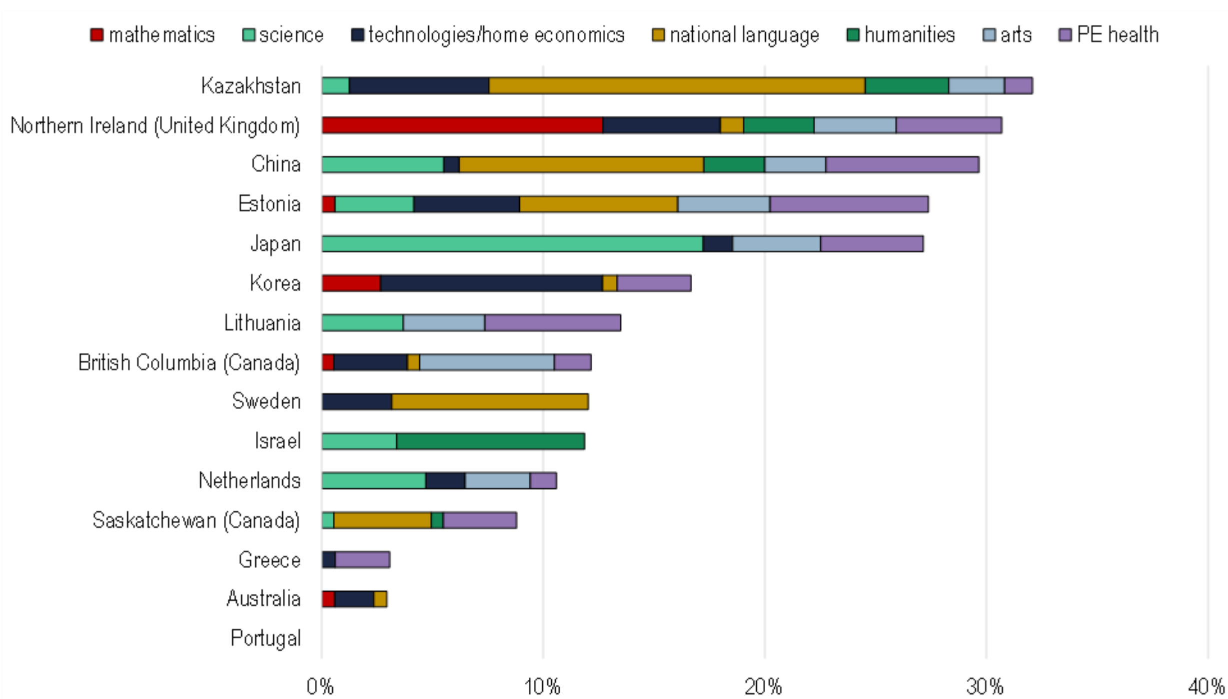
Co-operation/collaboration is embedded to varying degrees across the mapped curricula of different countries/jurisdictions (Figure 1.10). However, given the traditional view of mathematics as an individual pursuit, countries tend to integrate these competencies less into their mathematics curriculum and more into subjects such as national language, science and home economics, which more naturally involve teamwork. An exception can be found in **Northern Ireland (United Kingdom) (13%),** and to a much lesser extent in **Saskatchewan (Canada) (4%), Korea** and **Lithuania (both at 3%)**. In general, there is a large disparity among countries on including such competencies in their curriculum – for instance, Korea includes co-operation/collaboration in 71% of its curriculum, while it is less prominent in countries like Sweden (9%), the Netherlands (11%), Portugal (15%) and Australia (16%).

Social and emotional foundation: Persistence

Persistence refers to the disposition required to maintain effort or interest in an activity in the face of difficulties encountered, the length of time or steps involved, or when opposed by someone or something. The American Psychological Association defines resilience as the process of adapting well in the face of adversity, trauma, tragedy, threats or significant sources of stress — such as family and relationship problems, serious health problems or workplace and financial stressors. It means "bouncing back" from difficult experiences (OECD, 2020[20]). Yet the incorporation of persistence into educational curricula varies significantly across different countries/jurisdictions (Figure 1.11).

Figure 1.11. Persistence in curricula

Distribution of content items in the mapped curricula targeting persistence (as main or sub target), by learning area



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Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

StatLink https://stat.link/wphedl

Persistence is critical in the mathematical context, as it enables students to tackle complex concepts, overcome challenges, and ultimately build a deeper understanding of the subject – it transforms frustration into progress, and ultimately, into a sense of achievement and confidence in their abilities.

Despite this competency being critical to math, only **Northern Ireland (United Kingdom) (13%)**, and to a much lesser extent **Korea (3%), Estonia, British Columbia (Canada)** and **Australia (all at 1%)** embed persistence into their mathematics education, whereas other countries/jurisdictions mostly integrate them within PE/health, national language or technologies/home economics. In general, the integration of persistence in curricula is quite low compared to other competencies related to socio-emotional foundations: while Kazakhstan, Northern Ireland (United Kingdom) and China integrate these into around 30% of their curricula items, others, such as Portugal, do not explicitly focus on this competency.

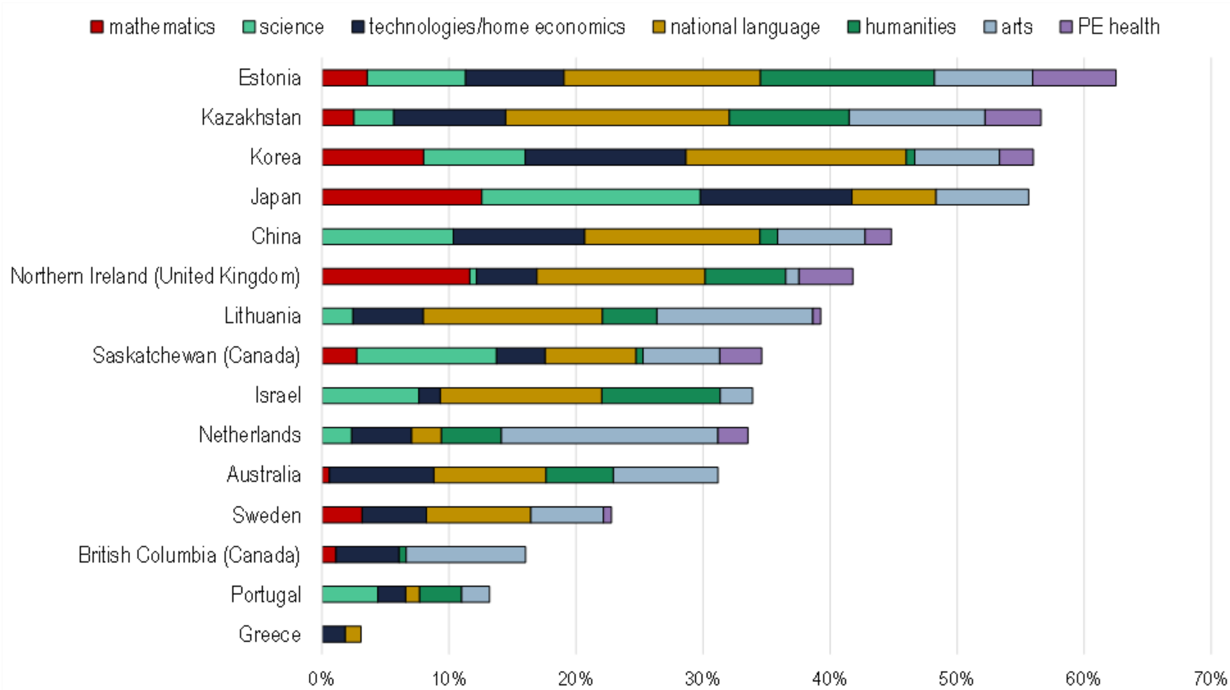
Transformative competencies: Creating new value/creative thinking

The CCM exercise mapped curriculum content items related to the broader concept of creating new value. Creating new value refers to the ability to contribute to society by identifying new sources of growth, such as developing innovative solutions, products, services, jobs, processes and methods. This competency prepares students for future challenges by fostering new ways of thinking, new enterprises and new social and business models. Creativity is a core element of creating new value and is often described as “outside-the-box thinking” – the ability to approach problems or situations from fresh perspectives, resulting in novel and unconventional solutions (OECD, 2020[20]). Figure 1.12 demonstrates how countries embed the competency of creating new value across their curricula. In mathematics education, fostering creativity can lead to new approaches to problem solving, flexible thinking and deeper understanding, encouraging students to think beyond conventional methods.

While mathematics is not the subject that most countries use to foster creating new value, it is incorporated into mathematics education in various countries/jurisdictions, including **Japan (13%), Northern Ireland (United Kingdom) (12%), Korea (8%)**, and to a lesser extent in **Estonia (4%), Sweden, Kazakhstan, Saskatchewan (Canada) (all at 3%)**, as well as **Australia and British Columbia (Canada) (1% for both).** Countries like Estonia, Kazakhstan, Korea and Japan lead in embedding creating new value in their content items, embedding it in over 50% of their mapped curriculum across various subjects including national language, arts, technologies/home economics and science. In contrast, countries like Greece (3%) and Portugal (13%) show less emphasis on fostering creating new value in their mapped curricula.

Figure 1.12. Creating new value in curricula

Distribution of content items in the mapped curricula targeting creating new value (as main or sub target), by learning area



Notes:
1. Year of reference for data collection is 2018.
2. The findings from the CCM analysis in the Netherlands are included here for their research interest. The country did not participate in the CCM main study. The curriculum mapping was conducted on a proposed revision to their curriculum, which was ultimately not approved by the Dutch Parliament and never implemented. OECD (2019[37]), Education 2030 Curriculum Content Mapping: An Analysis of the Netherlands Curriculum Proposal, OECD Publishing, Paris, https://www.oecd.org/content/dam/oecd/en/about/projects/edu/education-2040/6-bilateral-support/E2030_CCM_analysis_NLD_curriculum_proposal.pdf.
Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

StatLink https://stat.link/a9ngz7

Compound literacies/competencies

The E2030 project refers to compound competencies as the integration of knowledge, skills, attitudes and values that are crucial for individual, social and environmental well-being in 2030. These competencies are multi-dimensional, requiring a combination of cognitive, emotional and social capabilities to prepare students for the complex challenges they will face. In the CCM exercise, several key compound competencies were mapped, including computational thinking, financial literacy, entrepreneurship, media literacy, global competency and literacy for sustainable development.

Compound literacies/competencies: Computational thinking

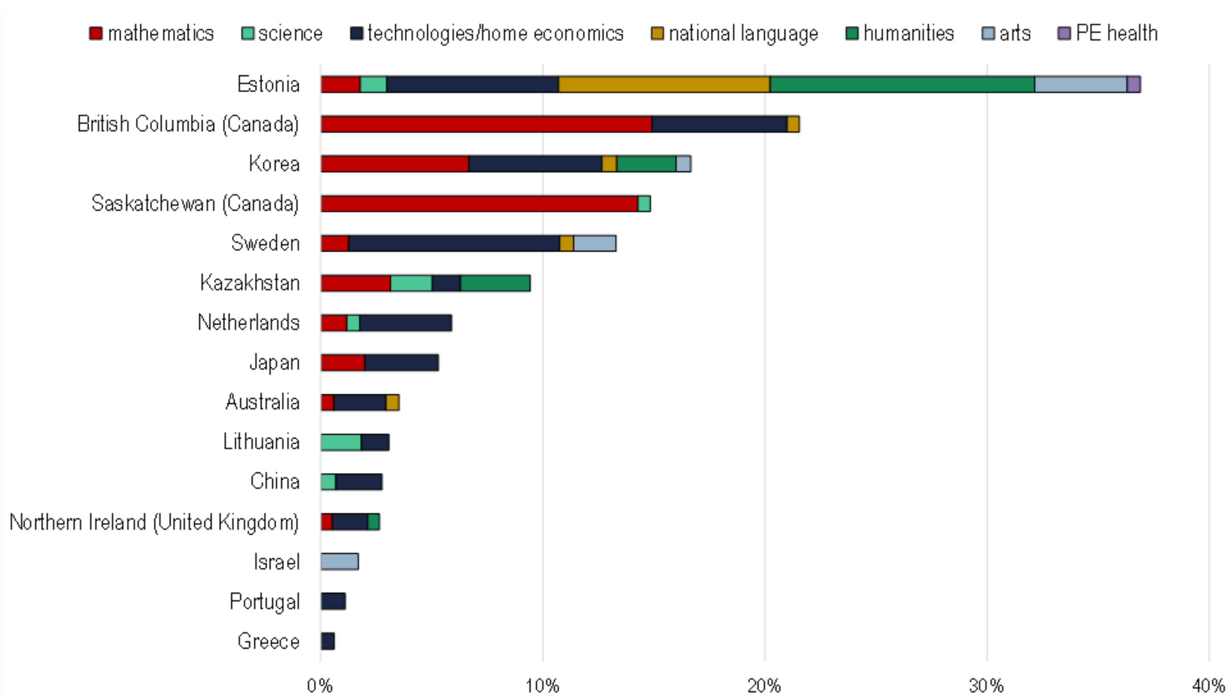
Computational thinking involves formulating problems and developing solutions that can be carried out by computer-based technologies, is increasingly recognised as a key competency in modern education. Programming and coding involve the development of knowledge, understanding and skills regarding the language, patterns, processes and systems needed to instruct/direct devices such as computers and robots (OECD, 2020[20]). As Figure 1.13 illustrates, computational thinking is less widely embedded into the mapped curricula than critical thinking or problem solving, with only Estonia and British Columbia (Canada) integrating it into more than 20% of their curriculum items.

The association with mathematics is that computational thinking involves logical, systematic thinking, pattern recognition, abstraction and algorithm design (through e.g. coding), while at the same time fostering critical thinking and adaptability.

In most countries/jurisdictions, computational thinking is primarily embedded within technologies/home economics and mathematics. For instance, **Saskatchewan (Canada)** embedded 96% of their computational thinking content into mathematics **(representing 14% of content items**). **British Columbia (Canada) (15%), Korea (7%), Kazakhstan (3%), Estonia (2%), Japan (2%), Australia, the Netherlands, Northern Ireland (UK) and Sweden (all at 1%)** all demonstrate a slightly broader distribution, integrating computational thinking across humanities, national language and science, while still embedding items into mathematics.

Figure 1.13. Computational thinking in curricula

Distribution of content items in the mapped curricula targeting computational thinking (as main or sub target), by learning area



Notes:
1. Year of reference for data collection is 2018.
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Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

StatLink https://stat.link/yispr6

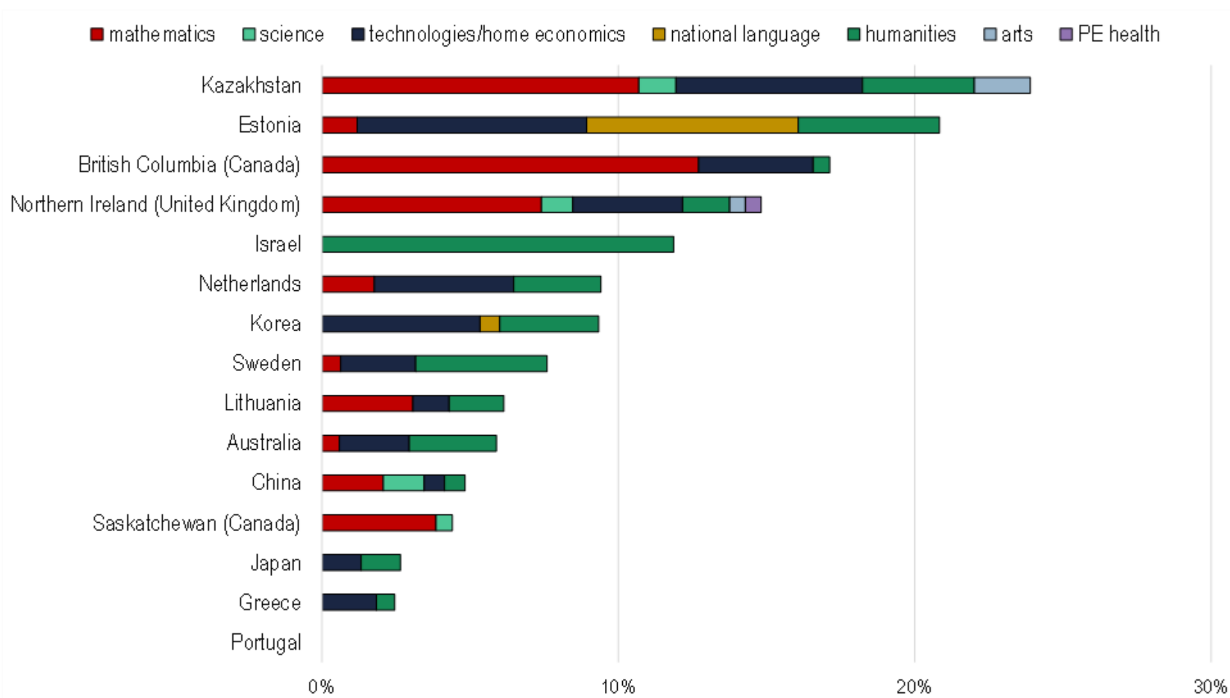
Compound literacies/competencies: Financial literacy

Financial literacy is defined as the ability to apply financial knowledge and skills to real-life situations involving financial issues and decision making. It involves knowledge and understanding of financial concepts and risks, and the skills, motivation and confidence to apply such knowledge and understanding in order to make effective decisions across a range of financial contexts. Financial decisions are part of everyone's lives at all ages, from spending pocket money, to entering the world of work, managing one's own budget, purchasing goods, saving for future expenses, understanding credit and loan payments, and retirement planning. Financial literacy helps individuals to navigate these decisions and strengthens their individual financial well-being as well as that of society as a whole, as it promotes inclusive growth and more resilient financial systems and economies (OECD, 2020[20]).

As Figure 1.14 illustrates, it is embedded to a lesser extent in the mapped curricula compared to other competencies such as numeracy and data literacy.

Figure 1.14. Financial literacy in curricula

Distribution of content items in the mapped curricula targeting financial literacy (as main or sub target), by learning area



Notes:
1. Year of reference for data collection is 2018.
2. The findings from the CCM analysis in the Netherlands are included here for their research interest. The country did not participate in the CCM main study. The curriculum mapping was conducted on a proposed revision to their curriculum, which was ultimately not approved by the Dutch Parliament and never implemented. OECD (2019[37]), Education 2030 Curriculum Content Mapping: An Analysis of the Netherlands Curriculum Proposal, OECD Publishing, Paris, https://www.oecd.org/content/dam/oecd/en/about/projects/edu/education-2040/6-bilateral-support/E2030_CCM_analysis_NLD_curriculum_proposal.pdf.
Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

StatLink https://stat.link/qiofnz

Mathematics and financial literacy are inextricably linked – financial literacy provides students with practical real-world applications for mathematical skills, empowering them to make sound financial decisions throughout their lives. While there is considerable variation in the distribution of financial literacy across learning areas, most countries tend to embed financial literacy within two to three learning areas, predominantly in mathematics, technologies/home economics and humanities. For instance, financial literacy is embedded to a great extent in math curricula in **British Columbia (Canada) (13%), Kazakhstan (11%), and Northern Ireland (United Kingdom) (7%),** and to a lesser extent in **Saskatchewan (Canada) (4%), Lithuania (3%), China, the Netherlands (both at 2%), Australia, Estonia and Sweden (all three at 1%).** The figure also shows that while countries like Kazakhstan and Estonia have integrated financial literacy into more than 20% of their curricula, others such as Portugal (0%), Greece (2%) and Japan (3%) have included it minimally or not at all.

Compound literacies/competencies: Literacy for sustainable development/environmental literacy

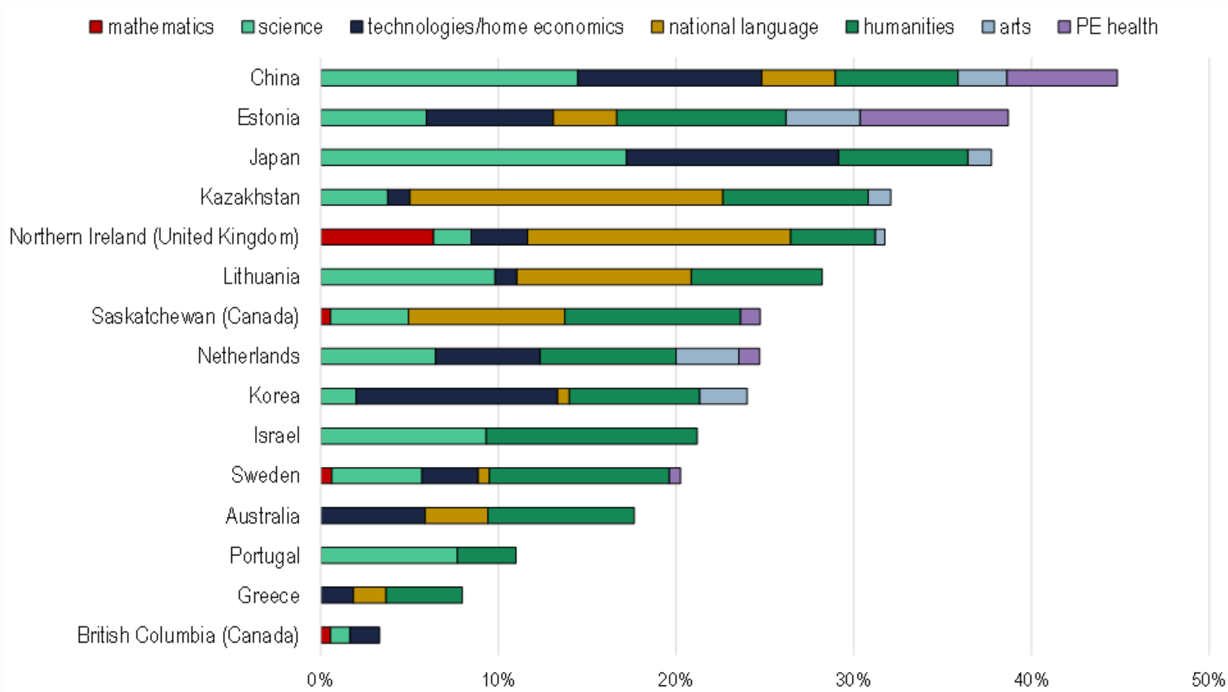
Literacy for sustainable development refers to the knowledge, skills, attitudes and values needed to promote sustainable development. To be literate in sustainable development requires understanding how social, economic and environmental systems interact, recognising and appreciating different perspectives that influence sustainable development and participating in activities that support more sustainable ways of living (OECD, 2020[40]). Many countries/jurisdictions have responded by embedding sustainability content across various subjects, yet the level of integration varies significantly between curricula (Figure 1.15).

In the mathematics context, it empowers students to use mathematical skills to address sustainability challenges with quantitative insights and informed decision making. Connecting sustainability topics with mathematical skills such as data analysis and statistical reasoning is crucial for understanding and evaluating complex environmental issues. Moreover, integrating tools such as modelling for environmental challenges into mathematics education also shows students how math skills are directly applicable to pressing global issues, inspiring a practical commitment to sustainability and problem solving.

Despite its potential to play a critical role in addressing real-world challenges, the integration of literacy for sustainable development in mathematics is rare in the mapped curricula, with **Northern Ireland (United Kingdom) (6%), British Columbia, Saskatchewan (both Canada)** and **Sweden (all at 1%),** representing close to negligeable exceptions. China leads with the highest level of integration, embedding sustainable development across 45% of its curriculum, covering six out of seven learning areas, with a particular focus on humanities, science and technologies/home economics. Estonia (39%) and Japan (38%) follow closely, showing a strong focus on sustainable development in subjects like science, technologies/home economics and humanities.

Figure 1.15. Literacy for sustainable development in curricula

Distribution of content items in the mapped curricula targeting literacy for sustainable development (as main or sub target), by learning area



Notes:
1. Year of reference for data collection is 2018.
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Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

StatLink https://stat.link/nplqbm

Challenges in mathematics curriculum reform

Curriculum reform in mathematics is considered as inherently complex and resource-intensive, probably more than in other learning areas for a number of reasons, such as:

- **The nature of mathematics as a discipline**. The relative stability of content topics in mathematics curriculum compared to other disciplines over the years (Schmidt et al., 2022[41]); the difficulties of modifying curriculum given the hierarchical and progressive nature of the discipline (Schmidt and Prawat, 2006[42]).
- **The disproportionate pressure of high-stakes examinations on mathematics curriculum**. The pressure from what is prioritised on high-stakes examinations (Stacey, 2010[43]).
- **Over-reliance on mathematics textbooks**. The overwhelming reliance on mathematics textbooks, which are often outdated (Fan, 2011[44]).

- **The role of students' attitudes – particularly "mathematics anxiety" – in learning.** The particular role that students' attitudes and beliefs play in learning mathematics (Boaler, 2016[45]).
- **Teacher shortages, teacher education and professional development in mathematics.** The need for targeted investments to align mathematics curriculum with teacher professional learning (Ball and Cohen, 1999[46]).

The nature of mathematics as a discipline

The global evolution of mathematics over centuries has given it a unique position within school curriculum as a discipline that consistently builds upon the foundations laid by earlier civilisations. Mathematical concepts that are featured in today's school curricula were recorded in Babylonian times, developed by ancient Greek mathematicians, and influenced by ancient Chinese and Islamic mathematics. Modern mathematics, which has developed with the advent of the computer, of chaos theory, topology, mathematical physics and category theory, builds on and extends, rather than replaces, what earlier civilisations established. This continuity of advancement highlights the role of mathematics not just as a historical subject but as an ever-progressing field essential for addressing current and future global challenges.

As mathematics evolves alongside technological advancements, as a school discipline, it has been regarded as a "hard to change" learning area. Its hierarchical structure with learning sequences requiring gradual progression from simple to complex notions, or from basic principles to advanced ones, challenges how much change can be made to the curriculum while respecting its disciplinary integrity (Roche, Sullivan and Walker, 2014[47]). The inherent foundational and sequential nature of mathematics explains some of the concerns about the limited adaptability of mathematics curriculum in response to the new societal demands, including the integration of technology (Hoffmann and Egri-Nagy, 2021[48]).

While the discipline remains at the forefront of education, preparing students for increasingly complex and dynamic environments poses a question to curriculum designers and educators about how to develop and maintain a curriculum that is:

- responsive to both local and global contexts, equipping students not only with the knowledge but also the competencies needed for their adult lives in diverse, rapidly changing societies;
- manageable within the constraints of available resources, such as instruction time, teaching materials and teacher capacity.

The disproportionate pressure of high-stakes testing and examinations on mathematics curriculum

Examinations convey messages about what to teach and how to assess learning, and high-stakes testing can serve to either broaden teaching and learning or make them more uniform and narrow. A test or examination is considered high-stakes when its results are used to make important decisions that affect students, teachers, administrators, schools and/or districts (Madaus, 1988[49]). High-stakes tests usually link performance to grade promotion, high school graduation, and, in some cases, decisions about teacher and principal salaries and tenure (Orfield and Wald, 2000[50]). Furthermore, the results of these tests, along with the rankings and categorisations of schools, teachers and students, are often made public, increasing the stakes for all involved (McNeil, 2002[51]).

Raising the standards of learning in school is an important priority in most countries and jurisdictions. Policymakers throughout the world have increasingly introduced national and local standards and mandated testing programmes to assess and report on student performance in core areas like mathematics. In countries/jurisdictions with a heavy emphasis on high-stakes mathematics tests, students' grades and future academic opportunities are closely tied to their performance in these assessments.

Examinations and assessment practices vary across contexts and education systems and, depending on how well they are designed, they might have some positive influences on students, for example, by motivating them to make informed decisions about their future (Perico E Santos, 2023[52]; Bishop, 1998[53]). They can also serve an important purpose in providing accountability information on system level performance (Wößmann, 2003[54]).

That being said, some research suggests that high-stakes assessment may also be counterproductive, particularly in relation to disadvantaged students. Low-achieving students tend to demonstrate lower (rather than improved) performance when being graded (Klapp, 2015[55]). In their review of research on the impact of high-stakes testing on student motivation, Harlen and Deakin Crick conclude that results from such tests have been found to have a “particularly strong and devastating impact” on low-achieving students (2003[56]).

High-stakes testing has also been shown to have an impact on how teachers teach. The relationship between high-stakes testing and classroom practice is, however, a more complex matter. While the primary consequences of high-stakes testing are that curricular content tends to be narrowed and subject area knowledge fragmented into test-related pieces (Minarechová, 2012[57]), there are also studies that indicate that certain types of high-stakes tests may actually lead to curricular content expansion or have other positive consequences, with test design being a critical determining factor of these outcomes (Au, 2007[58]).

Since mathematics (alongside other core subjects, such as national language) is more often assessed in high-stakes exams compared to other subjects, high-stakes examinations can disproportionally influence the “taught curriculum” in mathematics compared to other subjects, especially when given priority over other disciplines such as science, social studies and the arts (King and Zucker, 2008[59]; Klein, 2000[60]; Davis and Martin, 2006[61]).

The risk of curriculum narrowing and fragmentation can be inadvertently detrimental to the inclusion of broader educational goals. (Van den Heuvel-Panhuizen and Becker, 2003[62]). While recognising positive associations between mathematics and numeracy for further education, employment and life outcomes, a holistic education can also support students in developing critical thinking, empathy, and social responsibility, all of which are essential for tackling complex societal issues (OECD, 2024[63]). Education systems that focus on such holistic approaches have observed students’ improved academic performance, emotional well-being and social skills, preparing them for diverse life challenges (Datnow et al., 2022[64]; Mahmoudi et al., 2012[65]).

Over-reliance on mathematics textbooks

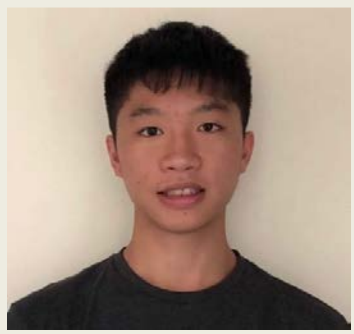
In classrooms all over the world, textbooks are used as a key tool to support the teaching and learning of mathematics (Schmidt et al., 2001[66]). Although there is variation across countries, jurisdictions and even schools and classrooms as to how, and the extent to which, textbooks are used, they are one of the main influencing factors in the teaching of mathematics. Textbooks shape didactical situations together with the teacher, the students and the mathematics (Rezat and Straesser, 2014[67]). Results from the TIMSS 2011 indicated that for more than half of students in secondary school in countries such as Australia, Canada, Finland, Singapore, South Africa and Sweden, the textbook was used as the basis of instruction. In the United States, the textbook was the foundation of mathematical education for 48% of students, and in some countries the percentage was higher than 90% (Mullis et al., 2012[68]).

While textbooks are used frequently as a primary teaching tool, they may not always promote a deep understanding of mathematical concepts or encourage innovative teaching practices. One study highlighted that teachers often use textbooks for structuring lessons and providing exercises, but this can lead to a "shallow teaching" approach where procedural understanding is emphasised over conceptual understanding. This kind of reliance on textbooks can inhibit the adoption of more effective, student-centred teaching methods that encourage critical thinking and problem-solving skills (Ling, Jones and Pepin, 2018[69])

The extent to which textbooks are outdated and misaligned with a country's overall and subject-specific curriculum goals is an area of great concern for policymakers, and a clear limiting factor in connecting policy intentions to practice. This is unfortunately the case in many countries, as will be discussed in more detail in Chapter 2 (Schmidt et al., 2022[41]).

Box 1.1 provides an example of the challenges related to over-reliance on textbooks, which might leave little room for deeper understanding and real-world application of mathematics, highlighting the pressures of examination-focused learning.

Box 1.1. Over-reliance on textbooks: A student's struggle with exam-driven learning



Ho Chi, a 20-year-old university student in Hong Kong (China), reflects on his high school mathematics curriculum and remembers the thick textbooks. These textbooks typically contained around 10 chapters, each spanning approximately 50 pages. Every chapter featured 10-20 examples, followed by sets of questions: fifteen Level 1 questions, five Level 2 questions, and one or two Level 3 questions. Students were expected to spend around two hours completing these question sets.

Ho Chi recalls how mathematics lessons were primarily focused on preparing for the public examination. He felt constant pressure to complete the numerous exercises without having sufficient time to raise questions with the teacher or to follow up on challenges. The pace of the lessons was so fast that his class often skipped to the most complex Level 3 questions, with the teacher solving them for the students, leaving little room for understanding the foundational concepts leading up to that level.

Sometimes students get lost in a question, and then they are lost for all subsequent questions. Ho Chi considers mathematics as a way of thinking, which requires advancing step by step, building on knowledge gained. Without understanding the initial steps before moving on to an advanced level, it is not possible to grasp the advanced level. He often got lost on one question, which made it difficult to keep up with the rest. The constant rush meant that students were always trying to catch up and rarely had the time to explore the material thoroughly.

Moreover, Ho Chi found it challenging to engage with many of the questions in his textbook because the logic behind them was not always clear. This left him questioning the purpose of studying mathematics, and he often struggled to see the relevance of training himself to master different types of questions just for the sake of passing the public exam. For him, mathematics lessons were a painful experience because he lacked a deeper understanding of why the material mattered.

Source: Presentation on 23 March 2022 for a workshop on co-producing the OECD Future of Education and Skills 2030 mathematics curriculum analysis publication.

The role of students' attitudes – particularly "mathematics anxiety" – in learning

Researchers identify mathematics anxiety as a unique form of anxiety related to numbers and mathematical problem solving. Mathematics anxiety is commonly understood as a feeling of tension and stress that interferes with an individual's ability to perform mathematical tasks, both in academic settings and in everyday life (Richardson and Suinn, 1972[70]).

There are significant physiological, cognitive and behavioural correlates of mathematics anxiety, including physiological reactivity to numbers, avoidance, feelings of helplessness and negativity when confronted with mathematical tasks, and negative attitudes towards one's own problem-solving abilities (Ashcraft and Kirk, 2001[71]). Ashcraft and Moore (2009[72]) argue that mathematics anxiety causes an "affective drop," a decline in performance under timed, high-stakes conditions in educational settings, such as examinations. This means that achievement and proficiency scores for maths-anxious individuals are underestimates of their true abilities.

Furthermore, a person's attitude towards mathematics – whether they enjoy or fear it – can strongly influence their decision to pursue further studies or careers requiring mathematical skills (Brown, Brown and Bibby, 2008[73]). Thus, mathematics anxiety plays a critical role in both the development of mathematical competencies and overall well-being, as it can cause considerable stress and frustration (Dowker, Sarkar and Looi, 2016[74]).

Most students want to achieve in mathematics. Younger students are likely to understand that this is something their teachers and parents think is important. Older students know it is important for future jobs and careers. Sources of mathematics anxiety, despite the desire to achieve, may include students receiving negative feedback about their ability; this may be a result of comparing themselves to others, or more formally through poor results.

Developing positive attitudes to understanding and applying mathematical knowledge and skills, including fostering a growth-mindset, are thus critical to combatting mathematical anxiety, as will be examined in more detail in Chapter 3 (Dowker, Sarkar and Looi, 2016[74]; Dweck, 2006[75]). The task of embedding such perspectives in the mathematics curriculum may not be straightforward, as it pertains as much to questions about "taught curriculum" as it does to the design of curriculum and learning materials (Dweck, 2014[76]).

While mathematics curriculum has rarely been the subject of international analysis, the next chapter will describe some of the findings from the international curriculum studies carried out by the OECD Future of Education and Skills 2030 project. They shed light on how mathematics curricula are evolving across countries/jurisdictions, both in relation to mathematical content coverage and in relation to how countries are integrating some of the so-called 21st century competencies in their mathematics curricula. The findings also invite reflection on some gaps identified between current curricula and aspirations for the future.

Teacher shortages, teacher education and professional development in mathematics

For students to be well-equipped with mathematical literacy for the 21st Century, simply updating a curriculum or setting new learning standards is insufficient; quality teachers are essential. However, countries face challenges in attracting, recruiting, retaining and developing their teaching workforce.

Mathematics teacher shortages are widely reported across various educational systems, particularly in high-need schools and rural areas (OECD, 2023[29]). These shortages are a global concern and have a notable impact on educational quality and equity. In Australia, for example, 61% of students attended schools where principals reported that teaching was hindered "a lot" or "to a large extent" due to shortages of teachers, marking a significant increase of more than 40 percentage points from the previous 2018 assessment. This shortage particularly affected schools in disadvantaged and remote areas. In remote areas in Australia, for example, 95% of principals reported difficulties due to staffing shortages in 2022 (Thomson, De Bortoli and Underwood, 2024[77]; OECD, 2023[29]). Research suggests that shortages in mathematics are often driven by a combination of factors, including the limited supply of qualified teachers, teacher attrition and competition with other higher-paying professions (Ingersoll, 2001[78]; Sutcher, Darling-Hammond and Carver-Thomas, 2016[79]).

In order for curriculum reform, particularly in subjects like mathematics, to be effective, there must be a strong alignment between the curriculum and the professional learning opportunities available (Cohen and Ball, 1999[80]). Teachers must have the knowledge, skills and professional support necessary to effectively implement curriculum changes in the classroom. Ongoing professional development is crucial to address changing curricula, new educational technologies and evolving pedagogical strategies. However, professional development in mathematics is often criticised as being "fragmented, underfunded, or misaligned with teachers' needs" (Desimone, 2009[81]; Garet et al., 2001[82]).

The quality of teacher preparation programmes for mathematics teachers is another concern. Research has pointed to inconsistencies in the rigor and content of teacher education programmes, e.g. not providing sufficient depth in mathematical content knowledge or pedagogical strategies specifically tailored to teaching mathematics (Loewenberg Ball, Thames and Phelps, 2008[83]; Monk, 1994[84]).

Investments should be made not just in developing new curricula, but also in designing teacher education programmes, professional development programmes and support programmes that are closely aligned with the content and pedagogical shifts required by the new curriculum.

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Notes

[1] CCM participating countries/jurisdictions: OECD Members: Australia, British Columbia (Canada), Saskatchewan (Canada), Estonia, Greece, Israel, Japan, Korea, Lithuania, Northern Ireland, Portugal, Sweden. Partners: China, Kazakhstan.

[2] MCDA participating countries/jurisdictions: OECD Members: Australia, Estonia, Greece, Hungary, Israel, Japan, Korea, Latvia, Lithuania, the Netherlands, New Zealand, Norway, Portugal, Sweden, the United States. Partners: Argentina, Chinese Taipei (China), Hong Kong (China), Kazakhstan.

[3] PQC participating countries/jurisdictions: OECD Members: Australia, British Columbia (Canada), Ontario (Canada), Quebec (Canada), Chile, Costa Rica, Czechia, Denmark, Estonia, Finland, Hungary, Ireland, Japan, Korea, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Sweden, Türkiye, Northern Ireland (United Kingdom), Scotland (United Kingdom), Wales (United Kingdom), the United States. Partners: Argentina, Brazil, China (People’s Republic of), Hong Kong (China), India, Kazakhstan, Singapore, South Africa, Vietnam.

[4] ICT refers to all devices, networking components, applications and systems that allow people and organisations to interact in the digital world (OECD, 2020[20]).

2 Curriculum evolution from the past, and stock-taking towards the future

This chapter examines the evolution of mathematics curricula over the past 25 years, highlighting global trends on content coverage patterns in mathematics curricula, including an examination of countries' different design choices for organising and introducing curriculum topics across grade levels. It analyses the extent to which 21st-century competencies – such as problem solving, critical thinking, and data literacy – are integrated into mathematics curricula across countries. The chapter concludes by highlighting some gaps between current mathematics curricula and future aspirations to meet modern educational demands, most notably a significant discrepancy across education systems between curriculum standards (intended curriculum) and textbooks (implemented curriculum) with implications for students learning (achieved curriculum).

The increasing availability of international data on student performance has provided the opportunity for researchers to examine the influence of mathematics curriculum across countries on students' achievement (Schmidt et al., 2001[1]). Further analysis of mathematics curricula is needed to better understand global educational trends and outcomes.

This chapter describes the key findings from the international mathematics curriculum studies carried out by the OECD Future of Education and Skills 2030 project. It focuses on the following aspects of curriculum development for which systematic comparative data are available: i) how mathematics curricula are evolving across countries, particularly on content coverage; and ii) how countries are integrating some of the so-called 21st-century competencies in their mathematics curricula. The findings invite a reflection on some gaps identified between current curricula and aspirations for the future, which require further investigation.

A 25-year retrospective: Content structure and organisation in mathematics curricula

Content coverage in mathematics curricula

Comparison of curricula worldwide, and the subsequent association of curriculum with student achievement, has only become possible in the last 30 years with the increased participation of nations and jurisdictions in international assessments such as the Trends in International Mathematics and Statistics Study (TIMSS) and the Programme for International Student Assessment (PISA). As part of TIMSS in 1995, Schmidt et al. (2001[1]) studied the structure of the mathematics curricula across the participating countries. TIMSS was the earliest opportunity for the comparison of student achievement, through large-scale testing of students across over 50 countries. The study demonstrated a clear relationship between the structure of mathematics and science curricula and achievement of students, as measured by TIMSS assessments, and showed significant differences among the national curricula analysed by structure and content.

Twenty-five years later, participating countries in the OECD Future of Education and Skills 2030 (E2030) project agreed to look deeper into how mathematics curricula have changed and how they still need to evolve to prepare students to meet the demands of the 21st Century, such as societal changes including technological advances. This section outlines the key findings from the E2030 Mathematics Curriculum Document Analysis (MCDA) study (Schmidt et al., 2022[2]) with respect to curriculum content.[1]

Recognising the evolving transformations in society, a future-oriented mathematics curricula needs to continue to include an education about formal mathematics (formal ideas, concepts, algorithms and procedures that shape the discipline), but also include opportunities for children to develop the type of subject-specific reasoning that equips them to develop their understanding and application of mathematics (mathematics, statistics, geometric and algorithmic reasoning) in real life. This is reflected in the MCDA Framework, which was used for cross-country comparison of curricula. The framework includes the content in Table 2.1, organised around the key focus areas covered in mathematics curriculum in the first eight years of education: **quantity, space and shape, change and relationships, statistics, probability and data**.

Table 2.1. Mathematics Curriculum Document Analysis Content Framework

Quantity	Whole number • Meaning (place value, ordering, comparison) • Operations (meaning and computations) • Properties of operations (order of operation, relationship among operations) Fractions & decimals • Common fractions • Decimal fractions & percentages • Properties and relationships of common & decimal fractions Number sense & estimation • Measurement units, estimation & errors • Rounding & significant figures • Estimating computations • Exponents & orders of magnitude Number systems • Integers, negative numbers & their properties • Rational numbers & their properties • Real numbers, their subsets & properties • Complex numbers Other number concepts • Simple number patterns & sequences • Binary arithmetic &/or other number bases • Roots, radicals & complex numbers • Combinatorics (permutations & combinations) • Computational thinking: Algorithmic mathematics & computer simulations • Computer coding (including both formal and informal (pseudocode) syntax)
Space and shape	Position, visualisation & shape • 2-D Geometry: Basics (points, lines, segments, rays, angles) • 2-D Geometry: Polygons & circles (formulas, properties, perimeter, area) • 3-D Geometry (shapes, volume, surfaces, cross-sections) • Co-ordinate geometry (analytical geometry) • Trigonometry of right-angled triangles, including the Pythagorean Theorem • Vectors & matrices • Geometric approximation for irregular shapes Symmetry, congruence & similarity • Symmetry • Transformations (including geometric patterns) • Congruence & similarity
Change and relationships	Algebra foundations • Rates & ratios • Proportionality Beginning algebra • Algebraic sequences and patterns • Expressions • Simple linear equations • Slope & intercept Algebra • Linear equations and inequalities • Trigonometric equations and identities • Other equations and inequalities (quadratics, polynomials, including factorization and expansion) • Linear functions • Exponential functions • Other non-linear functions Change • Infinite processes (e.g. sequence, series, limits and convergence)

	• Calculus and analysis • Linear, non-linear, and exponential for modelling growth and change
Statistics, probability and data	Descriptive statistics • Mean, mode, median, variance, etc. • Displays of distributions Probability distributions • Definition of discrete probability and related theorems • Conditional probability and independent events • Bayes Theorem • Discrete and continuous random variables and their distributions Statistical inference • Populations and their parameters • Sampling from the population/random sampling • Estimation of parameters (e.g. mean, variance) • Sampling distributions (standard errors, bias) • Confidence intervals • Hypothesis testing • Definition of correlation coefficient • Relationship among categorical variables (contingency tables) • Relationship involving continuous variables (regression) • Relationship involving categorical and continuous variables (ANOVA) • History of Mathematics as a Human Activity
Quantitative reasoning	• Mathematics • Algorithmic • Geometric • Statistical
21st-century skills/competencies relevant to mathematics	• Critical thinking • Creativity • Information use • Systems thinking • Communication • Reflection • Resistance/resilience

Source: Schmidt, W. et al. (2022), "When practice meets policy in mathematics education: A 19 country/jurisdiction case study", OECD Education Working Papers, No. 268, OECD Publishing, Paris, https://doi.org/10.1787/07d0eb7d-en.

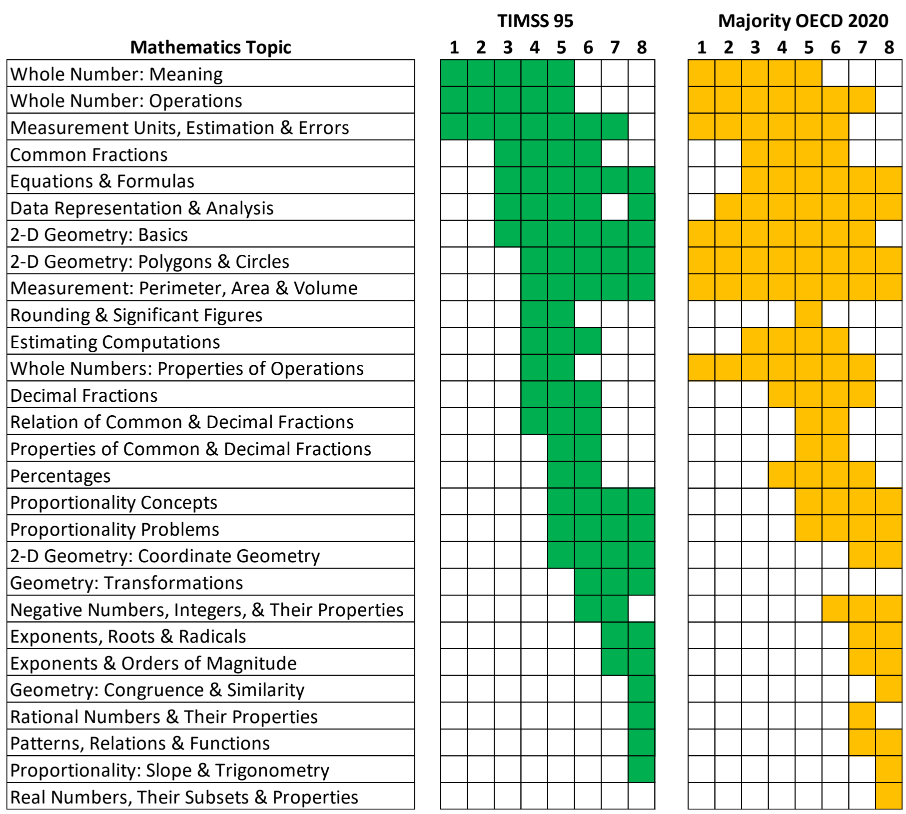
Figure 2.1 provides a visual comparison of content coverage across the 19 participating countries/jurisdictions between 1995 (content included in the curricula of top-performing countries in TIMSS-95) and 2020 (MCDA study).

The curriculum content coverage comparison shows which topics formally appear in the curriculum standards of the MCDA participating countries/jurisdictions, as well as the grade year in which they are included. Overall, the study reveals:

- a relative stability in mathematics curriculum coverage patterns over this 25-year period;
- a noticeable increase in topics related to statistics;
- the predominance of mathematical literacy in curriculum standards (discussed later in this chapter), particularly quantitative reasoning, real-world applications, and 21st-century competencies (albeit at varying degrees of emphasis);
- the rare inclusion of algorithmic reasoning (also part of mathematical literacy) and non-linear statistical models.

Other important findings emerged – related to the accompanying analysis of textbooks – which will be discussed later in this chapter. In the sequence, we discuss the rise of mathematical literacy and of statistics. These changes are significant and understandable given many changes to the societal, political and academic landscape that influence curricula development. The impetus for change in modern curricula comes from many sources, as seen in Chapter 1, including globalisation, access to and use of digital and other technologies, emerging opportunities and demands of workplaces and wider citizenship, concerns over social inequity and learnings from research in mathematics and statistics education. Participatory citizenship also demands greater ability to apply academic knowledge of mathematics and statistics to situations, from managing spending and borrowing, to interpreting advertising data, to designing houses for functionality, to planning and booking travel, to comparing quotations for services, to evaluating data about educational and health facilities.

Figure 2.1. Topic coverage over 25 years (top-performing countries in TIMSS-95 vs. national standards of MCDA participating countries/jurisdictions in 2020)



Note. Green cells indicate coverage defined by TIMSS A+; orange cells indicate coverage defined by at least a simple majority of the 19 countries/jurisdictions.
Source: Schmidt, W. et al. (2022[2]), "When practice meets policy in mathematics education: A 19 country/jurisdiction case study", OECD Education Working Papers, No. 268, OECD Publishing, Paris, https://doi.org/10.1787/07d0eb7d-en.

The rise of mathematical literacy (numeracy)

The concept of numeracy, which first appeared in the British Crowther Report in 1959 (Kus, 2018[3]) has grown significantly in importance over time. This increase has been driven by the recognition that applying mathematics is not only a key predictor of individual success, but also an essential driver of national economic performance. As numeracy became more politically and socially significant, it began to influence mathematics curricula worldwide. This evolution in the role of numeracy has led to its deeper integration into curricula, reflecting societal demands for a more future-ready workforce.

On an individual level, it is well established that knowledge of mathematics and statistics is positively associated with personal life outcomes. High achievement in numeracy at school exit predicts employability, income and socio-economic status, as well as health and well-being outcomes in adulthood (Bruine de Bruin and Slovic, 2021[4]; Bregant, 2016[5]). Numeracy and higher income are also positively associated with life satisfaction, in general (Bjälkebring and Peters, 2021[6]). At a societal level, numeracy contributes significantly to national economic growth and stability. Higher levels of numeracy contribute to more efficient labour markets, as workers are better equipped to handle tasks requiring calculation, measurement as well as data analysis, technological proficiency, and critical thinking. In turn, this enhances productivity across various industries, from finance to healthcare and manufacturing. Furthermore, a numerate workforce is essential for addressing complex societal challenges, such as climate change, public health and economic inequality, all of which require data-driven decision-making (OECD, 2019[7]).

The growing importance of numeracy has reshaped educational approaches, with a focus on equipping students with skills applicable to real-world contexts. The OECD Learning Compass for Mathematics 2030 (OECD, 2023[8]) defines numeracy as the ability to interpret, assess and communicate mathematical information and ideas in a variety of contexts. In line with this, numerate students are expected to apply their mathematical understanding not just in school, but in everyday life. Often referred to as "mathematical literacy" in the PISA assessments, numeracy requires students to engage with mathematics and statistics in realistic situations, many of which may extend beyond their immediate experiences. These contexts provide opportunities for students to broaden their perspectives, but they also increase the cognitive demand by requiring them to draw on prior knowledge and apply multiple strategies for problem solving. In this way, numeracy education, with its emphasis on contextual problem solving, represents a greater challenge than traditional mathematics instruction, which has, in the past, often developed concepts and skills in isolation from application.

In the past, mathematics education often focused heavily on rote memorisation and the mastery of standard procedures, such as long division or algebraic manipulation. However, the shift towards numeracy in recent years reflects a broader aim: to equip students with the ability to apply their mathematical understanding to dynamic and often unfamiliar situations. This evolution in pedagogy has brought about the inclusion of more complex, open-ended tasks and problem-solving activities in curricula, encouraging students to think critically and flexibly.

However, the integration of numeracy into curricula presents its own set of challenges. Educators now need to balance the development of traditional mathematical skills, such as manual calculation or proof-based reasoning, with newer competencies that emphasise real-world application and digital fluency. In today's classrooms, content that once focused on repetitive manual calculations is being reconsidered. With the increasing accessibility and importance of digital tools, students are learning how to use technology – such as spreadsheets, graphing software, statistical modelling programs and generative AI – to analyse data, simulate real-world scenarios and make informed decisions. This shift has sparked debates about the relevance of traditional topics like written algorithmic or advanced algebra, which some argue can be outsourced to technology. Instead, curricula are gradually prioritising tasks that allow students to engage with mathematical reasoning and problem solving through the lens of digital tools, enabling them to work more efficiently and creatively in data-driven environments.

The rising relevance of statistics education

While the discipline of mathematics has a long history dating back many thousands of years with contributions from many civilisations and cultures, the discipline of statistics is relatively new. Although data collection, such as census-taking, dates back to the Roman Empire, the development of ways to makes sense of such data began in the 18th Century and emerged strongly as a modern approach in the late 19th Century. Statistics emerged as a discipline in the 1960s and 1970s, with increasing formalisation of statistics education in curriculum in the 1980s, reflecting the importance of encouraging students to engage more deeply with practical applications of statistics, rather than merely learning abstract concepts. This focus on the applicability of statistics to various fields of knowledge through statistical reasoning and real-world data analysis underscores the growing importance of statistics in modern curricula.

This has provided strong support for inclusion in the curriculum of two aspects of statistics: statistical literacy and probability (Shaughnessy, 2019[9]). Literacy involves reasoning about the data-based reports of others, by applying critical thinking about the methods used (sampling, measures, treatment of confounding variables, etc.) and the efficacy and significance of the findings. Variability is at the heart of statistical enquiry, and all results must be treated with a degree of uncertainty. Probability began as a field of mathematics. The models applied in statistics, such as types of distributions, are founded on probability. However, in the real world, the probability of most events, such as a given weather condition occurring, cannot be established theoretically. The statistical enquiry cycle is enacted with large samples by experiment to predict probabilities. The relationship between theoretical and experimental probability in school curricula is not uniformly agreed, even among statistics educators. Student misconceptions about probability abound in the research literature on this topic, leading some commentators to advocate that probability should be treated informally in primary school, using a more experimental than theoretical approach.

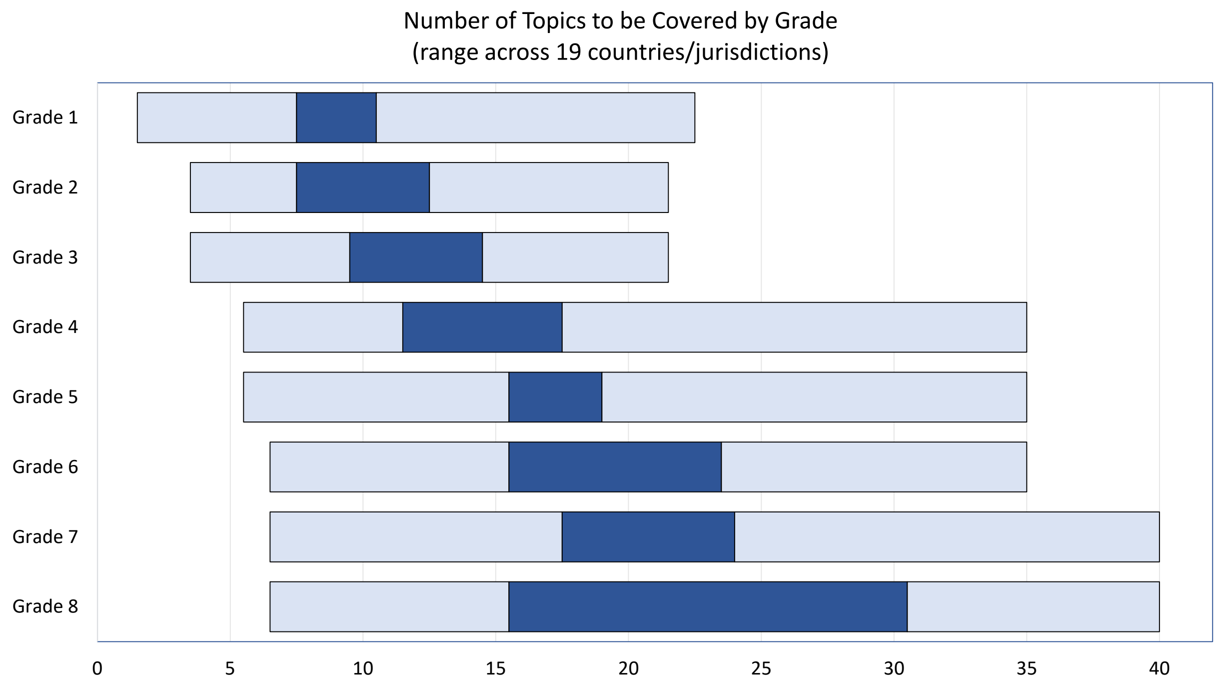
Burrill and Pfannkuch (2024[10]) presented four areas of development for statistics curriculum going forward, as a summary of 50 papers by experts in the field. “Data Science” represents the interface between statistical data analysis and programming to create explanatory models. “Social Statistics” positions statistical investigation and literacy as fundamental to student exploration of issues that are important to society, and advocates for students to become agents for informed societal change. “Contexts for learning” explores the potential for technological data display tools to allow new ways for students to explore real contexts that are of relevance to them. “Visibilising Statistical Concepts” is about the development of new ways of supporting students to develop concepts, such as using technology to illustrate variability in samples.

Despite strong arguments for statistical education at all levels, there are considerable differences in adoption across countries and jurisdictions (Burrill and Biehler, 2011[11]) In the competition for curriculum space, important statistical ideas are often lost, particularly at elementary/primary levels. Statistics can be frequently relegated to the category of non-essential, in contrast to mathematical topics, usually number-related, that are designated as “basic”, despite the importance of statistical literacy to citizenship and workplaces.

Number and distribution of topics in mathematics curricula (Grades 1-8)

Education systems participating in the MCDA study were asked to identify the number of content topics from the framework included in their curriculum standards, as well as the grade levels in which they are expected to be taught. The results underline the various curriculum choices countries make about coverage of these topics, the order in which they are introduced (by grade) and how long they remain in the curriculum. Distinct design choices emerge from a cross-country comparison regarding the focus of curriculum (breadth, depth, balance) and its organisation.

Figure 2.2. Number of topics in mathematics curricula



Notes: Light-coloured bars: The range for the number of topics participating countries/jurisdictions intended to cover.
Dark-coloured bars: The inter-quartile range (25th to 75th percentile) within the broader range representing the number of topics intended to be covered.
Source: Schmidt, W. et al. (2022[2]), "When practice meets policy in mathematics education: A 19 country/jurisdiction case study", OECD Education Working Papers, No. 268, OECD Publishing, Paris, https://doi.org/10.1787/07d0eb7d-en.

Figure 2.2 illustrates the number of topics from the TIMSS 1995 benchmarking list across all 19 countries/jurisdictions intended to be covered at each grade according to their 2020 curriculum standards. A notable finding is the remarkable expansion in the range of topics introduced in the curriculum, particularly from Grade 4, across participating countries/jurisdictions: as students progress through grades, the variability in the number of topics covered tends to increase.

The range remains wide in the following grades, further expanding in Grades 7 and 8. Grade 8 shows the greatest number of topics intended to be covered across curricula. This seems to reflect the cumulative organisation of the mathematics topics in curricula (with many early topics remaining present in late grades but at a more advanced levels), as seen in Figure 2.1. The wide range of topics planned for Grades 7 and 8 may also signal the potential pressure to prepare students for high school more broadly, and an intention to gear the curriculum towards higher-stakes examinations later. A cross-country analysis provides further insight into these trends (Table 2.2).

Table 2.2 provides an insightful comparison of the range of topics covered across different countries/jurisdictions, categorised into three groups: those below, within, and above the middle inter-quartile range. A few key trends and patterns emerge from these data.

When looking across grade levels, most countries, including **Australia, Estonia, Korea, Lithuania and the United States**, consistently fall within the middle inter-quartile range across grades. This reflects a balanced approach to curriculum coverage, where the number of topics remains relatively consistent and aligned with the global trends observed in this set of countries/jurisdictions.

Japan, **Argentina** and **Hungary** often fall below the middle inter-quartile range, especially in the earlier grades (Grades 1-5). This suggests a more focused or streamlined approach in their mathematics curriculum, where fewer topics are covered, favouring in-depth coverage rather than breadth of coverage, possibly focusing on foundational concepts.

Table 2.2. Cross-country analysis of number of topics included in mathematics curriculum standards

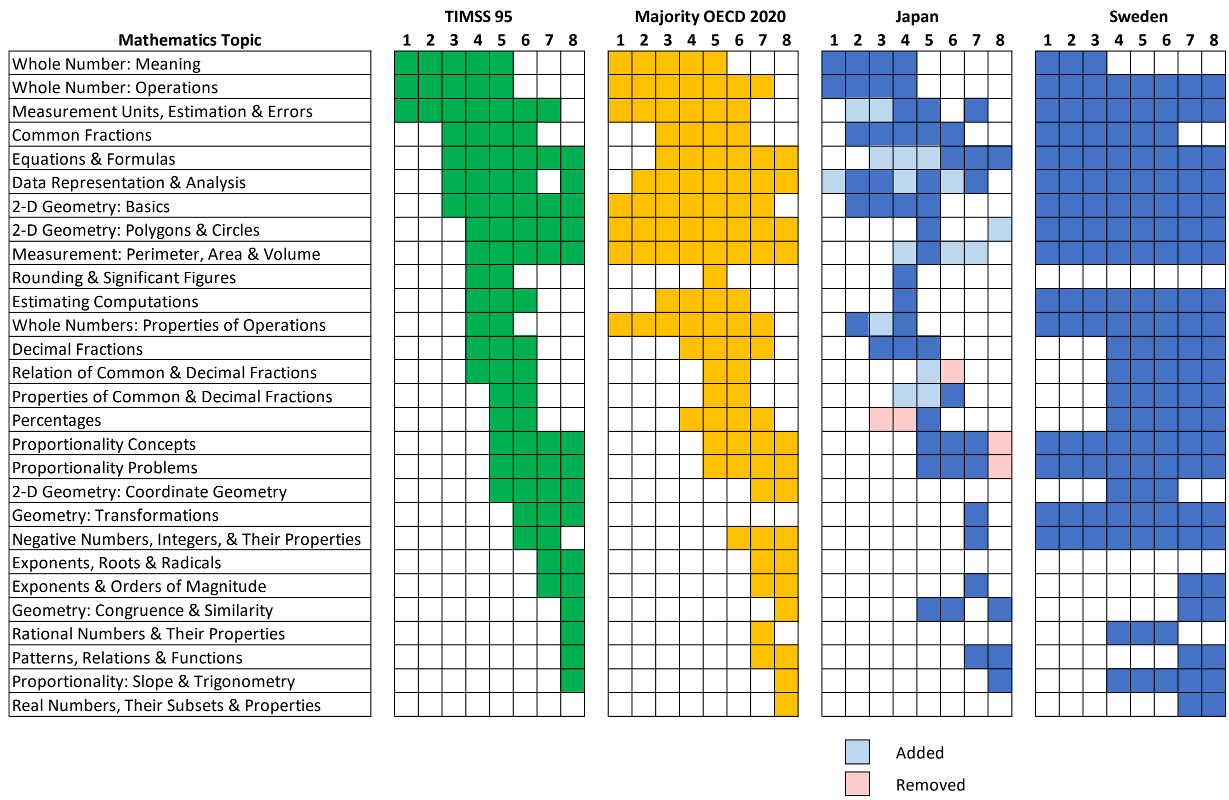
GRADE	Below the middle inter-quartile	Within the middle inter-quartile	Above the middle inter-quartile
Grade 1	Japan, Argentina, Hungary, Chinese Taipei (China)	Australia*, Estonia, Greece, Israel, Korea, Lithuania, Netherlands, New Zealand, Portugal (right in the middle), United States, Hong Kong (China), Kazakhstan	Latvia, Norway*, Sweden
Grade 2	Hungary, Japan, Argentina	Australia*, Estonia, Greece, Korea, Latvia, Lithuania, Netherlands, New Zealand, Portugal, United States, Chinese Taipei (China), Hong Kong (China), Kazakhstan	Israel, Norway*, Sweden
Grade 3	Australia*, Lithuania, Japan, Argentina	Estonia, Greece, Hungary, Israel, Korea, Netherlands, New Zealand, Norway*, United States, Chinese Taipei (China), Hong Kong (China), Kazakhstan	Latvia, Portugal, Sweden
Grade 4	Korea, Lithuania, Japan, Argentina, Hong Kong (China)	Australia*, Greece, Hungary, Israel, Netherlands, New Zealand, Portugal, United States, Chinese Taipei (China), Kazakhstan	Estonia, Latvia, Norway*, Sweden
Grade 5	Australia*, Japan, Netherlands, Argentina, Hong Kong (China)	Greece, Israel, Korea, Lithuania, New Zealand, Portugal, United States, Chinese Taipei (China), Kazakhstan	Estonia, Hungary, Latvia, Norway*, Sweden
Grade 6	Australia*, Korea, Japan, Argentina, Hong Kong (China)	Estonia, Greece, Hungary, Israel, Lithuania, Netherlands, Portugal, United States, Chinese Taipei (China), Kazakhstan	Latvia, New Zealand, Norway*, Sweden
Grade 7	Australia*, Korea, Japan, Argentina, Hong Kong (China), Kazakhstan	Estonia, Greece, Hungary, Israel, Latvia, Lithuania, New Zealand, Portugal, United States, Chinese Taipei (China)	Netherlands, Norway*, Sweden
Grade 8	Greece, Japan, Argentina, Chinese Taipei (China), Hong Kong (China), Kazakhstan	Australia*, Estonia, Israel, Korea, Latvia, Lithuania, New Zealand, Norway*, United States	Hungary, Netherlands, Portugal, Sweden

Note: *The data for these countries reflect their curriculum standards at the time of the MCDA study. Revisions to their curriculum that were awaiting approval at the time of the study are not reflected here.
Source: Adapted from Schmidt, W. et al. (2022), "When practice meets policy in mathematics education: A 19 country/jurisdiction case study", OECD Education Working Papers, No. 268, OECD Publishing, Paris, https://doi.org/10.1787/07d0eb7d-en.

Countries like **Latvia**, **Norway**, and **Sweden** appear frequently above the middle inter-quartile across multiple grades. These countries tend to cover a much greater number of topics compared to the majority of other participants, potentially reflecting a broader curriculum in earlier education. This wide range of topics seems to have contributed to some of the shifts observed in the analysis of curriculum standards in 2020 compared to 1995. A number of topics that in the past were introduced much later in the curriculum started being included in earlier grades, such 2-D geometry, measurement, whole numbers and percentages.

Figure 2.3 allows for an appreciation of the evolution of mathematics curriculum in **Japan** and **Sweden** as well as their curriculum design choices, which diverge from the global trends observed.

Figure 2.3. Topic coverage over 25 years: Curriculum evolution in Japan and Sweden



Notes: Green cells indicate coverage defined by TIMSS A+; orange cells indicate coverage defined by at least a simple majority of the 19 countries/jurisdictions; blue cells indicate specific country/jurisdiction coverage. At the request of the Japanese Ministry of Education, changes were made to the data collected at the original work session. The modifications are identified by a change in the colour of each cell for which a change was requested.
Source: Schmidt, W. et al. (2022[2]), "When practice meets policy in mathematics education: A 19 country/jurisdiction case study", OECD Education Working Papers, No. 268, OECD Publishing, Paris, https://doi.org/10.1787/07d0eb7d-en.

Japan and **Sweden** provide a clear contrast in the number of topics covered in their curriculum standards: Japan introduces few topics in early grades and maintains that same approach with a very focused curriculum in Grades 7 and 8. Sweden, on the other hand, clearly shows an extensive range of topics to be covered throughout the curriculum. This illustrates the variations in national priorities when it comes to mathematics education, particularly around the introduction of advanced topics in middle school, including different emphasis placed on depth versus breadth in topic coverage.

Mandatory versus optional content

The extent to which topics included in curriculum documents are mandatory varies among education systems. Just as countries differ in the coverage of content topics in their curriculum, they may also differ on what is regarded as core/essential learning vs. optional, and on whether such a distinction is needed. These decisions depend largely on their goals, but also on their national and local traditions.

For example, some countries may include a wide range of topics in their curriculum while indicating that not all topics are mandatory. Such non-mandatory topics may be categorised as **optional** or

recommended. They may be added with the intention of giving schools and teachers the flexibility to decide whether to include them in their teaching. This allows for a more **adaptive** curriculum that can cater to regional needs, school priorities, or even student interests, but it may also create long curriculum documents. It is important that these decisions take into account the local traditions and the likely reactions of teachers to avoid the risk – real or perceived – of content overload (OECD, 2020[12]).

To this end, it makes sense that some education systems explicitly identify their "core learning" or "essential knowledge" in their curriculum documents – e.g. "common core" in **Brazil, Costa Rica** and **the United States;** "core components" in **the Netherlands;** "essential learning" in **Portugal** – as they signal to teachers what every child should know by the end of a given learning cycle (OECD, n.d.[13]).

In mathematics curricula, the inclusion of optional content can be formalised in different ways:

- Advanced mathematics options: In countries like **Singapore** and **Australia**, while there is a core set of topics that every student must cover, there are also optional advanced topics, typically at later grades in primary education and in secondary education. For example, students pursuing higher-level mathematics might encounter additional topics such as calculus, complex numbers or discrete mathematics, which are not required for all students but are offered as elective or specialised topics (Ministry of Education Singapore, 2023[14]; OECD, n.d.[13]).
- Elective pathways: Countries like **Finland** and **the United States** offer differentiated pathways in mathematics. Students can choose between standard, advanced or honours-level math courses, each with varying content depth. The more advanced pathways include topics that are optional for students who are not on the specialised or advanced math track (OECD, n.d.[13]; National Agency of Education., 2020[15]).
- Enrichment programmes: In some countries, such as **Australia**, **the United Kingdom,** and **the United States,** there are enrichment opportunities that allow high-achieving students to explore additional mathematical topics that go beyond the standard curriculum. These topics, while not mandatory, are designed to deepen mathematical understanding and may be part of extracurricular programmes or offered to students who excel in mathematics (Massachusetts Institute of Technology (MIT), n.d.[16]; Australian Maths Trust, n.d.[17]; Piggott, 011[18]; Millennium Mathematics Project, University of Cambridge, 2023[19]).

This balance between mandatory and optional topics allows countries to maintain **rigorous national standards** while providing schools with the flexibility to adapt the curriculum to meet local and student-specific needs.

Integration of 21st-century competencies into mathematics curricula

While the previous section takes stock of mathematics topics included in curriculum standards, this section describes the results of the E2030 Curriculum Content Mapping (CCM) exercise, which provides a supplementary picture of countries'/jurisdictions' mathematics curricula. In particular, it shows **how countries embed various 21st-century competencies into their lower secondary mathematics written curricula**. This question has been partially examined in Chapter 1, which presented the findings for how various competencies are being incorporated across learning areas, including mathematics. The findings in this section are specific to the mathematics curricula of the participating countries/jurisdictions[2].When mapping their mathematics curriculum, participating education systems in the CCM exercise used a content framework that includes topics typically present in mathematics lower secondary curricula (Table 2.3, first column). Curriculum experts then rated to what extent each of the various 21st-century competencies indicated (Figure 2.5, columns 1-28) are intended to be targeted in the teaching of these mathematics topics. They used a 4-point colour-coding scale ranging from "not present" (lightest colour) to "main target" in the curriculum (darkest colour). The results (most frequent rating across

14 countries/jurisdictions) are shown in the "heat map" below (Table 2.3 and Table 2.4) with darker blue cells indicating competencies that are more explicitly targeted across curriculum content items.

Table 2.3. Mapping Grid Mathematics (2018), lower secondary education, Part 1

CONTENT / COMPETENCIES	Key Concepts		Core Foundations - Cognitive & meta-cognitive							Health	Socio-emotional skills					
	Student Agency[1]	Co-agency[2]	Literacy	Numeracy	Data literacy	ICT literacy/Digital literacy	Critical thinking	Problem solving	Learning to learn	Physical/health literacy	Co-operation/collaboration	Self-regulation/self-control	Persistence/resilience	Empathy	Respect	Trust
Strands/branches/contents/concepts/ activities	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Number																
The formal meaning of number using a number line	2	1	3	4	1	2	3	4	2	1	2	1	2	1	1	1
Real numbers (rational and irrational numbers)	2	1	3	4	1	2	2	4	2	1	2	2	2	1	1	1
Complex numbers	1	1	1	4	1	1	3	4	1	1	1	1	1	1	1	1
Computational strategies to solve problems involving whole and real numbers	2	1	3	4	2	3	3	4	2	1	2	2	2	1	1	1
Computational strategies to solve problems involving common and decimal fractions	2	1	3	4	1	3	3	4	2	1	2	2	2	1	1	1
Proportion, percentage and ratio	2	2	3	4	1	3	3	3	1	1	2	2	2	1	1	1
Modelling and operations on vectors	1	3	2	4	3	1	4	4	2	1	2	2	1	1	1	1
Measurement																
Units of measurement and scale	2	1	3	4	1	2	3	3	1	1	2	1	2	1	1	1
Data and probability																
Random sampling	2	2	1	4	4	4	2	4	1	1	2	1	2	1	2	1
Organising, displaying, and interpreting data	2	1	4	4	4	4	3	4	2	1	2	1	2	1	1	1
Chance processes	2	2	2	4	4	3	3	4	1	1	2	1	2	1	1	1

Probability models	2	1	3	4	4	1	4	4	2	1	2	1	2	1	2	1
Center and variability in different data sets	2	1	3	4	4	3	3	3	1	1	2	1	2	1	1	1
Linear models	1	1	3	4	1	3	4	4	1	1	2	1	1	1	1	1
Bivariate associations (and correlations)	3	3	3	4	4	4	3	1	1	1	2	1	2	1	2	2
Expressions, equations and algebra																
The use of patterns to represent relationships	2	1	2	4	2	2	3	4	2	1	2	2	2	1	1	1
Algebraic expressions	2	2	1	4	1	2	3	4	2	1	2	2	2	1	1	1
Radicals	2	1	3	4	2	4	2	4	2	1	2	2	2	1	1	1
Polynomials	2	2	3	4	2	2	2	4	1	1	2	2	2	1	1	1
Linear equations and inequalities	2	1	3	4	2	2	3	4	2	1	2	2	1	1	1	1
Functions																
The use of functions to model relationships	2	1	3	4	1	3	2	3	2	1	2	1	2	1	1	1
Quadratic functions	2	1	1	4	1	3	3	4	1	1	2	2	2	1	1	1
Exponential functions	1	1	1	1	1	3	3	4	1	1	1	1	1	1	1	1
Trigonometric functions	1	1	1	4	1	1	3	4	1	1	2	2	1	1	1	1
Geometry																
Spatial relationships: 2D and 3D geometric theorems and properties	2	2	2	4	1	1	4	4	1	1	2	1	2	1	1	1
2D and 3D geometric rotation and transformations, including similarity transformations	2	2	2	4	1	4	4	4	2	1	2	1	1	1	2	1
Pythagorean Theorem	2	2	3	4	1	2	3	4	1	1	2	1	2	1	1	1
General description, where relevant																
The work of mathematicians, how to think like mathematicians, how mathematics contributes to and relates to real life/real world (epistemic knowledge)	2	2	2	4	2	2	4	4	2	1	2	1	2	1	1	1

Moral and ethical issues in mathematics (e.g. reporting "average" or "median" to tell a different story)	2	2	2	4	4	2	4	4	2	1	2	1	2	1	1	1
Concepts related to programming, data science, computational thinking	1	1	3	4	3	4	4	4	2	1	2	1	1	1	1	1
Concepts related to global citizenship and sustainable development education, including environmental sustainability (e.g. reducing the cost of reducing carbon emissions by X & Y); education for international understanding, co-operation and peace; and education relating to human rights and fundamental freedoms	1	2	2	2	1	3	2	2	2	1	2	1	1	1	1	1

[1] Student agency (e.g. motivation, purposefulness, growth mindset, self-directed learning, self-efficacy)
[2] Co-agency (e.g. student-teachers, student-peers, student-parents, student-community outside of school)
Notes:
The numbers in the cells represent the most frequent rating (mode) observed across 14 participating countries/jurisdictions. A four-point colour-coded scale was used for the rating of competencies as follows (darker colours indicating greater emphasis): 1. Not targeted in this learning area; 2. Not targeted in this learning area but there are some opportunities for teachers to include this when teaching this learning area/subject; 3. Sub-target of the learning area's branches/strands or in specific grades only; 4. Main target of the learning area's branches/strands. Year of reference for data collection is 2018.
The findings from the CCM analysis in the Netherlands are included here for their research interest. The country did not participate in the CCM main study. The curriculum mapping was conducted on a proposed revision to their curriculum, which was ultimately not approved by the Dutch Parliament and never implemented. OECD (2019), Education 2030 Curriculum Content Mapping: An Analysis of the Netherlands Curriculum Proposal, OECD Publishing, Paris, https://www.oecd.org/content/dam/oecd/en/about/projects/edu/education-2040/6-bilateral-support/E2030_CCM_analysis_NLD_curriculum_proposal.pdf.
Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise

Table 2.4. Mapping Grid Mathematics (2018), lower secondary education, Part 2

CONTENT / COMPETENCIES	Transformative competencies			Compound competencies for 2030						Competency development for 2030		
	Creating new value	Taking responsibility	Reconciling dilemmas and tensions	Computational thinking/programming/coding	Financial literacy	Entrepreneurship	Media literacy	Global competency	Literacy for sustainable development	Anticipation	Action	Reflection
Strands/branches/contents/concepts/activities	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)
Number												
The formal meaning of number using a number line	1	2	1	2	1	1	1	2	1	1	2	1
Real numbers (rational and irrational numbers)	1	2	1	2	2	1	1	1	1	1	2	1
Complex numbers	1	1	1	1	1	1	1	1	1	1	1	1
Computational strategies to solve problems involving whole and real numbers	1	2	1	2	1	1	1	1	1	1	3	4
Computational strategies to solve problems involving common and decimal fractions	1	2	1	2	2	1	1	1	1	1	3	4
Proportion, percentage and ratio	1	2	1	2	1	1	1	1	1	1	2	2
Modelling and operations on vectors	2	2	1	1	1	1	1	1	1	1	3	4
Measurement												
Units of measurement and scale	1	2	1	1	1	1	1	1	1	1	1	1
Data and probability												
Random sampling	1	2	1	2	1	1	2	2	2	3	3	2
Organising, displaying, and interpreting data	1	2	1	2	1	1	2	1	2	3	3	4
Chance processes	1	2	1	2	1	1	1	1	2	3	2	1
Probability models	2	2	2	2	1	1	2	2	2	2	2	1

Center and variability in different data sets	1	2	1	2	1	1	2	1	2	3	3	4
Linear models	2	2	1	2	2	1	1	2	2	2	2	2
Bivariate associations (and correlations)	3	2	2	1	2	2	1	1	2	1	2	1
Expressions, equations and algebra												
The use of patterns to represent relationships	1	2	1	2	2	1	1	1	1	2	2	1
Algebraic expressions	1	2	1	2	1	1	1	1	1	2	2	1
Radicals	1	2	1	2	1	1	1	1	2	1	2	1
Polynomials	2	2	2	2	1	1	1	1	2	2	2	1
Linear equations and inequalities	1	2	1	1	1	1	1	1	1	2	2	1
Functions												
The use of functions to model relationships	2	2	1	2	1	1	1	1	1	2	3	1
Quadratic functions	1	2	1	1	1	1	1	1	2	1	1	1
Exponential functions	1	1	1	2	1	1	1	1	1	1	1	2
Trigonometric functions	2	2	1	1	1	1	1	1	1	1	1	1
Geometry												
Spatial relationships: 2D and 3D geometric theorems and properties	2	2	1	2	1	1	1	1	1	1	2	1
2D and 3D geometric rotation and transformations, including similarity transformations	2	2	1	2	1	1	1	1	1	2	2	1
Pythagorean Theorem	1	2	1	1	1	1	1	1	1	1	2	1
General description, where relevant												
The work of mathematicians, how to think like mathematicians, how mathematics contributes to and relates to real life/real world (epistemic knowledge)	2	2	1	2	1	1	1	1	2	2	2	1
Moral and ethical issues in mathematics (e.g. reporting "average" or "median" to tell a different story)	2	2	1	2	1	1	1	2	1	2	2	1
Concepts related to programming, data science, computational thinking	2	2	1	4	1	1	1	1	1	1	4	1

Concepts related to global citizenship and sustainable development education, including environmental sustainability (e.g. reducing the cost of reducing carbon emissions by X & Y); education for international understanding, co-operation and peace; and education relating to human rights and fundamental freedoms	1	2	1	1	1	1	1	1	1	1	1	1

Notes:
The numbers in the cells represent the most frequent rating (mode) observed across 14 participating countries/jurisdictions. A four-point colour-coded scale was used for the rating of competencies as follows (darker colours indicating greater emphasis): 1. Not targeted in this learning area; 2. Not targeted in this learning area but there are some opportunities for teachers to include this when teaching this learning area/subject; 3. Sub-target of the learning area's branches/strands or in specific grades only; 4. Main target of the learning area's branches/strands. Year of reference for data collection is 2018.
The findings from the CCM analysis in the Netherlands are included here for their research interest. The country did not participate in the CCM main study. The curriculum mapping was conducted on a proposed revision to their curriculum, which was ultimately not approved by the Dutch Parliament and never implemented. OECD (2019), Education 2030 Curriculum Content Mapping: An Analysis of the Netherlands Curriculum Proposal, OECD Publishing, Paris, https://www.oecd.org/content/dam/oecd/en/about/projects/edu/education-2040/6-bilateral-support/E2030_CCM_analysis_NLD_curriculum_proposal.pdf.
Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise

As expected, **numeracy** and **problem solving** stood out as the most strongly targeted competencies across content topics in mathematics curricula. This was followed by a strong rating of **critical thinking** and **literacy** as two other key competencies intended to be developed in the teaching of most mathematics topics, although to a lesser degree. The heavy emphasis on literacy may seem counter-intuitive, as this may be thought to be a more natural competency in language learning, but the results highlight the unequivocal value of literacy and language proficiency for conceptual understanding, for representation of mathematics problems, for interpretation of data, and for problem solving in any discipline/learning area (Caponera, Sestito and Russo, 2016[20]; Jiban and Deno, 2007[21]; Beal, Adams and Cohen, 2009[22]).

These competencies, together with **data literacy** and **ICT/digital literacy** are heavily represented, particularly among topics related to data and probability, confirming a growing emphasis in curriculum on statistics (as observed in early grades from the MCDA study) and a growing interest in helping students develop competencies that are essential for learning, working and living in digital environments. This is reinforced separately, too, by the emphasis placed on **computational thinking/programming/coding** in the teaching of “concepts related to programming, data science, computational thinking”.

The predominance of these foundational cognitive competencies remains at the heart of current mathematics curricula. Furthermore, the results recognise opportunities for teachers to include in their teaching:

- socio-emotional skills, particularly collaboration, self-control/self-regulation, persistence;
- meta-cognitive skills, such as learning to learn;
- self-initiated actions/dispositions, which are captured by the findings related to agency, responsibility and action. To some extent, the Anticipation-Action-Reflection cycle (OECD, 2020[23]) included in the study mirrors this layering of priorities with “reflection” as a primary target for the teaching of problem solving (numbers) and data-related topics, followed by “action”. This may indicate the areas in which mathematics curricula lean themselves more easily to concrete, real-world applications.

A surprising finding is the lower emphasis placed on **creativity** in mathematics, in spite of its recognised importance as a competency for the future (World Economic Forum, 2016[24]; Azzam, 2009[25]), given its role in advancing knowledge in any field, including in mathematics and technology. Other areas, such as

financial literacy and **global citizenship**, that are less frequently emphasised, also point to opportunities for further integration of practical, real-world skills into mathematics teaching.

Taking stock of the gaps in mathematics curriculum

Intended versus taught curriculum

The MCDA study provides an opportunity for exploring how the **intended curriculum** in mathematics (curriculum standards) compares to the **taught curriculum** (as represented by textbooks) in participating countries/jurisdictions with respect to key mathematics-related competencies, namely: quantitative reasoning, higher-order thinking skills, and selected 21st-century competencies. This section describes the results of such comparisons.

Quantitative reasoning

Figure 2.4 and Figure 2.5 depict the emphasis placed on various types of **quantitative reasoning** across countries/jurisdictions, as expressed in their mathematics curriculum standards (Figure 2.4) and the corresponding emphasis in representative textbooks (Figure 2.5) used in these participating education systems. While the scales of these graphs are not strictly commensurable, they each represent the explicit or implicit emphasis placed on the given mathematics-related competencies, and as such, they shed light on the alignment – or misalignment – between what education systems intend to teach and what ends up being taught in classrooms.

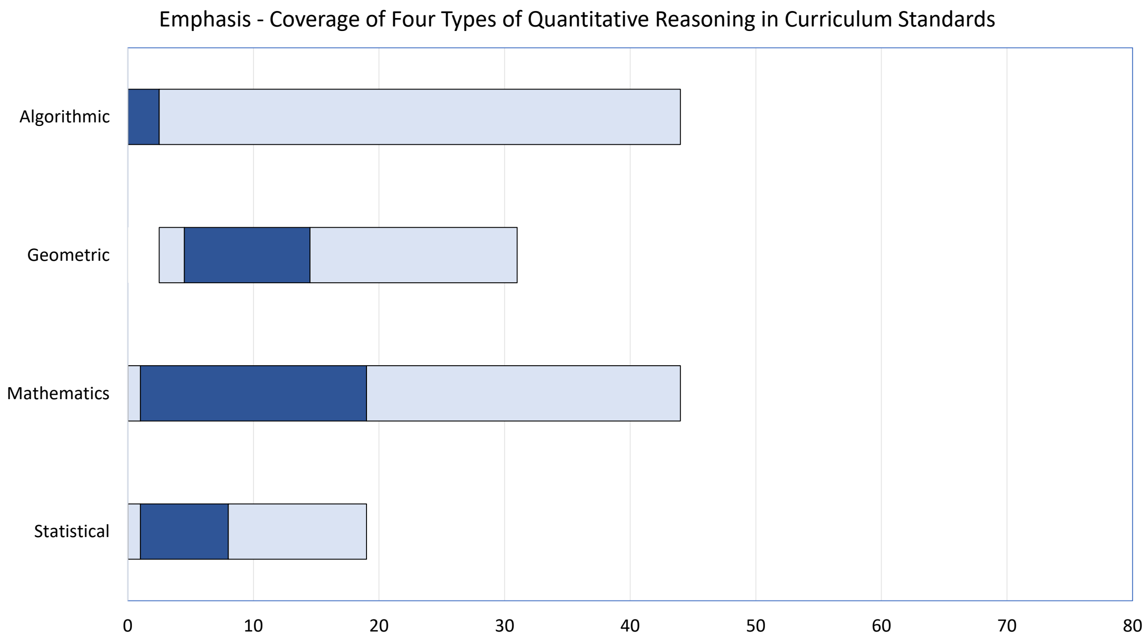
In areas such as **mathematics** (e.g. **basic numerical reasoning**) and **geometric reasoning,** the charts show a closer alignment between the curriculum standards and textbooks. This suggests that in these areas, what policymakers intend to be taught is more faithfully being translated into textbooks.

Traditional mathematics reasoning (such as in algebra, arithmetic and number theory) receive the strongest emphasis both in curriculum and in the textbooks. This type of quantitative reasoning seems to be well-integrated into both the intended and taught curriculum, possibly reflecting the chief priority across countries to offer students a strong foundation in these essential skills.

The moderate emphasis placed on **geometric reasoning** in curriculum is closely mirrored in textbooks, recognising geometric concepts as essential but not overly dominant in these first eight grades of mathematics education. The emphasis on statistical reasoning is modest but consistent both in the curriculum standards and in textbooks, reflecting an increasing recognition of the importance of data literacy and statistics in contemporary education.

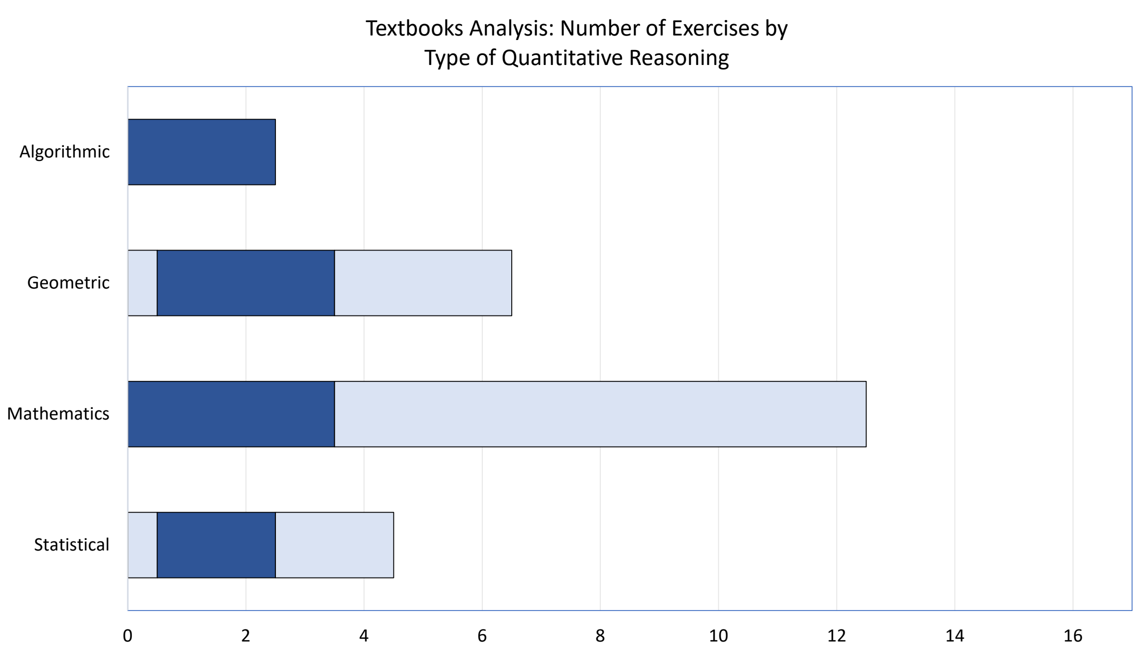
The cross-country analysis of curriculum standards also shows a significant emphasis placed on **algorithmic reasoning** in the intended curriculum, perhaps linked to computational and algorithmic thinking in modern mathematics education. This is contrasted by a much weaker emphasis on algorithmic reasoning in textbooks in general, showing that these skills may not be adequately reinforced through textbook exercises.

Figure 2.4. Quantitative reasoning in curriculum standards



Notes: Light-coloured bars: The range for the number of topics participating countries/jurisdictions intended to cover. Dark-coloured bars: The inter-quartile range (25th to 75th percentile) within the broader range representing the number of topics intended to be covered.
Source: Schmidt, W. et al. (2022[2]), "When practice meets policy in mathematics education: A 19 country/jurisdiction case study", *OECD Education Working Papers*, No. 268, OECD Publishing, Paris, https://doi.org/10.1787/07d0eb7d-en.

Figure 2.5. Quantitative reasoning in textbooks



Notes: Light-coloured bars: The range for the number of topics participating countries/jurisdictions intended to cover. Dark-coloured bars: The inter-quartile range (25th to 75th percentile) within the broader range representing the number of topics intended to be covered.
Source: Schmidt, W. et al. (2022[2]), "When practice meets policy in mathematics education: A 19 country/jurisdiction case study", OECD Education Working Papers, No. 268, OECD Publishing, Paris, https://doi.org/10.1787/07d0eb7d-en.

Higher-order thinking

The Mathematics Curriculum Document Analysis Study (MCDA) report emphasises the importance of developing 21st-century competencies through mathematics education, particularly by engaging students in *quantitative reasoning* and in *higher-order thinking*, including both higher-order-real-world applications (HoRw), and higher-order math-world applications (HoMw) (Schmidt et al., 2022[2])

HoRw tasks are set in real-life contexts that require students to sift through complex data, identify what is relevant, and formulate problems mathematically. These problems often have multiple solutions, reflecting the complexity of real-world decision-making.

In contrast, **HoMw** tasks are situated within mathematics itself, where students must use deductive reasoning and connect various mathematical concepts – such as recognising theorems and constructing proofs – to find a solution. Both types of tasks focus on fostering reasoning skills that go beyond simple computation, encouraging deeper mathematical thinking and problem solving.

The study found that while countries/jurisdictions emphasise higher-order applications in their curriculum standards (albeit at varying degrees), a profound gap of those intentions exists while analysing their mathematics textbooks for Grade 8, used as a proxy for "taught curriculum". The textbooks, which are recognised as being widely used in these countries/jurisdictions, overwhelmingly fail in providing students sufficient opportunities to develop higher-order thinking skills, particularly those related to real-world applications. The textbooks analysed were found to be dominated by computational exercises and word problems of little value to help students develop the types of higher-order thinking/reasoning expressed in curriculum documents.

21st-century competencies

The contrasting figures highlight a significant **discrepancy between curriculum standards and textbooks**, particularly in the competencies of **information use** (linked to digital literacy)**,** **persistence/resilience** in the face of difficulties, and **systems thinking** (the ability to think holistically beyond isolated parts). These are all important skills that allow students to develop their higher-order thinking. Their weak presence in textbooks reinforces the gap in higher-order thinking both in mathematics and in real-world applications observed in the study and discussed earlier.

A misalignment is also observed – albeit to a lesser degree – in **critical thinking** and **reflection**, which receive greater emphasis in curriculum standards compared to what is found in textbooks. Consistency between the intended curriculum and textbooks was only found for **communication skills**, not surprising given the finding that textbooks are dominated by word problems

The gaps observed suggest that while education systems recognise the importance of these skills, students may not be receiving adequate opportunities to practice and develop them in the classroom. To bridge this gap, textbooks and instructional materials need to be updated to better reflect the competencies emphasised in the curriculum, and teachers need to receive adequate preparation in line with the intended curriculum.

Figure 2.6 and Figure 2.7 allow for a comparison of the emphasis placed on a range of 21st-century competencies in mathematics curriculum standards and in textbooks.

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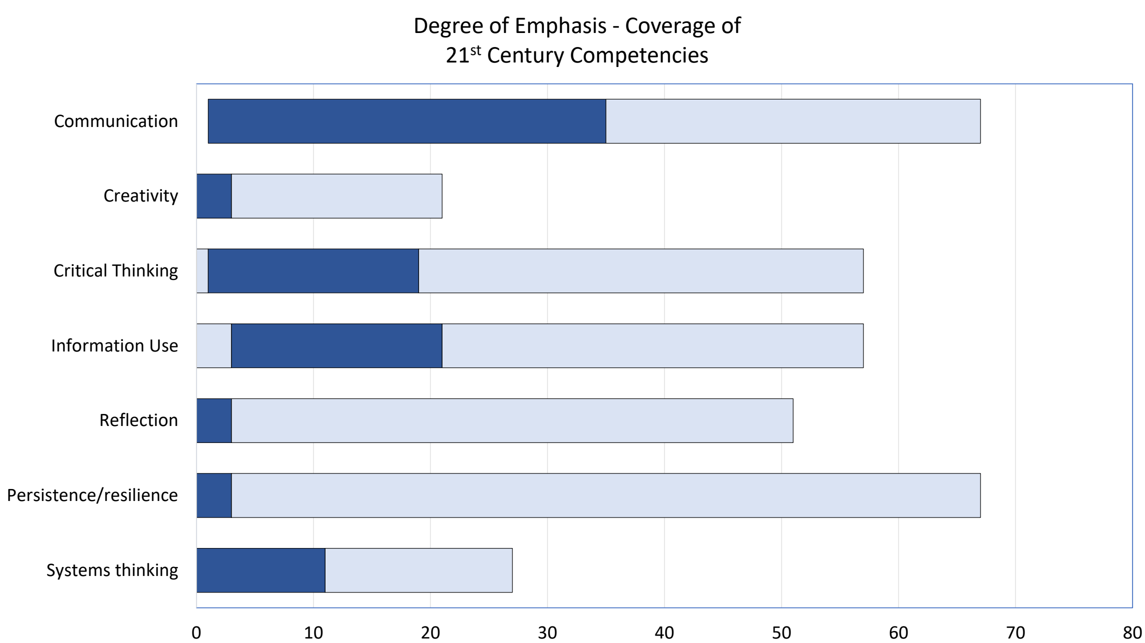
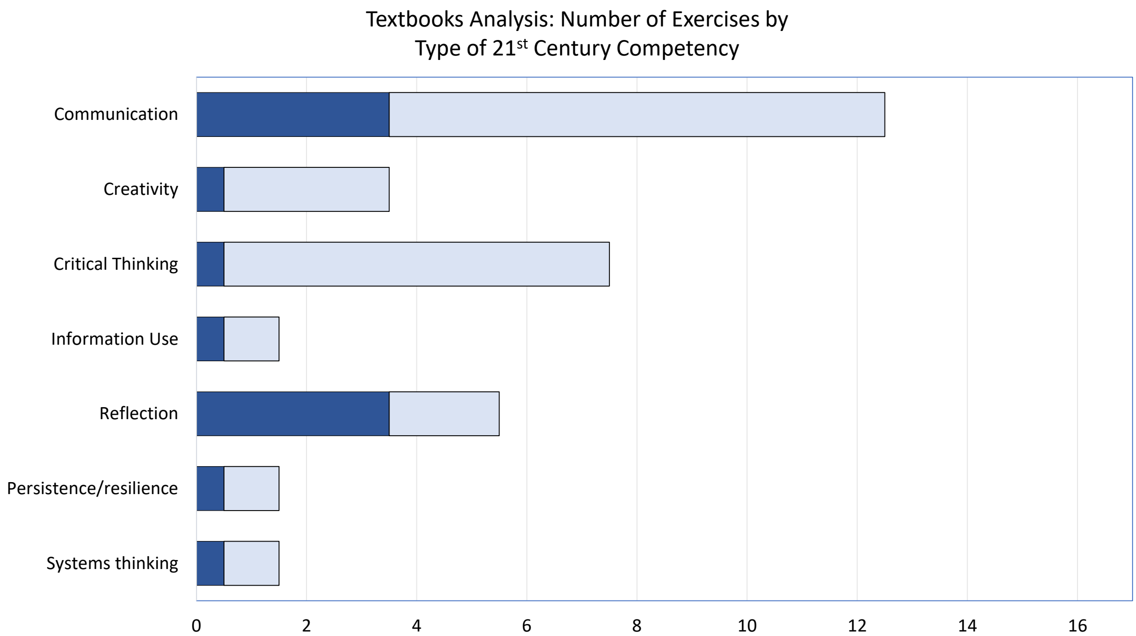
Figure 2.6. 21st-century competencies in curriculum standards



Notes: Light-coloured bars: The range for the number of topics participating countries/jurisdictions intended to cover. Dark-coloured bars: The inter-quartile range (25th to 75th percentile) within the broader range representing the number of topics intended to be covered.
Source: Schmidt, W. et al. (2022[2]), "When practice meets policy in mathematics education: A 19 country/jurisdiction case study", OECD Education Working Papers, No. 268, OECD Publishing, Paris, https://doi.org/10.1787/07d0eb7d-en.

Figure 2.7. 21st-century competencies in textbooks



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Source: Schmidt, W. et al. (2022[2]), "When practice meets policy in mathematics education: A 19 country/jurisdiction case study", OECD Education Working Papers, No. 268, OECD Publishing, Paris, https://doi.org/10.1787/07d0eb7d-en.

Intended versus achieved curriculum

Education systems use a variety of means for assessing students' learning, which then are fed back into their own system for evaluating how closely students are demonstrating the types of learning intended and prioritised in their mathematics curriculum. The most immediate level of assessment takes place in **classrooms,** where teachers get to evaluate on an individual basis to what extent students' performance reflects their teaching. They can use formative assessment methods like quizzes, observations and in-class assignments as well as summative assessment methods such as examinations and grades (Black and Wiliam, 2018[26]).

Making inferences from students' learning in a way that allows for comparisons across groups of students, classrooms, schools and regions often requires a certain level of standardisation. This is captured by **national standardised testing**, often administered at selected time points (grade levels), allowing for some diagnostic understanding and monitoring of how closely students' performance meets given learning goals/standards, including some manoeuvring from a policy perspective for targeted interventions at critical stages of the learning cycle, by age or grade level (Shepard, Penuel and Pellegrino, 2018[27]; Shepard, 2019[28]).

Content topics in mathematics, given its hierarchical and formal nature, seem to allow for standardisation more easily than other learning areas, such as humanities. Standardised testing may be used at varying degrees in **high-stakes assessments**, such as high school exit and university entrance examinations. These are placed at the end of compulsory education, at which point the opportunities for reversing trajectories of low achievement in mathematics are very limited (Brookhart, 2020[29]); their suitability for a global assessment of one's learning has also been questioned.

Challenges related to assessment – and assessment frameworks – remain. While there is a strong tradition of standardised testing of basic knowledge and skills, standardised assessment of higher-order thinking and other competencies emphasised in maths curricula presents significant methodological challenges (OECD, 2013[30]). Higher-order thinking by nature requires students to arrive at their own solution to problems. Wide variation in responses makes it difficult to assess such skills in a standardised way; similarly for the assessment of other competencies, such as critical thinking, creativity and collaboration (Darling-Hammond, 2020[31]). Nevertheless, countries are trying to address these limitations by adopting diverse approaches to assessment. In **Sweden**, for example, the assessment of mathematical reasoning includes not only written but also oral testing Box 2.1). This is an innovative way to address the difficulties of aligning forms of assessment to broader curriculum goals, and it requires a thoughtful approach – as well as well-prepared educators – to ensure that open assessments remain consistent and fair.

Box 2.1. Mathematical reasoning in Sweden

Sweden places significant emphasis on developing mathematical reasoning and communication skills, aligning its national curriculum with competencies that go beyond procedural knowledge. One key aspect of this approach is oral reasoning, where students are expected to be able to articulate their thought processes and solutions in mathematics.

Upper secondary education in Sweden does not include any compulsory final exams, though compulsory national assessment is included for some courses. This leaves much of the assessment in the hands of teachers, who evaluate students based on a combination of written and oral performance throughout the course. To test their mathematical reasoning skills, students work in small groups to discuss and solve mathematical problems, where their ability to explain concepts like geometry, reasoning and problem solving verbally is evaluated. This oral component complements written exams, assessing students' communication skills and their grasp of mathematical reasoning. In primary and secondary education, these small group discussions are also included in compulsory national assessment.

The national test in mathematics in grade 6, 2017/2018

Instructions to students

One component of the national test is an oral part. It is carried out in groups of 3–4 pupils together with a teacher. The task is about decimal numbers, diagrams, and graphs.

- The teacher gives each of you and your classmates a task. You will have a few minutes to think about this before you present your task.
- Each of you presents your task for the others in the group. After each presentation your classmates can ask questions and make additional comments.
- When all of you have made your presentations you and your classmates will get new tasks to think about and you will then present them in the same way. You will also discuss some tasks together in the group.
- Remember to try to show as much knowledge as you can. This applies both when you make your own presentation, after the presentations by your classmates and in the discussions.
- When the teacher assesses what you have shown during the oral part, the teacher listens to and watches for the following aspects:
    - what knowledge you show about mathematical concepts and relationships between these
    - how you solve mathematical problems
    - how you reason

- how you present the tasks and how you use mathematical language.

Your result on the oral part will later on be added to your result on the written parts. The result on the oral part can be used as a basis for both the autumn and spring term grade in mathematics.

Instructions to teachers

Here are some of the things the teacher checks during the test:

Problem solving

- Quality of strategies that the student uses.
- How well the pupil interprets results and draw conclusions.

Reasoning

- The quality of the student's analyses, conclusions and reflections and other forms of mathematical reasoning.
- The degree to which the student follows, in front of and respond mathematical reasoning.

Communication

- The quality of the student's accounting. How well the student uses mathematical forms of expression (language and representation).

Source: Skolwerket, National Assessment and Grading in the Swedish School System: https://www.skolverket.se/download/18.6bfaca41169863e6a655954/1553958924171/pdf1524.pdf.
Skolwerket Curriculum for the compulsory school, preschool class and school-age educare: https://www.skolverket.se/download/18.31c292d516e7445866a218f/1576654682907/pdf3984.pdf.

International assessments of students' learning, such as PISA and TIMSS, provide additional opportunities for education systems to monitor how closely students' learning reflects their own national/local priorities, as stated in their curricula documents.

The PISA 2022 mathematical framework addresses some of the concerns of assessing not only what can be easily measured (content knowledge), but also highly valued competencies for mathematics, such as applying mathematical knowledge to unfamiliar situations and to solve real-world problems or demonstrating proficiency in mathematical reasoning.

To bring an international perspective to the reflection on how intended curriculum compared to achieved curriculum, Table 2.5 displays the pattern of curriculum content coverage of four PISA top-performing countries/jurisdictions: **Hong Kong (China)**, **Japan**, **Korea**, and **Chinese Taipei (China)**[3]. While strong inferences cannot be drawn from such exploratory comparison, it allows for an appreciation of curriculum features that these countries seem to have in common. For example:

- All four education systems' curriculum standards align with global trends on content areas covering the full range of topics in the MCDA benchmarking framework.
- Japan and Korea concentrate on fewer topics in early grades compared to Hong Kong (China) and Chinese Taipei (China).
- They each show a structured, staggered expansion in the range of topics introduced from early to late grades with some noticeable steps: an expansion occurs around Grades 3 or 4; another in Grade 5; with a fuller range of topics being covered by Grades 7 and 8. Japan's coverage patterns show the most gradual choices compared to the other systems.

Table 2.5 provides a supplementary picture of this by overlaying countries' curriculum coverage (given by the range of topics) with the latest PISA performance in mathematics. This table draws on Table 2.2, only this time with the PISA performance levels identified.

In the table, the four top-performing education systems mentioned above are now seen in the context of comparison to other countries/jurisdictions. All of them maintain a somewhat selective to moderate range of topics covered across grades, with some convergence towards fewer topics in later grades. This seems to reflect these systems' preference to offer a narrower but focused curriculum, allowing students sufficient time to build solid foundations in learning in early grades before introducing new or more advanced content. This is in line with earlier cross-country findings that identified focus, rigour and coherence as important characteristics of mathematics curriculum in high-achieving systems (Schmidt et al., 2001[1])

A few countries also performed above the OECD average in mathematics while including a broader range of content topics in their curriculum: **Latvia** and **Sweden** (in early grades), together with **Estonia**, **the Netherlands**, and **New Zealand** (from Grade 4). Some countries with below average performance in PISA, namely **Argentina**, **Greece** and **Kazakhstan** also display similar patterns of content coverage as the top performers, underlying the complexities of arriving at direct inferences about the gaps between curriculum standards and student learning. Strong factors explaining discrepancies between mathematics curriculum and student outcomes include the mismatch between:

- written curriculum and textbooks (Schmidt et al., 2022[2]; Valverde and Schmidt, 1997[32]; Schmidt et al., 2013[33]);
- curriculum and teacher preparation (Darling-Hammond et al., 2017[34]; Shulman, 1986[35]);
- curriculum and assessment (Brookhart, 2020[29]; Pellegrino, 2018[36]).

Table 2.5. Range of topics in mathematics curriculum by PISA performance level

Grade	Below the middle inter-quartile	Within the middle inter-quartile	Above the middle inter-quartile
Grade 1	Japan, Chinese Taipei (China)	Australia*, Estonia, Korea, Netherlands, New Zealand, Hong Kong (China)	Latvia, Sweden
	Hungary	Lithuania, Portugal, United States	Norway*
	Argentina	Greece, Israel, Kazakhstan	
Grade 2	Japan	Australia*, Estonia, Korea, Latvia, Netherlands, New Zealand, Chinese Taipei (China), Hong Kong (China)	Sweden
	Hungary	Lithuania, Portugal, United States	Norway*
	Argentina	Greece, Kazakhstan	Israel
Grade 3	Australia*, Japan	Estonia, Korea, Netherlands, New Zealand, Chinese Taipei (China), Hong Kong (China)	Latvia, Sweden
	Lithuania	Hungary, Norway*, United States	Portugal
	Argentina	Greece, Israel, Kazakhstan	
Grade 4	Korea, Japan, Hong Kong (China)	Australia*, Netherlands, New Zealand, Chinese Taipei (China)	Estonia, Latvia, Sweden
	Lithuania	Hungary, Portugal, United States	Norway*
	Argentina	Greece, Israel, Kazakhstan	
Grade 5	Australia*, Japan, Netherlands, Hong Kong (China)	Korea, New Zealand, Chinese Taipei (China)	Estonia, Latvia, Sweden
		Lithuania, Portugal, United States	Hungary, Norway*
	Argentina	Greece, Israel, Kazakhstan	
Grade 6	Australia*, Korea, Japan, Hong Kong (China)	Estonia, Netherlands, Chinese Taipei (China)	Latvia, New Zealand, Sweden

		Israel, Lithuania, Portugal, United States	Norway*
	Argentina	Greece, Hungary, Kazakhstan	
Grade 7	Australia*, Korea, Japan, Hong Kong (China)	Estonia, Latvia, New Zealand, Chinese Taipei (China)	Netherlands, Sweden
		Israel, Lithuania, Portugal, United States	Norway*
	Argentina, Kazakhstan	Greece, Hungary	
Grade 8	Japan, Chinese Taipei (China), Hong Kong (China)	Australia*, Estonia, Korea, Latvia, New Zealand	Netherlands, Sweden
		Israel, Lithuania, Norway*, United States	Portugal
	Greece, Argentina, Kazakhstan		Hungary

Notes: Colours in the cells refer to different levels of students' performance in mathematics (PISA 2022) as follows: dark blue: above the OECD average; light blue: at the OECD average; grey: below the OECD average.
* The data for these countries reflect their curriculum standards at the time of the MCDA study. Revisions to their curriculum that were awaiting approval at the time of the study are not reflected here.
Source: Adapted from Schmidt, W. et al. (2022), "When practice meets policy in mathematics education: A 19 country/jurisdiction case study", OECD Education Working Papers, No. 268, OECD Publishing, Paris, https://doi.org/10.1787/07d0eb7d-en.

Other gaps remain to be explored that go beyond the scope of this chapter, as they pertain to various other dimensions of curricula. For example, as the relevance of mathematics extends far beyond the classroom and is becoming increasingly important for societies not only for progress in STEM-related fields, but also for individuals in many aspects of daily life (as discussed in Chapter 1), to what extent mathematics curriculum can integrate broader expectations held by multiple social actors (*expected curriculum*) remains to be explored. Or to what extent intended curriculum compares to students' lived experiences of learning in classrooms (*experienced curriculum*)? And how to incorporate new research evidence from learning sciences as well as new approaches to teaching and learning in the digital era as classroom environments start to incorporate artificial intelligence? These questions will continue to offer opportunities for further exploration and for continuous evolution of mathematics curricula with important implications for self-directed and personalised learning, teacher professional development, and new forms of assessment of learning, among others (OECD, 2020[37]).

In retrospect, this chapter reviewed the evolution of mathematics curriculum in various countries/jurisdictions, highlighting the growing emphasis being placed on mathematical reasoning and statistics. It explored how countries structure and distribute content across grade levels, showing variations – even among high performing systems – in their curriculum design, with some choosing a focused curriculum with fewer topics (suggesting deep learning as a priority) while others offer a broad curriculum from early years (perhaps putting emphasis on respecting teachers' culture of professional autonomy and choice of topics).

The chapter also revealed which key 21st-century competencies are already being explicitly integrated into lower secondary education in various systems. An emphasis on core cognitive and meta-cognitive foundations was observed with **numeracy** and **problem solving**, followed by **critical thinking** and **literacy** being strongly represented in the curricula analysed. **Data** and **ICT/digital literacy** are also now embedded in mathematics curricula, expressing the importance placed on helping students develop skills required for them to navigate technology-rich environments in school, work and life.

The exploration of gaps in mathematics curricula across education systems revealed concerning discrepancies between curriculum standards and textbooks, which are widely used in mathematics education. This is particularly concerning when it comes to the fostering of **higher-order thinking** and **real-world applications,** as textbooks overwhelmingly fail to offer adequate opportunities for students to develop these important competencies. Other important 21st-century competencies well-articulated in curriculum documents are often very poorly represented in textbooks, particularly **information use**, **persistence/resilience** and **systems thinking**, all of which are essential for students to develop proficiency in mathematics reasoning and to comfortably navigate the digital world.

Finally, when looking at how intended curriculum translated into achieved curriculum, the analysis uncovered the complexities of aligning assessment to broader curriculum goals, including not only content mastery but also future-oriented competencies. It also shed some light on important intervening factors that link curriculum to student learning, as these are more likely to reflect implemented curriculum (textbooks, teaching practices, opportunities to learn) rather than intended curriculum. The following chapter will address a series of challenges in curriculum design and implementation, offering examples of how countries are trying to address these challenges in mathematics curriculum.

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Notes

[1] MCDA participating countries/jurisdictions: *OECD Members*: Australia, Estonia, Greece, Hungary, Israel, Japan, Korea, Latvia, Lithuania, the Netherlands, New Zealand, Norway, Portugal, Sweden, the United States. *Partners*: Argentina, Chinese Taipei (China), Hong Kong (China), Kazakhstan.
Curriculum standards and the contents of popular textbooks were coded against a framework of mathematical content and type of activity. Individual reports were produced for participating countries so interested parties could reflect on their position in respect to coverage of topics, emerging goals such as higher-order thinking and 21st-century skills, and textbook contents by mathematical topic and task type.
[2] CCM participating countries/jurisdictions: *OECD Members*: Australia, British Columbia (Canada), Saskatchewan (Canada), Estonia, Greece, Israel, Japan, Korea, Lithuania, Northern Ireland, Portugal, Sweden. *Partners*: China, Kazakhstan.
[3] Four of the six East Asian education systems that outperformed other countries in PISA took part in MCDA, namely: Hong Kong (China), Japan, Korea and Chinese Taipei (China). The two other 2022 PISA top performers in mathematics were Macao (China) and Singapore.

3 Common challenges in mathematics curriculum reform: International experiences

This chapter highlights some considerations for mathematics curriculum reform, based on the series of curriculum analysis reports from OECD Future of Education and Skills 2030 (E2030) project and the relevant country experiences discussed therein. The analyses include trends in curriculum redesign, innovations in curriculum implementation and evaluation, as well as lessons learned from countries. The issues examined include: time lag between the curriculum of today and that of the future, overcrowded curriculum, ensuring an inclusive curriculum, incorporating values into curriculum, and curriculum flexibility and autonomy. This chapter interprets the findings though the lens of mathematics as a discipline, discussing the implications for teaching and learning mathematics.

This chapter highlights some considerations for mathematics curriculum reform, based on the series of curriculum analysis reports from OECD Future of Education and Skills 2030 (E2030) project. The reports discuss significant issues related to holistic curriculum development generally, rather than on reform in specific subject areas, and provide examples of innovation from around the world. The reports include:

1. *What Students Learn Matters: Towards a 21st Century Curriculum*: Managing time lag between today's curriculum and future needs. (OECD, 2020[1])
2. *Curriculum Overload: A Way Forward*: Addressing the pressures schools face to keep up with the pace of societal changes and issues related to overcrowded curriculum. (OECD, 2020[2])
3. *Adapting Curriculum to Bridge Equity Gaps: Towards an Inclusive Curriculum*: Confronts issues related to equality, equity and inclusion in curriculum innovation. (OECD, 2021[3])
4. *Embedding Values and Attitudes in Curriculum: Shaping a Better Future*: Incorporating values in curriculum as competencies for students' positive lifelong learning outcomes. (OECD, 2021[4])
5. Curriculum Flexibility and Autonomy: Promoting a Thriving Learning Environment: Discussing issues between curriculum prescription and autonomy in policy and practice. (OECD, 2024[5])
6. *Adopting an Ecosystem Approach to Curriculum Redesign and Implementation* (OECD, forthcoming).

Findings from this series of curriculum analysis reports are interpreted in this report though the lens of mathematics as a discipline, wherein the specific implications for mathematics curriculum reform are discussed.

Towards a 21st-century mathematics curriculum

Mathematical competencies comprise the knowledge and skills required to develop and apply mathematics, as well as the values and attitudes (dispositions) necessary to apply such knowledge and skills in appropriate contexts. The E2030 Mathematics framework reaffirms the importance of several areas of disciplinary knowledge that are integral to the OECD's Programme for International Student Assessment (PISA) mathematics assessment framework 2022 (OECD, 2023[6])

1. quantity (whole number, fractions and decimals, number sense and estimation, number systems, other number concepts);
2. space and shape (position, visualisation and shape, symmetry, congruence and similarity);
3. change and relationships (algebra foundations, beginning algebra, algebra, change);
4. uncertainty and data (descriptive statistics, probability distributions, statistical inference).

Traditional topics such as number, geometry and algebra are easily recognised within these important areas. Indeed, as discussed in previous chapters of this report, the findings from the Mathematics Curriculum Document Analysis (MCDA) and Curriculum Content Mapping (CCM) studies found that core foundational competencies, such as numeracy and data literacy, together with mathematical knowledge on essential content areas like algebra, geometry and number systems, continue to serve as the foundation of mathematics education worldwide. Moreover, the studies revealed that most countries/jurisdictions share a similar structure in terms of topic sequencing and instructional tasks (Schmidt et al., 2022[7]; OECD, 2020[1]).

At the same time, new demands are emerging for mathematics curricula in response to global and societal challenges, such as demographic shifts like population ageing, health management, and global concerns such as climate change. Growing economic inequality, the evolving demands of the modern workplace for higher-order thinking and collaboration, and rapid advancements in digital technologies are also shaping the need for more interdisciplinary approaches in education. While foundational mathematical knowledge remains crucial, these changes highlight the necessity of integrating mathematics with other disciplines to equip students with the skills required to tackle complex, real-world problems, as is stressed in both learning and assessment frameworks (see Table 1.1 in Chapter 1).

This section will illustrate some of the concrete examples of how mathematics curriculum accommodate 21st-century demands, reflecting the diverse approaches to preparing students for citizenship and for work.

Student agency, co-agency and collective agency at the heart of mathematics curriculum for citizenship and for work

As discussed in Chapter 1, the OECD Learning Compass for Mathematics sets out a broad vision for learning mathematics, for students to be able to navigate through unfamiliar contexts and shape a better future (OECD, 2023[8]). While the compass is not designed to be a curriculum document itself, it acknowledges that influences on student learning go beyond the education system and offers considerations to policymakers involved in curriculum design.

Key concepts and constructs central to the compass, among others, include:

- **Student agency, co-agency and collective agency**. Agentic students are driven by a sense of purpose, intrinsic motivation and responsibility to influence people, events and circumstances around them. Co-agency and collective agency recognise that students participate in social settings and interact with others, which also guides and influences student personal growth (OECD, 2019[9]). The implication for the enacted mathematic curriculum is that students' agency, co-agency and collective agency are developed through opportunities to exercise control over their own learning and to participate in communities of practice through **collaborative sense-making**, in which meaningful situations are investigated by students.
- **Critical thinking** is crucial for solving complex problems where students need to evaluate patterns, question assumptions and devise strategies for solutions. In this sense, critical thinking enables students to engage deeply with mathematical content. Learning mathematics also requires critical thinking as students must understand abstract concepts and apply them to new situations, fostering their ability to think logically and analytically.
- **Curiosity and creativity** are both a means and an outcome of mathematics education. Solving non-routine mathematical problems often requires thinking creatively, particularly when standard procedures fail to provide solutions. In turn, mathematics also encourages creativity by presenting students with open-ended problems, which require innovative approaches to develop multiple solutions or explore different strategies.
- **Research and inquiry skills** also contribute significantly to mathematics education. Students learn to formulate hypotheses, explore mathematical questions and investigate patterns or real-world applications. This promotes an inquisitive mindset, fostering independence as students engage in deeper inquiry-based learning.
- **Persistence** and **resilience** are equally important. Problem solving in mathematics is often iterative and challenging, requiring students to persist through failure and uncertainty. These skills prepare students to tackle real-world problems and instil a sense of perseverance, which extends beyond the classroom into everyday life.

These competencies are not only essential for mastering mathematical concepts, but also for studies outside of math classrooms. Furthermore, these competencies are also important beyond school – for citizenship and for work.

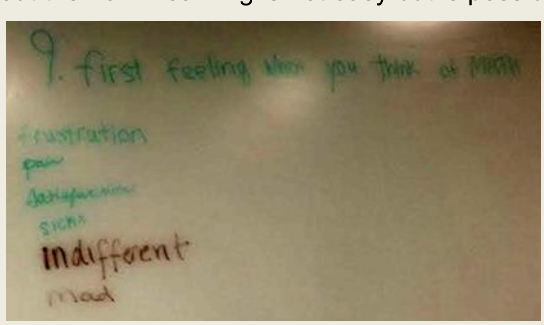
To promote such competencies, partnerships – including those between schools and higher education – are crucial to supporting schools in curriculum design and implementation; see Box 3.1 for an example.

Box 3.1. Fostering curiosity, adventurousness and an innovative mindset through a Math 101 course

Professor Steven Strogatz of Cornell University has proposed an innovative approach: integrating a "Math 101" course into school curricula, focused on math appreciation through exploration. The course promises to equip students not only with technical knowledge but also with curious, brave and innovative mindsets to navigate and solve the complex challenges of our time.

The traditional education system, which has the goal of imparting technical skills and knowledge, often fails to ignite a passion for learning among students. Many perceive math as a rigid and daunting subject. However, Strogatz argues that through courses like Math 101, this perception can be transformed. At Cornell, the “Math Explorations” course exemplified this transformation. This course employs inquiry-based learning, where students engage in intriguing puzzles and activities that require imagination and teamwork, with no lectures or tests. The role of the teacher shifts from lecturer to coach, guiding students on their learning journey.

For example, the course starts by asking questions such as: what is the first feeling when you think of math?, what are some words you would use to describe math?, and why are you taking this class?. Students’ answers often include a few positive but mostly reluctant feelings such as frustration, pain, dissatisfaction, sick, indifference, anger, etc., indicating some common extent of math anxiety. To change one’s perception about their own learning is not easy but is possible.

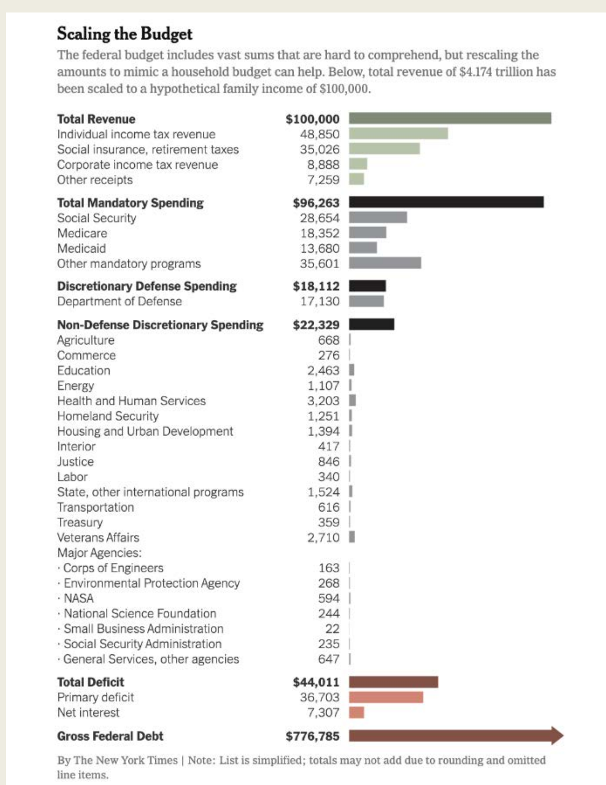


Strogatz’s Math101 class focuses on sense-making for students. For example, for students who get frustrated with math, a course or an activity can focus on experimentation and persistence, with hands-on quizzes. For example, students were given “folding-and-straight-cutting challenges” with different types of triangles.

In a carefully designed and safe environment, its students felt more okay to struggle and to say they do not know the answer. They were seated at tables of four, sharing their ideas and discussing with each other to find solutions. Some found solutions faster than others, but Strogatz reported that when he offered a hint, they refused to take it. He felt this was a true mathematical moment, as a sign of students’ deep engagement, making sense of the activity for them, enjoying the struggle, feeling the pleasure of thinking, without questioning “what is this for?” or “what will I use this for?”.

He also reported that students’ reactions were, for instance: “I am feeling exceptionally accomplished. I have to admit: this math assignment has made my day. I never thought I would ever be saying this”; “This process of experimentation and persistence has real-world application, as it demonstrates the importance of continuing a task while simultaneously approaching it in new and unusual ways. I have already learned a great deal from this class while still enjoying math, a feat I thought impossible only two weeks earlier.”. This is a sign of students developing experimentation and persistence, fundamental attitudes for 21st-century skills in mathematics.

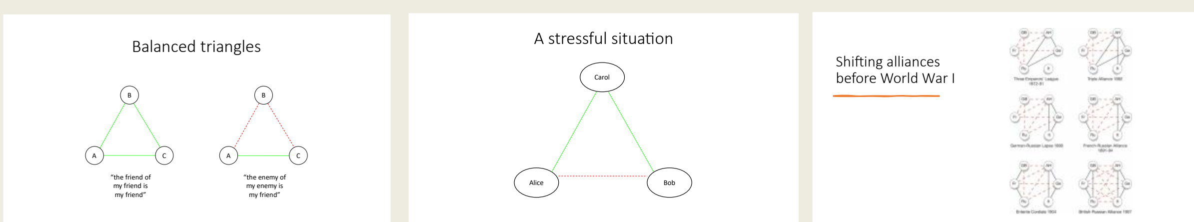
Another effective activity is making sense of big numbers. Students were tasked to re-imagine the budget of household spending for a family of four. This exercise, developed with Aiyana Green, helps students make sense of large numbers by relating them to everyday experiences. By comparing national financial data to a family's budget, students can better grasp the significance and scale of government spending. This method not only demystifies big numbers, but also fosters critical thinking as students consider the implications of financial decisions on a smaller, more relatable scale. Understanding the federal budget in terms of household spending will also make it easier to comprehend complex economic policies and their potential impact on daily life in the future.



Another noteworthy activity is the use of analogies to illustrate mathematical concepts and their applications. For example, the statement that “the enemy of my enemy is my friend” can be seen as an analogy of the mathematical concept that (−1) x (−1) = +1. Following this scheme, balanced triangles can be used to explain relationships, ranging from a stressful situation among friends (relating to their daily life) to shifting alliances prior to World War I (relating to another subject, like history, as cross-disciplinary learning).

This analogy helps students understand the dynamics of daily lives or historical events through a mathematical lens, making the subject matter more engaging and relatable. By likening alliances to balanced triangles where the enemy of my enemy is my friend, students can visualise and better grasp the strategic relationships between countries. This approach not only aids in understanding historical events but also demonstrates how mathematical thinking can be applied to various disciplines, enhancing interdisciplinary learning.

The integration of courses like "Math 101" into school curricula holds significant relevance for modern education. By fostering student agency, co-agency, collective agency, curiosity, bravery and innovation, such courses prepare students to tackle the changes of our era. The success of "Math Explorations" at Cornell demonstrates that math can be taught in a way that is engaging, relatable and profoundly educational. For this approach to be successful, however, it requires support from educational institutions and policymakers to create a conducive learning environment, provide professional development for teachers and develop innovative teaching materials. Embracing this model can transform how students perceive and engage with math, ultimately nurturing a generation of creative and critical thinkers.



Source: Presentation of Professor Steven Strogatz (Cornell University) at the first Education and Innovation Practice Community (EIPC) international online knowledge exchange (IKE), organised by the OECD on 18th April 2023.

Box 3.2 serves as another good example that fosters critical 21st-century competencies in mathematics education by embedding curiosity, creativity and problem solving into mathematical tasks, allowing students to grow in both their mathematical understanding and broader competency development.

Box 3.2. Developing curiosity in mathematics

The “NRICH” Project provides free online resources designed to enrich the mathematical experiences of learners. Aimed at students and educators alike, the project offers problem-solving activities that encourage mathematical thinking, curiosity and resilience. Its mission is to promote a deeper understanding of mathematics by offering engaging, accessible challenges that foster a love for learning, making math more enjoyable and relevant to everyday life.

NRICH focuses on providing students with frequent opportunities to engage with challenging and unfamiliar mathematical problems, aiming to develop both their curiosity and perseverance when solutions are not immediately apparent. Recognising that many students often experience mathematics as a collection of endless facts and procedures, which can lead to disengagement, it shifts the emphasis toward fostering curiosity. This approach encourages students to become both problem-solvers and problem-posers. By nurturing curiosity, it aims to re-engage students who might otherwise become disenchanted with mathematics.

In 2017, the “Mathematics for the Inquiring Mind: Developing Curiosity in Mathematics” project was launched. This initiative focuses on cultivating an inquiring mindset in students aged 7-18, providing support for both teachers and parents. Through collaboration with researchers like Clare Lee and Sue-Johnson Wilder, research-backed strategies were integrated into their resource development.

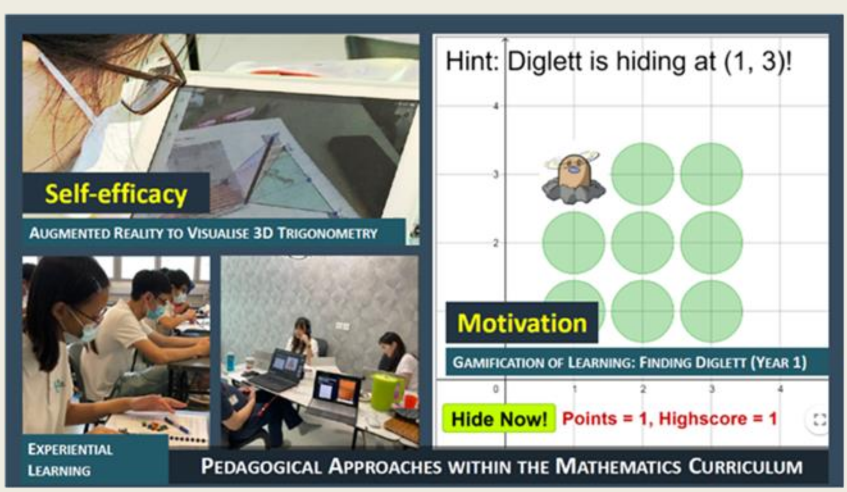
The project designed resource modules centred around rich mathematical problems, with tasks that challenged students to investigate patterns and question underlying mathematical principles. For example, some modules encouraged students to ask, "Will this always happen?" or "Why does it happen?" as they explored mathematical patterns. Other resources linked mathematics to real-world situations, encouraging students to investigate and model scenarios using their mathematical knowledge.

The project also included student events, online webinars and family-oriented activities aimed at fostering curiosity through collaboration and engagement. To ensure the project’s sustainability, they developed downloadable resources for schools and institutions globally, as well as professional development materials for teachers. Promoting teacher partnerships and encouraging the sharing of experiences helps to build classroom environments where curiosity-driven learning can thrive, with teachers continuously assessing outcomes and adapting their methods.

Source: The OECD Future of Education and Skills 2030, Case study submitted by Dr Ems Lord, Director of NRICH.

Box 3.3 also serves as a good example of how student agency can become a core driver of advanced mathematics learning in school.

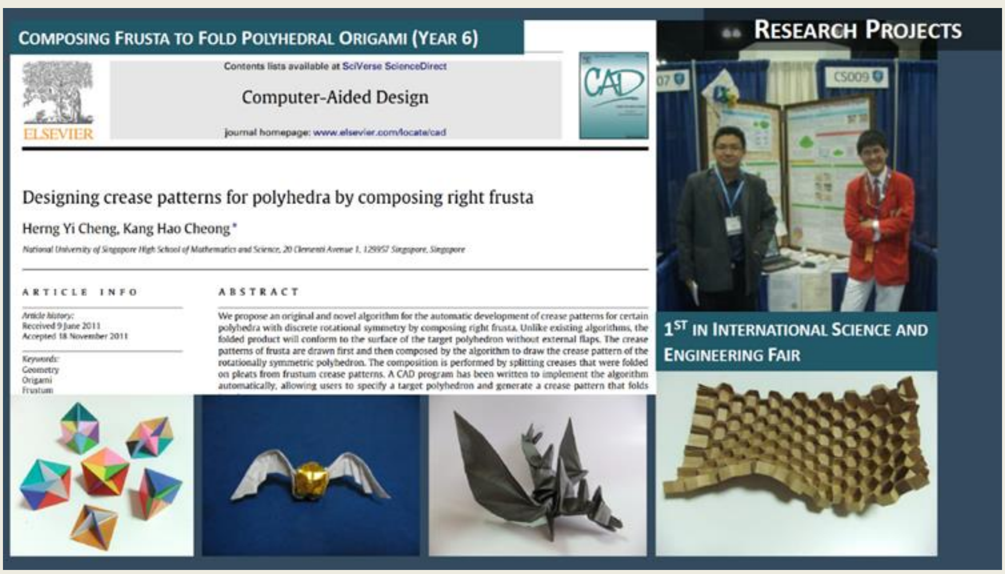
Box 3.3. Student agency as a core driver of mathematics learning



The NUS High School of Mathematics and Science is a specialised co-educational school in Singapore that offers a six-year diploma programme, from Grades 7-12 (13-18 years old). Students are admitted via a selection process that focuses on aptitude and passion in mathematics and science. The curriculum emphasises critical thinking, problem finding and solving, research and innovation. It is arranged in three modules: core modules are compulsory, whereas students can choose which elective and enrichment modules they want to take up according to their interests, which allows students to customise the pace, depth and breadth of their own learning.

The notion of "student agency", as outlined in the OECD Learning Compass, is widely fostered: students are constantly encouraged to choose what to learn, when to learn and how to learn. Students are also supported as they take risks to explore new areas of learning and wrestle with complex authentic issues. This is to help them to find a sense of self-efficacy, purpose and motivation. For example, pedagogical approaches include gamification of learning, e.g. to learn about cartesian co-ordinates.

Students have the autonomy to set their own learning goals and plan their own educational journey to achieve these goals. An alternative assessment used is the assignment of mathematical modelling, such as using calculus for optimisation (e.g. maximum height of sneeze droplet). Students take the initiative to find a problem that they would like to model, and in this way take charge of their own learning. Students' grades are not pegged to a few big exams but instead they are graded and assessed at the classroom level over the years. This supports continuous and self-directed learning, driving "assessment for learning" rather than "learning for assessment".



Opportunities for research are abundant and available at any level. When students are in Year 2, they can opt to take the Junior Mathematics Research module, where they propose their own mathematics research topic and carry out a project. The projects are mentored by mathematics teachers and entered into a local competition: the Singapore Mathematics Projects Festival. This has proved to be effective to develop students' creativity and to inspire them to follow their own interests. For example, a student who used to spend much of his free time folding various origami objects for leisure pursued research in and conducted three projects about various geometric blocks that could be folded and fused. This culminated in his project "Composing Frusta to Fold Polyhedral Origami". He then presented his project at the International Science and Engineering Fair 2011, the world's largest international pre-college science fair, and achieved the 1st prize in his category (Computer Science). This kind of experience inspires his peers to re-think the goals of mathematics and its potential for creative thinking.

Source: OECD Future of Education and Skills 2030 School Networks, NUS High School for Math and Science, Singapore (2023).

Including contemporary topics in mathematics education

In today's rapidly evolving technological landscape, mathematics education is expanding to include new topics that address the demands of the digital age. In addition to traditional areas such as numbers, algebra and geometry, contemporary topics like mathematical reasoning (with an understanding of how mathematicians think), statistics and **data science** are gaining prominence. These areas are critical for equipping students with the skills needed to navigate a world increasingly driven by technology, automation and data.

Epistemic knowledge

Many examples of epistemic knowledge are also included in the PISA framework (OECD, 2023[6]), with an aim of students understanding the ways in which knowledge is generated within the disciplines of mathematics and statistics.

- mathematical (including algebraic and geometric) and statistical reasoning;
- number systems and their algebraic properties;
- mathematics as a system based on abstractions and symbolic representation;
- the structure of mathematics and its regularities;
- functional relationships between quantities;
- mathematics modelling as a lens to the real world;
- variance as the heart of statistics;
- history of mathematics as a human activity.

These examples are not mutually exclusive. For example, representation is integral to mathematical and statistical reasoning, and to the structure of mathematics as a discipline. The main implication for curriculum writers is to ensure that there are opportunities for students to practice like mathematicians and to reflect on when a disciplinary methodology is in play. Inclusion of processes, competencies, disciplinary capabilities or proficiencies (whichever term is used) should be a key feature of 21st-century mathematics curricula.

Statistics and data science

The integration of **data science** into mathematics curricula reflects the growing importance of data in nearly every sector, from business to healthcare. Students are now being taught to collect, process and analyse large datasets to make informed decisions. Statistics, a fundamental component of data science, plays a crucial role in helping students understand variability, probability and statistical inference – skills necessary to draw accurate conclusions from data. **Computational thinking** – the ability to break down complex problems, recognise patterns and develop algorithmic solutions – is now recognised as a critical skill across disciplines. In mathematics education, it encourages students to think logically and analytically, building a strong foundation for problem solving.

The use of computer-based modelling and simulations in mathematics classrooms is revolutionising how students engage with abstract concepts and apply them to real-world situations. Modelling is now a key component in fields such as engineering, finance, environmental science and healthcare. By integrating simulations into the curriculum, students can explore complex systems – like climate models, population growth, or disease spread – through mathematical algorithms.

Connecting mathematics with other disciplines

Interdisciplinary learning, particularly through STEM (Science, Technology, Engineering and Mathematics) and STEAM (including the Arts), is recognised as essential for helping students connect knowledge across fields and view the world through varied disciplinary lenses. Teaching mathematics in the context of STEM/STEAM can help prepare students to tackle modern workplace challenges that demand collaborative, multidisciplinary thinking (OECD, 2023[8]).

By combining the abstract nature of mathematics with tangible applications in engineering, technology and the arts, students see how mathematical concepts apply to real-world tasks – such as designing bridges, coding or analysing data – bridging theory and practice. This interdisciplinary approach cultivates cognitive flexibility and adaptability, crucial for careers requiring diverse skills (Honey, Pearson and Schweingruber, 2014[10]). Engaging in projects like sustainable urban development allows students to apply math in calculating population density or resource needs, fostering motivation by illustrating math's practical value (Honey, Pearson and Schweingruber, 2014[10]; Modeste et al., 2023[11]). STEAM further enhances learning by incorporating creativity, as seen, for example, in geometry projects that merge mathematical rigour with aesthetic design, allowing students to view mathematics as both a precise tool and a means of creative expression, deepening appreciation and understanding of the subject (Perignat and Katz-Buonincontro, 2019[12]).

While integrative STEM/STEAM holds great promise for fostering interdisciplinary connections, its effective implementation within mathematics education requires thoughtful curriculum design, teacher training and tailored assessment strategies to overcome several challenges. Teachers need deep content knowledge across disciplines and the ability to create projects that are relevant and maintain mathematical rigour. Assessment can be particularly complex, as interdisciplinary projects often lack standardised frameworks, necessitating custom rubrics that assess both subject knowledge and broader skills, which is a time-intensive task. Additionally, disparities in resources and technology access mean that students in under-resourced schools may miss out on quality interdisciplinary learning, underscoring the need for investment in training, materials and infrastructure to ensure equitable access to STEM/STEAM education.

Digital curricula and digital textbooks

Digital curricula and **digital textbooks** together have the potential to transform mathematics education by incorporating interactive tools, simulations and adaptive learning features that can make complex concepts more accessible, engaging and suited to individual learning needs. Digital resources such as GeoGebra, Desmos and TinkerPlots enable students to visualise and experiment with mathematical models at their own pace. For instance, in geometry, students can manipulate shapes in real time to explore concepts like area and transformations, while in statistics, simulations help them understand probability distributions through hands-on, repeatable experiments. These tools can help make **abstract concepts tangible and relevant, bridging theory and practice** while preparing students for fields like engineering and data science.

Digital textbooks complement digital curricula by embedding multimedia resources, interactive exercises and adaptive assessments directly within the material. Unlike static print resources, digital textbooks allow students to engage with concepts through videos, animations and instant feedback. This adaptability supports **self-paced learning**, enabling students to progress at the speed that suits them best, which is particularly beneficial in diverse classrooms. For instance, a digital algebra textbook might include an interactive tutorial on solving equations, where students can see the effects of variable changes immediately and take as much time as needed to master the topic.

Furthermore, digital textbooks can enhance **personalised learning** by identifying areas where individual students may need additional support and offering targeted resources to reinforce understanding. In a geometry unit, for instance, students who need more practice with volume calculations can receive supplementary exercises within the textbook itself. This personalisation ensures that each student has access to tailored learning resources, making the experience more relevant and effective.

A key benefit of digital curricula and textbooks is their potential to provide **personalised feedback** to students. Many platforms offer real-time feedback on exercises and assessments, helping students immediately understand their mistakes and correct them. For example, if a student struggles with certain algebraic steps, the system can highlight areas of difficulty and offer targeted hints or alternative explanations. This immediate, tailored feedback helps students address gaps in understanding right away, building confidence and improving learning outcomes.

Digital curricula and textbooks support not only **self-directed independent learning (**Box 3.4**)** but also **collaborative and interactive learning**, with tools for discussion, shared projects and peer engagement. For example, students can work together on trigonometry problems, using embedded Desmos tools to adjust angles and observe changes collaboratively, while teachers monitor and provide feedback, fostering an interactive classroom dynamic. The combined approach of digital curricula and textbooks provides a holistic, flexible and responsive learning experience, allowing students to build foundational math skills, digital literacy and collaboration abilities.

Box 3.4. A journey through self-directed learning in mathematics

Sola Mahfouz was born in Afghanistan in 1996. At only 11 years old, she was forced to quit school due to the political turmoil under Taliban rule in Afghanistan at the time. With schooling abruptly halted, Sola's days were initially filled with mundane household tasks. However, her desire for knowledge and understanding of the world fuelled her determination to learn, despite the high risks.

Sola's journey into self-directed learning began out of a quest for meaning and understanding of the world. Initially focusing on learning English to connect with the wider world, she stumbled upon Khan Academy, which became her window to mathematics and science. Sola's approach to learning mathematics was unconventional; she did not simply memorise the learning material but sought to understand concepts deeply, which sometimes meant spending days grappling with a single concept. Her self-directed learning journey led her from not knowing basic arithmetic beyond addition and subtraction to studying calculus and physics within three years. Overcoming countless obstacles along the way, Sola finally took the SATs and got a scholarship to study in the United States. Today, she is working as a quantum computing researcher at Tufts University. Sola's incredible story emphasises the importance of access to educational resources that have the possibility of developing personalised curriculum for different context and situations, the power of curiosity and the transformative potential of self-directed learning.

Source: OECD Future of Education and Skills 2030. Presentation by Sola Mahfouz, in a Focus Group meeting of the Education 2030 project.

The rapid development of AI in educational contexts has sparked significant interest due to its potential to reduce teacher workload and enhance both student learning and performance. However, the full extent of the benefits and limitations of integrating these tools into educational settings remains largely unexplored. For instance, despite advancements in AI, tools like ChatGPT have demonstrated performance limitations in standardised mathematical assessments. An OECD study revealed that in November 2022, GPT-3.5 successfully answered 35% of a set of PISA mathematics tasks, significantly underperforming compared to humans, who successfully answered 51% of the tasks on average. By March 2023, GPT-4's performance had improved to 40% of the tasks successfully completed (OECD, 2023[13]). Although this marks a notable improvement, it also highlights persistent limitations and risks.

Technology has long been integral to teaching and learning in schools, including mathematics education, encompassing not only digital curricula but also essential tools and infrastructure, such as graphing calculators and digital whiteboards. While digital tools – and increasingly, AI – are pushing the boundaries of what is possible in education, much remains to be discovered about their efficacy in genuinely enhancing student learning. For example, the capacity of AI to deliver truly personalised learning experiences is still under investigation, with ongoing questions about whether AI can understand students as comprehensively as teachers do, beyond merely analysing performance on pre-programmed tests.

Regarding the use of AI in assessment, particularly the application of Large Language Models (LLMs) for grading student work, the field is still in its early stages despite years of development in automated scoring systems. The current use of LLMs in educational assessments is pioneering yet experimental, indicating that while the technology holds promise, substantial development and evaluation are needed to determine its viability and effectiveness (Hao et al., 2024[14]).

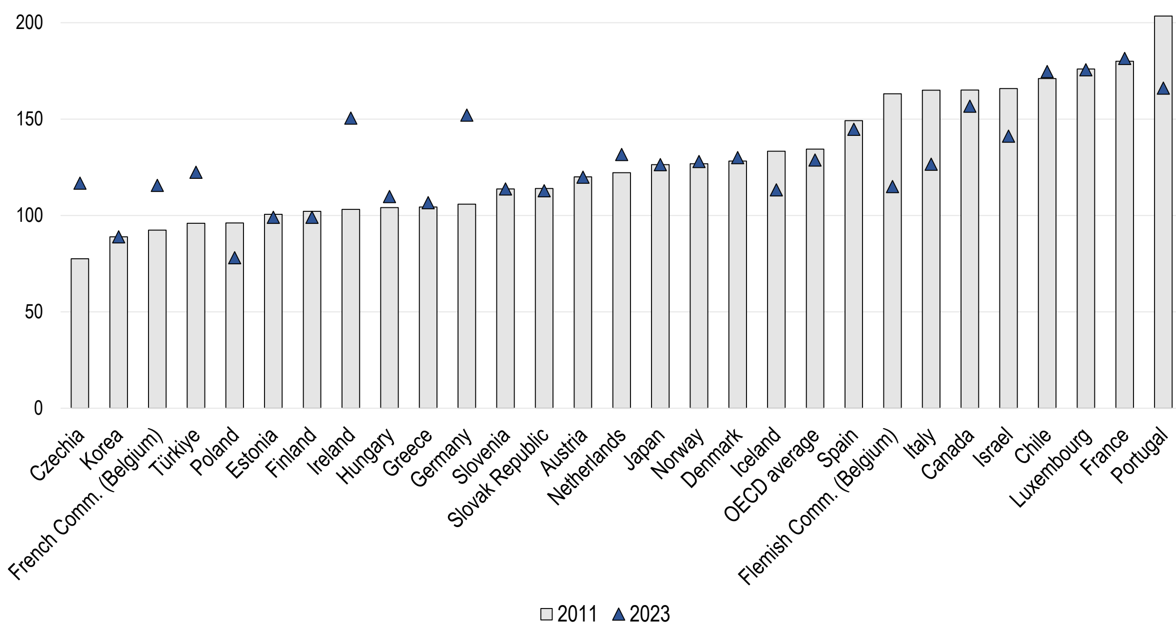
While the potential of digital technologies, particularly AI, to transform mathematics education is undeniable, their effective implementation carries inherent risks and limitations. To maximise the benefits and mitigate the risks associated with their use in classrooms, it is essential that the integration of these technologies into curricula and teaching practices be complemented by comprehensive teacher training and development. This important discussion about digital technology's capabilities and its practical implications in educational settings highlights the need for continued and more thorough examination in a dedicated analysis elsewhere.

Curriculum overload in mathematics

Curriculum overload occurs when the quantity of content required to be taught exceeds the available instructional time or capacity (OECD, 2020[2]; Erstad and Voogt, 2018[15]). Curriculum overload commonly occurs when policymakers attempt to meet the competing demands of different stakeholder groups or societal changes by introducing new topics into the curriculum without removing or adjusting existing ones. This expansion can take the form of adding new subjects or embedding additional topics within existing subjects. Both approaches significantly risk overwhelming an already crowded curriculum, potentially hindering effective teaching and learning. Today, this challenge is further amplified as policymakers strive to integrate 21st-century competencies – such as critical thinking, creativity and digital literacy – into curricula, intensifying the pressure on instructional time and content management.

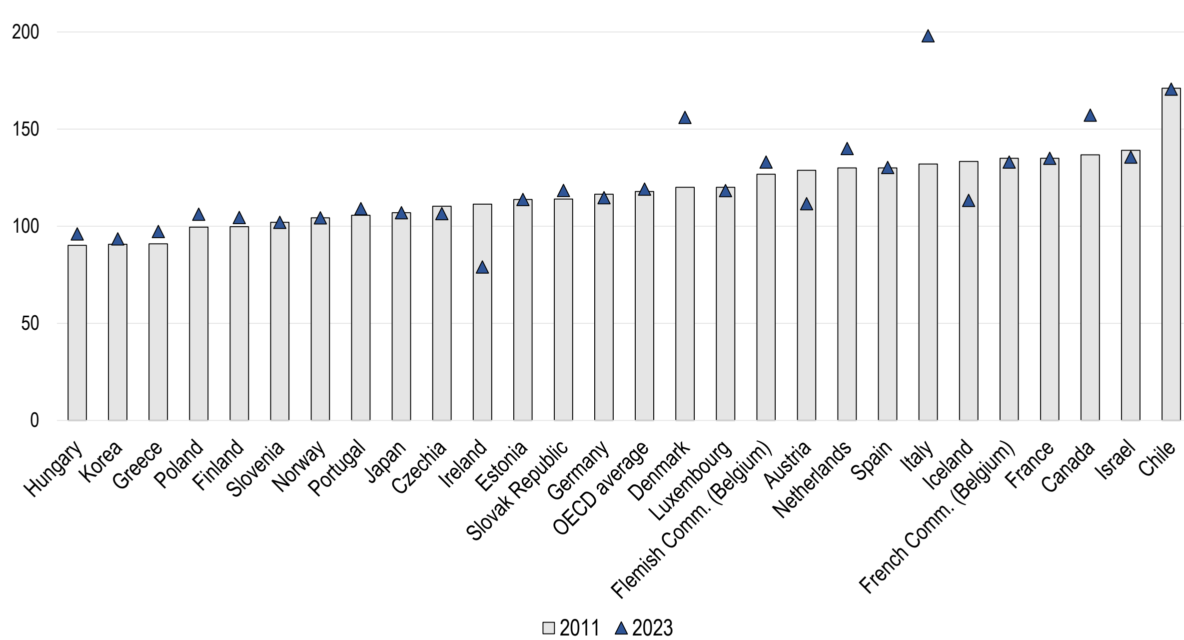
Despite the growing number of topics to be covered in mathematics education, the amount of teaching time available has changed very little across OECD countries in recent years. According to Education at a Glance data, mathematics remains a core subject in countries'/jurisdictions' curricula alongside reading, writing and literature, natural sciences, and second language subjects. Incorporating modern competencies alongside traditional mathematical content can also lead to a curriculum imbalance. For instance, while fields like algebra and geometry may dominate the curriculum, newer areas like data analysis and mathematical modelling, which are crucial for real-world applications, may be underrepresented. This imbalance may prevent students from gaining a holistic mathematical education that prepares them for interdisciplinary challenges. The dilemma thus persists as students still need to develop a solid understanding of traditional mathematics concepts to be able to apply them in different transversal contexts. Figure 3.1 and Figure 3.2 show the change in average instruction time in mathematics between 2011 and 2023 in primary and lower secondary education. Figure 3.1 reveals, with the exception of a few countries/jurisdictions – such as Czechia, the French Community of Belgium, Türkiye, Ireland and Germany – most countries/jurisdictions saw either no change or a slight decrease in the average compulsory instruction time dedicated to mathematics in primary education over the past 12 years. Similarly, Figure 3.2 shows that only a handful of countries, including Denmark and Italy, saw an increase in mathematics instruction time at the lower secondary level, while it remained stable in most other countries/jurisdictions with available data. These instruction hours translate to around 16% of total instructional time in primary education and 13% in lower secondary education dedicated to mathematics in 2023 on average across OECD countries/jurisdictions (OECD, 2023[16]).

Figure 3.1. Change in average instruction time in mathematics in primary education between 2011 and 2023



Source: Adapted from OECD (2023[16]) *Education at a Glance 2023: OECD Indicators*, OECD Publishing, Paris, https://doi.org/10.1787/e13bef63-en and OECD (2013[17]) *Education at a Glance 2013: OECD Indicators*, OECD Publishing, Paris, https://doi.org/10.1787/eag-2013-en.

Figure 3.2. Change in average instruction time in mathematics in lower secondary education between 2011 and 2023

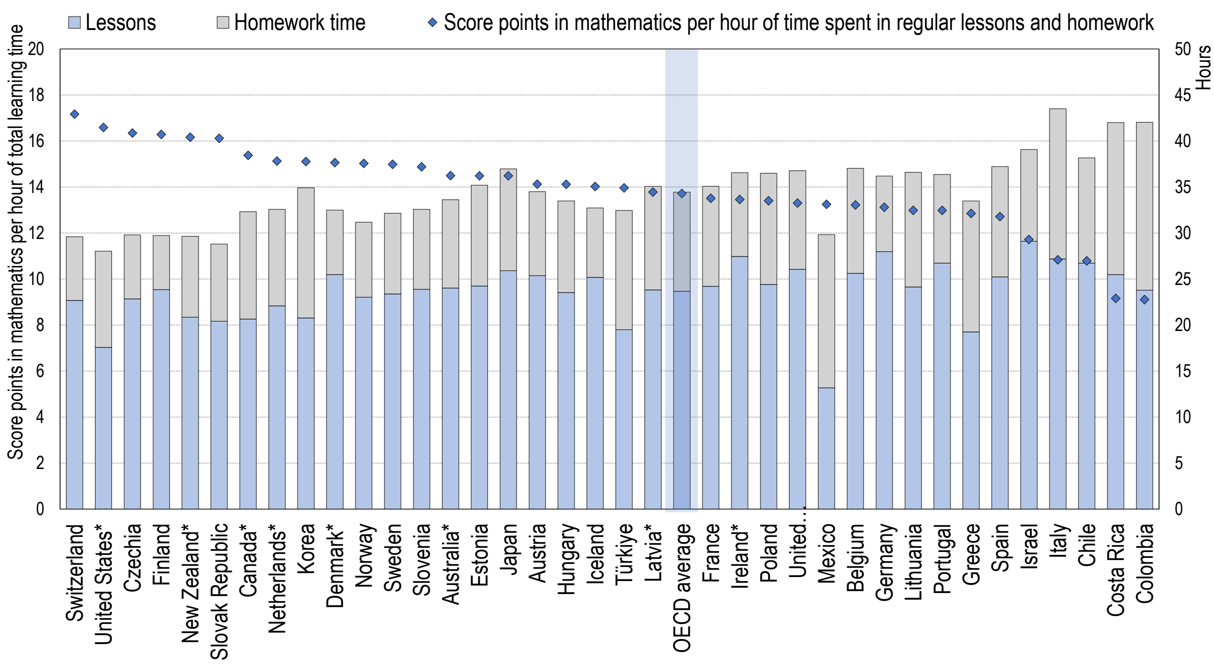


Source: Adapted from OECD (2023[16]) *Education at a Glance 2023: OECD Indicators*, OECD Publishing, Paris, https://doi.org/10.1787/e13bef63-en and OECD (2013[17]) *Education at a Glance 2013: OECD Indicators*, OECD Publishing, Paris, https://doi.org/10.1787/eag-2013-en.

Responding to demands for curriculum expansion (incorporation of new content and competencies into curriculum) by increasing instruction time may not only be unrealistic given the relative stability of instruction time in most countries, it may also be counter-productive. International data also show that excessive time spent on learning activities (in and outside of school) is not necessarily related to better students' outcomes (Figure 3.3). In fact, students in several high-performing systems spend less time on learning activities than their peers in lower-performing countries. The quality of their learning time is clearly more important than the number of hours they spend on it (OECD, 2023[18]).

Figure 3.3. Mathematics performance and time spent on learning activities

Based on students' reports



Notes: *Caution is required when interpreting estimates because one or more PISA sampling standards were not met (see Reader's Guide, Annexes A2 and A4).
Countries and economies are ranked in descending order of the score points in mathematics per hour of total learning time.
Source: OECD (2023[18]), *PISA 2022 Results (Volume II): Learning During – and From – Disruption*, PISA, OECD Publishing, Paris, https://doi.org/10.1787/a97db61c-en.

Curriculum expansion can result in content overload as mathematics curricula typically cover a wide range of essential topics like numbers, algebra and geometry. When additional subjects or topics are added, the breadth of the curriculum increases, potentially at the cost of depth of learning. Teachers may be forced to skim through important mathematical concepts to keep pace with the breadth of material, making it difficult for students to develop a deep understanding of foundational knowledge.

Incorporating modern competencies alongside traditional mathematical content can also lead to a curriculum imbalance. For instance, while fields like algebra and geometry may dominate the curriculum, newer areas like data analysis and mathematical modelling, which are crucial for real-world applications, may be underrepresented. This imbalance may prevent students from gaining a holistic mathematical education that prepares them for interdisciplinary challenges. The dilemma thus persists as students still need to develop a solid understanding of traditional mathematics concepts to be able to apply them in different transversal contexts.

Other sources of curriculum overload may come from the sheer size of curriculum documents and from teachers' interpretations about what they believe needs to be covered in a school year. For example, content overload is often linked to the extensive size of curriculum-setting statutory documents, which can include a vast amount of subject content and objectives. Several studies have noted that the physical size of curriculum documents can contribute to **perceived overload** (FitzPatrick and O' Shea, 2013[19]; Voogt, Nieveen and Klopping, 2017[20]; Hong and Youngs, 2019[21]). The more pages and words these documents contain, the longer it takes for teachers to comprehend the curriculum requirements. The extensive documentation can be a strong indicator of general overcrowding, suggesting that the more detailed and voluminous the curriculum documents, the more challenging it becomes for educators to quickly grasp and implement the required teaching objectives effectively, and not be overwhelmed by their volume.

Perceived curriculum overload, on the other hand, refers to the sense among teachers and students that the curriculum demands more than what can be reasonably managed with the given time and resources (OECD, 2020[2]; Kuiper, Nieveen and Berkvens, 2013[22]). Unlike actual overload, which arises from an objectively excessive curriculum, perceived overload often stems from subjective experiences shaped by the number of topics to be covered, the frequency and type of assessments and learning materials, and school expectations (OECD, 2020[2]). In mathematics, the intense focus on high-stake assessments can drive teachers to cover more material than required, prioritising test preparation over deeper, more meaningful learning. This "teaching to the test" culture, combined with a reliance on extensive textbooks and frequent assessments, creates an overwhelming experience for students and challenges that are difficult for policymakers to address as these pressures are often deeply embedded within local educational practices (OECD, 2020[2]; Jennings and Bearak, 2014[23]). Research has suggested that some design principles can be used by policymakers and curriculum designers in order to minimise the risks of curriculum overload. They are described as follows.

Key design principles to minimise maths overload

Three curriculum design principles can be applied as a strategy to avoid mathematics curriculum overload: ***focus***, ***rigour*** and ***coherence***. These principles provide a framework for balancing the integration of new demands, such as the incorporation of 21st-century competencies, with traditional content, ensuring that curricula remain both manageable and impactful. Each of the three principles has its own challenges for implementation and should be used jointly to avoid unintended consequences of using them in isolation (OECD, 2020[2]).

Focus: Prioritising key mathematical concepts

To mitigate the effects of curriculum overload, focus becomes a crucial design principle. Instead of expanding the curriculum by adding numerous new topics, emphasis should be placed on fewer, high-leverage ideas. For example, data literacy, an increasingly essential skill, can be embedded within core mathematical topics such as descriptive statistics and probability distributions. By concentrating on a smaller number of key mathematical concepts, students can explore these topics in greater depth, resulting in better mastery and application of knowledge. In-depth focus on a smaller number of key ideas is positively associated with student performance in the Trends in International Mathematics and Science Study (TIMSS) at 9 and 13 years of age (Schmidt et al., 2001[24]). More emphasis on teaching for conceptual understanding also positively associates with high achievement (OECD, 2020[2]; OECD, 2013[25]; Echazarra et al., 2016[26]). An example of how curriculum overload can be mitigated by focusing on key or "big" ideas in mathematics can be seen in Box 3.5.

Big ideas are key concepts that are essential for foundational knowledge, that are transferable to other topics in mathematics or other learning areas, that endure over time and appear in basic as well as in advanced topics (OECD, 2020[2]).

Focusing on big ideas as an approach to mitigate curriculum overload can be challenging, as it may meet resistance from stakeholders who wish to defend their specific subjects or interests. Reducing content can also be perceived as lowering educational standards, risking backlash that could result in future curriculum expansions or increased instructional time (OECD, 2020[2]). Decisions to streamline an overcrowded curriculum can benefit from the involvement of stakeholders to avoid such pitfalls.

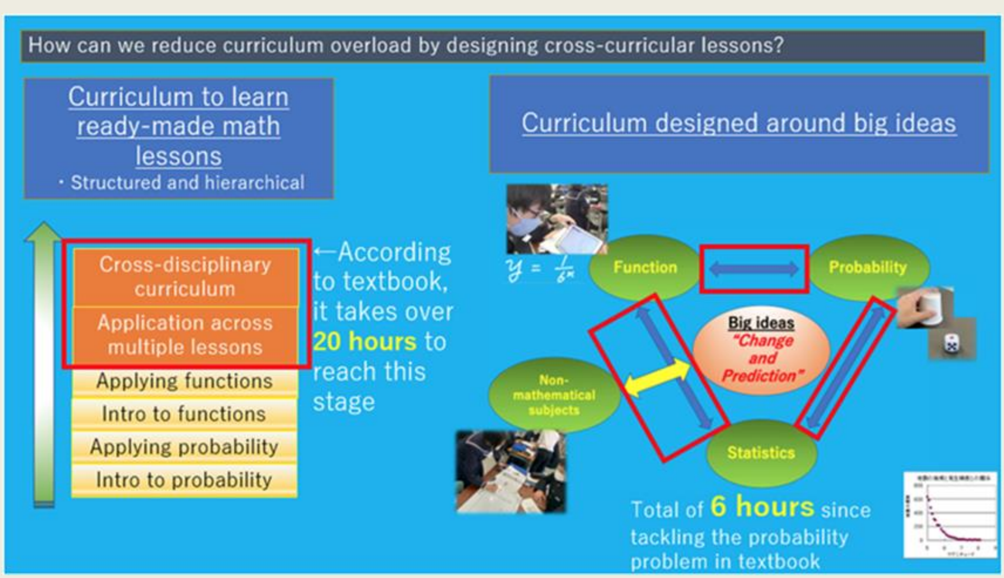
Box 3.5. Addressing curriculum overload by focusing on big ideas: An example from a junior high school mathematics teacher in Japan

At Compulsory Education School affiliated with University of Fukui in Japan, mathematics teacher, Ikkyu, has been leading efforts to redesign the school's mathematics curriculum, making a shift to cross-curricular content and a competency-based curriculum. Ikkyu's work is shaped by the question, "Why do we learn and teach mathematics?". Expanding the reasons to do so can cultivate the agency of students and teachers to learn and teach mathematics. For example, they might teach and learn something because it is in a textbook or because it will be in on a test, but they can go beyond such a notion and teach students how mathematics contributes to the well-being of society.

When designing cross-curricular classes within this traditional framework – e.g. application across multiple lessons, applying functions, introduction to functions, applying probability and introduction to probability – teachers feel that they must teach more. They voice dilemmas such as: "It takes time to master the basics, so cross-curricular classes are perceived to be for the privileged schools", "For children who are not good at math, we provide drill-based lessons", and "It's all I can do to finish math textbooks".

To help address teachers' concerns about curriculum overload with a cross-disciplinary curriculum, Ikkyu and his colleagues are designing their curriculum centred on "big ideas". The concept of big ideas increasingly appears in curricula as a way to highlight essential ideas that, approached from different angles, are crucial to multiple learning areas. In schools of British Columbia (Canada), for example, "change" is one of several big ideas taught across learning areas in the curriculum, including arts education, social studies, science, health/physical education and mathematics. Ikkyu's work focuses on "change and prediction" as a big idea: the re-designed curriculum crosses probability, functions, statistics and non-mathematical subjects.

Addressing curriculum overload



In the traditional 3-step curriculum, cross-disciplinary lessons come after teaching probability, inverse proportionality, and exponential law, taking about 20 hours. However, in their curriculum, they focus on "change" and "prediction" as big ideas, allowing them to introduce cross-disciplinary lessons in just 6 hours. This doesn't mean students learn all the 20-hour content in 6 hours, but rather, the big ideas provide context, enabling them to connect learning across different units, subjects and grade levels. By linking mathematics to real-life issues, students see the relevance, learn faster and deepen their understanding of mathematical concepts.

Source: Presentation by Ikkyu Yanagimoto, mathematics teacher, Toyo Junior High School, Japan on 27 January 2022 for a workshop on co-producing the OECD Future of Education and Skills 2030 mathematics curriculum analysis publication.

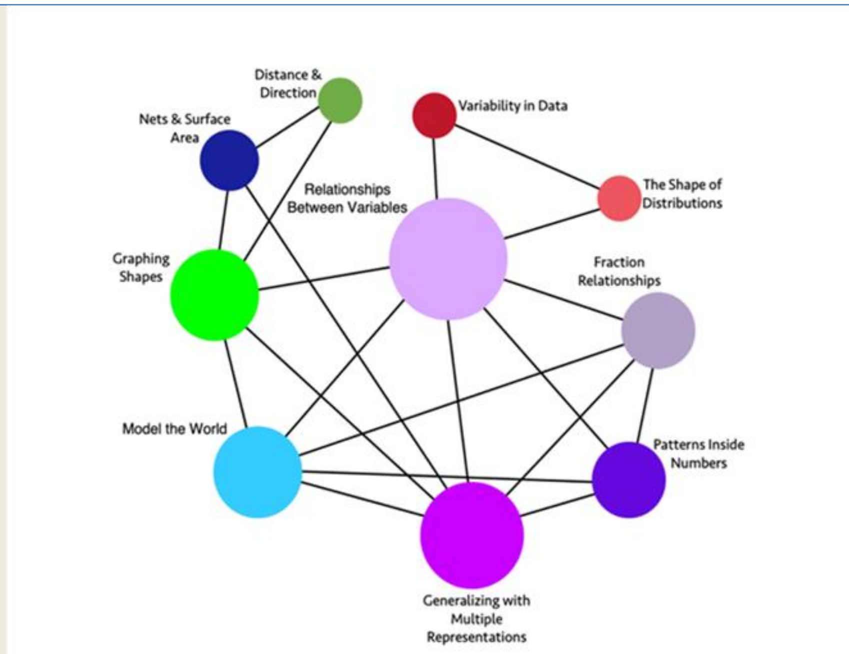
Another example of how curriculum overload can be addressed by focusing on key or "big" ideas in mathematics can be seen in Box 3.6.

Box 3.6. Use of big ideas in the California Mathematics Framework

The California Mathematics Framework was unanimously accepted into policy in July of 2023. It was developed by a committee of 20 teachers and leaders appointed from across the state of California, with input and advice provided over four years of development by hundreds more participants. The Framework recommended that instead of focusing primarily on a disparate set of individual Common Core mathematics standards, teachers should instead focus on big ideas and connections amongst the Common Core standards. Thus, the standards were organised into four content connections, spanning all of K-12, and further organised at each grade level into conceptual Big Ideas, with each Big Idea containing multiple grade-level standards. The Big Idea maps (see grade 6 below) illustrated the connections between Big Ideas in which the size of the node reflects the number of standards shared with other big ideas. The organisation of individual standards into each Big Idea was presented in an accompanying table (excerpt below). The Framework did not change any mathematics content standards and also expanded upon process standards by including consideration of authentic engagement in task design, amidst other advice on teaching. The advice included:

- plan teaching of big ideas;
- use open, engaging tasks;
- teach towards social justice;
- invite student questions and conjectures;
- prioritise reasoning and justification.

The Framework also emphasised that all students have the potential to go to high levels of understanding, and students should not be tracked into different, immoveable pathways in elementary school. It also showed ways to integrate data throughout the grades as well as the coherent development of number sense through the grades instead of timed tests and memorisation. The framework received some resistance, particularly from high-achieving STEM professionals and privileged parents who opposed any changes in mathematics and mobilised against it through the media and other means. State leaders responded by referring to research evidence and by thoughtfully considering feedback given through the state's established statutory process. The Framework was ultimately ratified by the State Board of Education on July 13, 2023, and passed with strong support from educators and equity-minded STEM professionals across the state.



Content Connection	Big Idea	Grade Six Content Standards
Reasoning with Data	**Variability in Data**	**SP.1, SP.5, SP.4:** Investigate real world data sources, ask questions of data, start to understand variability - within data sets and across different forms of data, consider different types of data, and represent data with different representations.
Reasoning with Data	**The Shape of Distributions**	**SP.2, SP.3, SP.5:** Consider the distribution of data sets - look at their shape and consider measures of center and variability to describe the data and the situation which is being investigated.
Exploring Changing Quantities	**Fraction Relationships**	**NS.1, RP.1, RP.3:** Understand fractions divided by fractions, thinking about them in different ways (e.g., how many 1/3 are inside 2/3?), considering the relationship between the numerator and denominator, using different strategies and visuals. Relate fractions to ratios and percentages.
Exploring Changing Quantities	**Patterns inside Numbers**	**NS.4, RP.3:** Consider how numbers are made up, exploring factors and multiples, visually and numerically.

Source: Submitted by Brian J. Lindaman, PhD, Professor of Mathematics Education, Writing Team Lead for the 2023 California Mathematics Framework, K-12, Dept of Mathematics and Statistics, California State University, Chico.

Rigour: Ensuring depth and challenge

It is important to aim for a sensible balance between breadth and depth of content in curricula. Breadth means the number of subjects included in the curriculum and the number of topics to be taught within subjects. Depth means the degree to which students have opportunities to explore and understand what they are learning, to solve problems and to connect ideas. Rigour aims to ensure the latter; it is about maintaining challenging content that promotes deep thinking and reflecting (Schmidt, Wang and McKnight, 2005[27]). This implies that curriculum goals must include application of knowledge and skills, along with application of conceptual knowledge, to realistic situations and transfer to unfamiliar contexts. While instructional focus is facilitated by reduction of content to a small number of key ideas, rigour requires deliberate prescription in curriculum documents and resources that support the curriculum.

In a mathematics curriculum that integrates 21st-century competencies, deeper understanding can be encouraged by linking conceptual knowledge to real-world applications. For example, computational thinking and data science can be embedded into core topics. Computational thinking can be introduced through algorithmic problem solving in algebra, where students write simple algorithms to solve equations or model real-world scenarios using programming. Moreover, interdisciplinary connections to STEM fields are becoming increasingly important. Integrating these skills not only strengthens the mathematics curriculum but also equips students with the necessary problem-solving skills for today's digital world. This approach ensures that students engage in cognitively demanding tasks while mastering key concepts like algebra and geometry. In PISA, teaching strategies identified with conceptual understanding are associated with higher student performance (OECD, 2013[25]). They are captured by the index of cognitive-activation instruction, composed of students' answers to the following prompts:

- The teacher asks questions that make us reflect on the problem.
- The teacher gives problems that require us to think for an extended time.
- The teacher asks us to decide on our own procedures for solving complex problems.
- The teacher presents problems for which there is no immediately obvious method of solution.
- The teacher presents problems in different contexts so that students know whether they have understood the concepts.
- The teacher helps us to learn from mistakes we have made.
- The teacher asks us to explain how we have solved a problem.
- The teacher presents problems that require students to apply what they have learned to new contexts.
- The teacher gives problems that can be solved in several different ways.

To further strengthen the curriculum, it is crucial to emphasise the balance between procedural fluency – a skill often prioritised in vocational and basic education programmes – and deeper conceptual understanding. This focus ensures that students not only learn how to perform mathematical operations but also understand the underlying concepts, which is essential for developing higher-order competencies that are often overlooked in less-advanced educational settings (OECD, 2024[28]).

Like any other design choice, the implementation of a rigorous curriculum poses several challenges, such as **balancing rigour with accessibility**. If a curriculum is too rigorous, it risks alienating students, particularly those from disadvantaged backgrounds who may not have access to the same resources or support as their peers. A curriculum that is overly challenging can lead to frustration, disengagement and even increased dropout rates among students who struggle to keep up with the pace and demands of the content. Achieving the right balance between focus and rigour is therefore essential (OECD, 2020[2]).

Coherence: Connecting topics and competencies

A well-designed curriculum must also exhibit coherence, which involves organising learning in a logical progression that connects topics and competencies. Coherence in mathematics curriculum can be understood in terms of vertical and horizontal connections. **Vertical coherence** refers to the logical progression of mathematical ideas through different grade levels. This can support students to build upon previous knowledge and progress from earlier to later grades. **Horizontal coherence** refers to making connections between different mathematical topics within the same grade (to support students in seeing how various mathematical concepts are interrelated) (Peters, 2024[29]; Schmidt, Wang and McKnight, 2005[27]).

Coherence is also reflected in the way curricula integrate topics, as well as in the way that progression is organised. Reduction to a small number of key ideas facilitates important connections. For example, calculation with decimals might be taught though measurement situations. Properties of two- and three-dimensional shapes and measurement of attributes such as perimeter, volume and surface area might be learned together. Geometric pattern, especially growing and repeating sequences, might be used to develop relations at all levels.

When adding new content or removing old content from the curriculum, it is crucial to maintain the coherence of the curriculum, ensuring that key concepts are built upon across grades and subjects without unnecessary overlap or gaps in learning. Eliminating redundancies (unnecessary repetition) is crucial, and requires good judgement, since mastering of certain topics and ideas in mathematics does require some practice and repetition in order to automate sequences of steps, thus supporting greater levels of proficiency (Jablonka and Bergsten, 2021[30]). This often means that subject experts work together to manage cross-disciplinary co-ordination and to ensure that the integrity and logic of individual disciplines are preserved.

The spiral curriculum, introduced by Bruner (1960[31]), plays a key role in achieving coherence by reintroducing key topics over time with increasing complexity. This approach is particularly effective in mathematics, where foundational concepts such as number sense, algebra and geometry need to be revisited and expanded upon as students advance in their learning trajectory. The spiral design ensures that students do not merely encounter topics once but build a deeper understanding of them as their knowledge and cognitive abilities develop. In mathematics education, coherence is crucial for enabling students to connect new learning with what they have previously mastered. The spiral approach reduces the need for extensive review by trusting that prior learning has been effectively absorbed, allowing for more instructional time to be dedicated to exploring new applications or deeper facets of a concept.

Moreover, research on **learning trajectories**, such as that by Clements and Sarama (2020[32]), provides a strong foundation for improving coherence in curricula; trajectories map out typical pathways that students follow in developing mathematical thinking, offering guidance on when and how to introduce particular concepts. Coherence is enhanced when curriculum designers align content with these trajectories, ensuring that the progression of topics is developmentally appropriate. However, a challenge arises in the varied nature of research on learning progressions. Studies may differ in terms of age groups, methodologies and content focus, making it difficult to create a unified approach. Nonetheless, ongoing research promises to integrate these findings into a more cohesive framework for curriculum design.

By applying all three principles: **focus, rigour** and **coherence** together, policymakers can design mathematics curricula that balance depth with breadth, ensuring that students develop essential 21st-century competencies along with key mathematical knowledge without risking curriculum overload.

Adapting mathematics curriculum to help bridge equity gaps

Equity in education seeks to ensure that every student has access to the resources, opportunities and support needed to reach their full potential. Unlike equality, which involves the provision of the same level of resources to all students, equity tailors these resources to meet individual needs, recognising that diverse learners may require varied levels of support to succeed (OECD, 2021[3]). Meanwhile, inclusion in curriculum development aims to provide every learner with a high-quality curriculum that allows them to achieve their full potential, embracing their diverse characteristics, needs, abilities and expectations. This approach focuses on removing structural and cultural barriers, including bias and discrimination (OECD, 2021[3]).

Equity gaps in mathematics performance

Despite ongoing efforts, achieving equity in mathematics education remains a work in progress across OECD countries. Certain student sub-groups confront unique barriers, contributing to persistent achievement gaps. PISA results over the years on learning and equity have consistently highlighted that female students, socio-economically disadvantaged students, students with an immigrant background, and students with special education needs frequently underperform in mathematics compared to their peers. Moreover, the design of educational pathways can further exacerbate these equity gaps. Students who struggle in school, particularly in mathematics, are frequently guided toward vocational education and training (VET) programmes or lower-level academic classes, which typically set limited expectations for developing higher-order competencies such as mathematical reasoning and problem solving. In contrast, educational systems that integrate these competencies across all levels, as observed in countries like Ireland and Poland, suggest potential strategies for reducing these gaps (OECD, 2024[28]).

Gender gap

The gender gap in mathematics performance, as reported by both PISA and TIMSS, highlights ongoing disparities, though the extent varies by region and educational level. According to PISA 2022, boys scored an average of nine points higher than girls in mathematics across OECD countries, a gap that has remained largely unchanged since 2018 due to declining performance for both genders (OECD, 2023[33]).

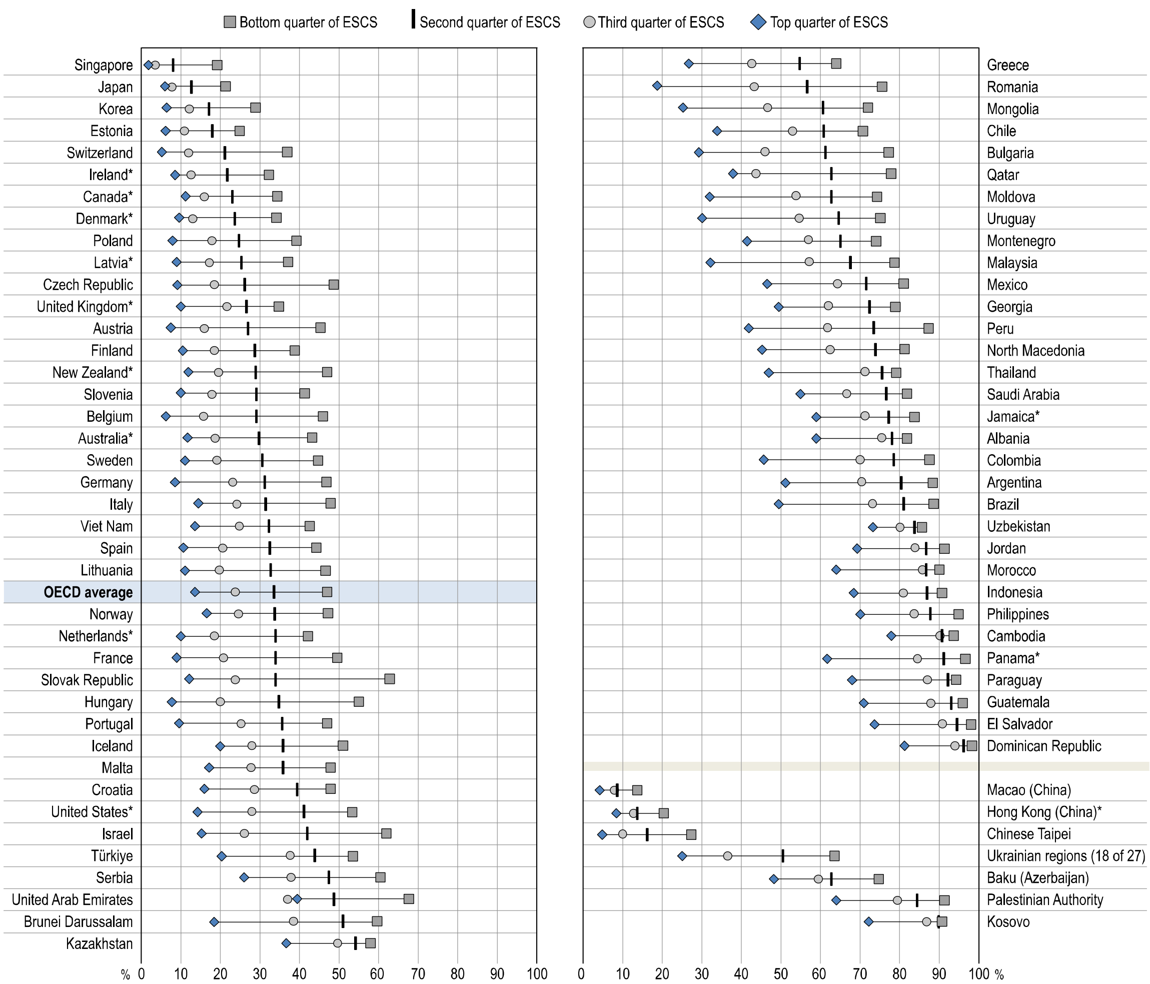
Similarly, TIMSS 2019 data from 4th-grade assessments found that boys tended to outperform girls in close to half of the participating countries, with girls scoring higher in only a few countries, and about half of countries showing no gender difference. By 8th grade, gender equity was even more prominent, with most countries showing little to no difference in average achievement between boys and girls, although a few leaned toward either boys or girls performing better. Over time, TIMSS data show that gender gaps tend to remain stable within countries, although some nations like Chinese Taipei, England, and Hong Kong (China) have successfully closed gaps that previously favoured boys, while others, including Germany and Singapore, saw new or widening gaps favouring boys from 2015 to 2019 (Mullis et al., 2020[34]).

Socio-economic gap

The socio-economic gap in mathematics performance is a significant issue across educational systems. PISA 2022 data reveal that nearly half (47%) of socio-economically disadvantaged students scored below proficiency Level 2 in mathematics, compared to only 14% of their advantaged peers – a notable 33 percentage-point difference on average across OECD countries (see Figure 3.4). In some cases, this gap is even more pronounced; for example, it exceeds 50 percentage points in Romania and the Slovak Republic. PISA's socio-economic gradient metric further illustrates this disparity, with a steeper gradient indicating greater inequity in educational outcomes (Willms, 2006[35]). TIMSS indirectly measures socio-economic status through indicators like the availability of educational resources at home, the number of books, internet access and parents' education levels. Findings consistently show that students from homes with more educational resources tend to achieve higher in mathematics and science at both the 4th and 8th-grade levels (Mullis et al., 2020[34]).

Figure 3.4. Low performers in mathematics, by socio-economic status

Percentage of students who scored below proficiency Level 2, by national quarters of the PISA index of economic, social and cultural status (ESCS)



Note: Only countries and economies with available data are shown. Countries and economies are ranked in ascending order of the share of low performers in mathematics for students in the second quarter of national socio-economic status.
Source: OECD (2023[33]) *PISA 2022 Results (Volume I): The State of Learning and Equity in Education*, OECD Publishing, Paris, https://doi.org/10.1787/53f23881-en.

Immigration and ethnic/racial gap

PISA data also highlight a consistent "immigration gap" in mathematics performance, where non-immigrant students score, on average, higher than immigrant students. This gap is notably influenced by socio-economic and linguistic barriers faced by immigrant students. Before accounting for these factors, non-immigrant students across OECD countries scored 29 points higher than their immigrant peers, but the gap reduced to 15 points after adjusting for socio-economic status and further to 5 points when considering language spoken at home (OECD, 2023[33]).

Special education needs gap

Students with special educational needs (SEN) face significant challenges in their mathematics learning. While international comparative data on mathematics achievement for SEN students is not readily available – largely due to varying definitions and classifications across countries – national studies suggest that these students consistently perform below their peers in mathematics (Gottardis, Nunes and Lunt, 2011[36]) (Gottardis, Nunes and Lunt, 2011[36]; Mazzocco et al., 2013[37]). This gap is largely due to the unique challenges these students face, which require specialised support and resources. The OECD categorises SEN into three broad groups: learning disabilities, physical impairments, and mental health conditions (OECD, 2023[38]) – all of which can have an impact on students' ability to learn mathematics.

Learning disabilities are neurological conditions that affect skills such as language processing, mathematical calculations, and attention. Common learning disabilities include dyslexia, dyscalculia, dysgraphia, and Auditory Processing Disorder, which can significantly impact mathematical understanding. For example, students with dyscalculia may struggle with basic numerical concepts, making it difficult to progress in mathematics without tailored support (Chen and Li, 2014[39]; Mazzocco et al., 2013[37]).

Physical disabilities can affect students' ability to access information and participate in classroom activities. For instance, students with visual impairments may struggle with interpreting visual aids, a common feature in mathematics instruction, while those with hearing impairments may face challenges in following verbal instructions (Gottardis, Nunes and Lunt, 2011[36]; Spinczyk et al., 2019[40]).

Mental health issues, such as anxiety disorders, ADHD and Autism Spectrum Disorder, also impact students' learning experiences. These conditions can affect focus, impulse control and social interactions, all of which are essential for engaging with complex mathematical tasks (Bullen et al., 2020[41]; Oswald et al., 2015[42]). Furthermore, the school environment itself can contribute to mental health challenges, with factors like bullying and social isolation exacerbating conditions like anxiety and depression, which in turn hinder academic progress (Samara et al., 2021[43]; Yu and Zhao, 2021[44]).

Addressing equity gaps

Addressing equity in mathematics education requires rethinking traditional teaching methods. Research highlights the need to create an inclusive environment that recognises and supports the diverse needs of learners (Gervasoni and Lindenskov, 2010[45]; Lambert, 2021[46]). To effectively address these gaps, teachers would need comprehensive training on the factors that exacerbate performance disparities. This includes understanding how reminding students of their group identity can lead to stereotype threat, a phenomenon that has been shown to negatively impact student performance (Beilock, 2008[47]; Beilock, Rydell and McConnell, 2007[48]). Other critical factors include the strategic choice of materials that avoid reinforcing stereotypes, managing time pressure to reduce anxiety, providing supports for executive function and self-regulation, and ensuring even availability of accommodations like text-to-speech. Such measures are essential for fostering a supportive and equitable learning environment.

Building on the need for comprehensive teacher training and awareness, one approach that has been found effective in promoting equity and inclusion is the implementation of Universal Design for Learning (UDL), which provides a framework for designing flexible learning environments that cater to all students. Universal Design for Learning (UDL) is a framework that aims to make education accessible for all students by designing curricula and learning environments to meet diverse needs (Meyer and Rose, 2000[49]). UDL emphasises removing learning barriers through three main principles: engagement (the "why" of learning), representation (the "what" of learning), and action and expression (the "how" of learning). These principles can guide educators to create more inclusive learning experiences by offering various ways to engage with content, represent information and demonstrate understanding. While UDL has been successfully implemented to support students with special needs, its adaptable nature makes it beneficial for all learners, fostering an inclusive educational environment (OECD, 2021[3]).

In mathematics, UDL can help bridge equity gaps by accommodating learner diversity. For example, engagement strategies might involve adapting to students' interests and providing real-world problem-solving contexts to enhance motivation. Representation can incorporate visual aids, multi-lingual resources, or adaptive digital tools to support comprehension (Lambert, 2021[46]; Abrahamson et al., 2018[50]). Lastly, varied methods of expression, such as interactive tasks or collaborative projects, allow students to demonstrate their understanding in ways that best suit their abilities (Lambert et al., 2021[51]). By designing with UDL, mathematics education can move away from a one-size-fits-all approach, instead supporting all learners – especially those from marginalised backgrounds or with learning disabilities – to access and excel in meaningful mathematical experiences.

To address the equity gaps present in mathematics education, many OECD member and partner countries, schools and teachers are adopting specific curriculum innovations designed to make mathematics curricula more inclusive and relevant for diverse learners. The E2030 report on adapting curriculum to bridge equity gaps (OECD, 2021[3]) identifies four major types of curriculum innovations that, when carefully designed and implemented, can help transform mathematics education to better meet the needs of all students in the 21st century:

- digital curriculum;
- personalised curriculum;
- cross-curricular content and competency-based curriculum;
- flexible curriculum.

Digital curriculum

In mathematics education, a digital curriculum holds the potential to address equity gaps by making learning more accessible for students with diverse needs, including those with special educational needs. By incorporating assistive technologies – such as screen readers, motion and voice recognition apps, Braille devices, augmented reality, AI and wearable tech – a digital curriculum can offer tailored support for students who face unique learning challenges, as well as enhance learning for all students.

Furthermore, digital tools can personalise learning pathways through interactive tutoring systems that deliver real-time, continuous feedback, allowing students to progress at their own pace. For teachers, learning analytics and Big Data provide valuable insights for early identification of learning difficulties, enabling more responsive goal setting and targeted support for individual learners. Digital curricula can also engage students at risk of disengagement or dropout by integrating gamified learning experiences and virtual reality.

Digital textbooks can also add another layer of support, especially for low-performing students, by enabling them to move back and forth across different grade-level content. This flexibility allows students to revisit foundational concepts they may have struggled with, providing a scaffolded learning experience that strengthens understanding and confidence.

Strategic implementation of digital technology in curriculum design thus enables more equitable learning opportunities beyond those possible in traditional, face-to-face mathematics environments. Many countries are already leveraging digital platforms to host and access documents and resources (such as Chile's Aula 360 platform, focused on mathematics, see Box 3.7), using tools like e-texts, videos and interactive learning objects. In the PQC survey of 31 OECD countries, 71% reported adopting or developing digital tools, including virtual learning environments (OECD, 2021[3]). Furthermore, the potential of artificial intelligence and augmented reality is beginning to be explored to personalise learning experiences based on data gathered from students' interactions with digital resources.

Box 3.7. Chile's Aula 360 digital and interactive platform

In a globalised and interconnected world, new ways of learning and teaching math classes are required for young people. The digital and interactive platform "Aula 360" was created in 2019 under the guidance of the Ministry of Education of the Republic of Chile.

Aula 360 offers contextualised and problem-based learning, using digital tools to promote the learning of geometry, calculus and statistics. The platform delivers permanent feedback and develops the autonomy of students to organise their learning. It offers suggestions for the evaluations at the end of each unit and for each session it offers exit tickets to evaluate the achievement of learning.

In 2021, 141 establishments accessed the platform, with a total of 417 teachers and 3 715 students from 11th and 12th grade. Establishments can access this platform as a support for teaching three of the new subjects of the "Humanistic-Scientist" plan:

- 3D geometry;
- limits, derivates and integrals;
- probabilities and descriptive and inferential statistics.

The use of this platform in the pilot year has made an excellent impression, mainly because the presented situations are really relatable to students and are designed to build mathematical knowledge during the different sections.

Source: OECD Future of Education and Skills 2030. Example submitted by the Ministry of Education of Chile.

Personalised curriculum

A personalised curriculum, also known as an individualised or tailored curriculum, aligns learning opportunities with the unique needs, skills, interests, learning preferences and cultural backgrounds of students (Pane, 2017[52]). By adapting content to each student's starting point and goals, personalised curricula can effectively address equity gaps, providing a tailored pathway that meets diverse learners where they are and supports their progress. Personalised approaches to mathematics have been shown to help students' performance in mathematics (Prain et al., 2013[53]).

For students with SEN, personalisation ensures that educational strategies are aligned with individual learning profiles. This might involve setting specific learning goals and using resources suited to the students' needs, such as tactile learning aids for students with sensory impairments or cognitive support for students with learning disabilities like dyscalculia. For students from different linguistic and cultural backgrounds, a personalised curriculum respects and incorporates students' identities by offering mathematics content that is culturally relevant and linguistically accessible. This approach can involve translating materials or integrating cultural examples within mathematics problems, helping students see themselves within the curriculum, inspiring increased engagement.

Furthermore, personalised curricula address socio-economic gaps by recognising the varied experiences of students from different backgrounds (Prain et al., 2013[53]). Teachers can adapt tasks to reflect real-world contexts that are familiar to students or use adaptive technology to provide timely feedback based on individual progress. For students from low-income backgrounds, early and targeted interventions in foundational mathematical skills can make a significant difference in closing gaps over time, enabling students to build confidence and resilience in mathematics.

Cross-curricular approach/competency-based curriculum

Adopting a cross-curricular and competency-based approach to mathematics education can also play a pivotal role in addressing equity gaps in mathematics. This approach allows mathematics to be integrated with other disciplines, making learning more meaningful and accessible to a diverse range of students by demonstrating the practical and interdisciplinary applications of mathematical concepts.

For students from socio-economically disadvantaged backgrounds or minority groups, cross-curricular content can provide authentic learning experiences, connecting mathematics with real-world contexts that resonate with their lived experiences. This approach can also enhance motivation and engagement by presenting mathematics not as an isolated subject but as a tool for solving practical problems across disciplines like science, literacy and social studies. For instance, inquiry-based learning, which is commonly used in science, can be adapted in mathematics to involve students in exploring mathematical concepts through real-life problem solving and argumentation. As an example, students could use statistical methods to analyse air quality data collected from different city areas, allowing them to apply mathematical concepts directly to meaningful community issues and enhancing their skills in argumentation and knowledge construction. Research indicates that such an integrative curricula, can have positive impacts on learning outcomes for low-income and minority students (Hand et al., 2018[54]; Tong et al., 2014[55]; Thadani et al., 2010[56]).

Competency-based curricula can further address equity gaps by focusing on skills that can be applied across various contexts, including critical thinking and problem solving. For example, a mathematics program designed for students with SEN might employ a competency-based approach by integrating explicit instruction with hands-on activities, such as using tactile learning tools to solve algebraic equations. This method allows students to physically engage with the concepts, facilitating a deeper understanding and retention of mathematical principles. Such structured, step-by-step approaches have proven beneficial for all learners, including those with learning disabilities, by providing concrete learning strategies tailored to their unique needs (Therrien et al., 2017[57]).

For cross-curricular approaches to succeed in closing equity gaps, adequate teacher preparation and support are essential. Integrative curricula often require teachers to adopt new pedagogical practices and adapt to interdisciplinary content, which may challenge traditional teaching routines. Professional development opportunities and access to curriculum resources are crucial to ensure that teachers can confidently implement these approaches, ultimately contributing to a more equitable and inclusive mathematics education.

Flexible curriculum

Flexible curricula are another policy approach that has the potential to address equity gaps in mathematics education by adapting to the diverse needs of students, particularly those from disadvantaged or underrepresented backgrounds. While research on flexible curricula is limited and results vary, successful implementations tend to incorporate adaptive instruction and targeted activities that support individual learning trajectories (OECD, 2021[4]). Flexibility, when thoughtfully designed and implemented, allows local education providers to adjust content, pedagogy and assessments to better serve students, enhancing inclusivity and accessibility.

A flexible curriculum enables customisation in multiple areas, such as the time and place of learning, which can greatly benefit students with different socio-economic needs. For instance, flexibility in learning schedules and locations, such as through blended or digital learning models, supports students who might otherwise struggle with traditional school hours due to external responsibilities or accessibility issues (Jonker, März and Voogt, 2020[58]). Such options can be particularly valuable for young carers or those with family responsibilities, creating opportunities to continue education while balancing other life demands.

In addition to flexible learning environments, flexibility in assessment can play a crucial role in achieving equity. By incorporating various assessment formats, educators can more accurately capture students' understanding, especially those with learning disabilities or who struggle in standardised testing environments. Formative assessments, for instance, reduce stress and provide students with ongoing feedback, creating a supportive atmosphere that encourages growth over high-stakes performance (Hayward and Spencer, 2010[59]). For students with special needs, this flexibility allows for alternative forms of demonstrating learning better aligning with their abilities and strengths, embodying principles of UDL.

Flexible curricula can also support diverse mathematical learning pathways and levels, as seen in countries like New Zealand, Ireland and Singapore, where students can choose options suited to their strengths, needs, and future ambitions. For example, Singapore's tiered mathematics levels (H1, H2, and H3) offer clear pathways that help students tailor their education to their goals, potentially reducing disengagement. In contrast, England's post-16 educational framework lacks similarly structured options, representing a potential fragility in addressing diverse student needs compared to other countries (OECD, 2024[28]).

Lastly, flexible curricula that incorporate real-world applications and service learning can engage students from all backgrounds, making mathematics more relevant and accessible. These practical learning opportunities, such as apprenticeships or community-based projects, provide authentic learning experiences that connect mathematical concepts to students' social and cultural contexts, enhancing both engagement and comprehension (OECD, 2021[4]).

Embedding attitudes and values in mathematics curriculum

Attitudes towards mathematics play a critical role in shaping students' learning experiences and their overall performance in the subject. Positive attitudes such as self-confidence, enjoyment and persistence are often linked to better academic outcomes, whereas negative attitudes like anxiety, fear or a lack of interest can severely hinder students' ability to engage with mathematical content (Mazana, Montero and Casmir, 2018[60]; Wen and Dubé, 2022[61]; Berger, Mackenzie and Holmes, 2020[62]). This is especially important as attitudes not only influence how students approach mathematics but also affect their long-term engagement with the subject, determining whether they continue to study mathematics at higher levels or avoid it altogether. A recent UNESCO report states that mathematics education is crucial not only for developing reflective and critical citizens who can handle the mathematical demands of everyday life but also for preparing a sufficient number of mathematicians and scientists capable of meeting the challenges of the contemporary world (UNESCO, 2022[63]). Encouraging students' interest in mathematics so they become lifelong practising mathematicians is therefore important to both their personal well-being and to society as a whole.

Attitudes and values for individual well-being

Students' attitudes towards mathematics are fundamental to their personal development, influencing not only their academic achievement but also their sense of self-confidence, resilience and willingness to engage with challenging material. A positive relationship with mathematics can support students' growth mindsets and their capacity for problem solving, which are beneficial both within and beyond the classroom. This section explores specific factors that shape individual attitudes, such as mathematics anxiety and fear of failure, as well as the significance of fostering teacher competencies to support a positive learning environment.

Attitudes towards mathematics: Hindering factors

Students’ attitudes towards mathematics (ATM) develop in response to their interactions with others and their personal experiences of learning and doing mathematics. Negative experiences can lead to long-term negative reactions towards mathematics. Mathematics anxiety and fear of failure are well-documented in research for their negative impact on learning and on self-confidence.

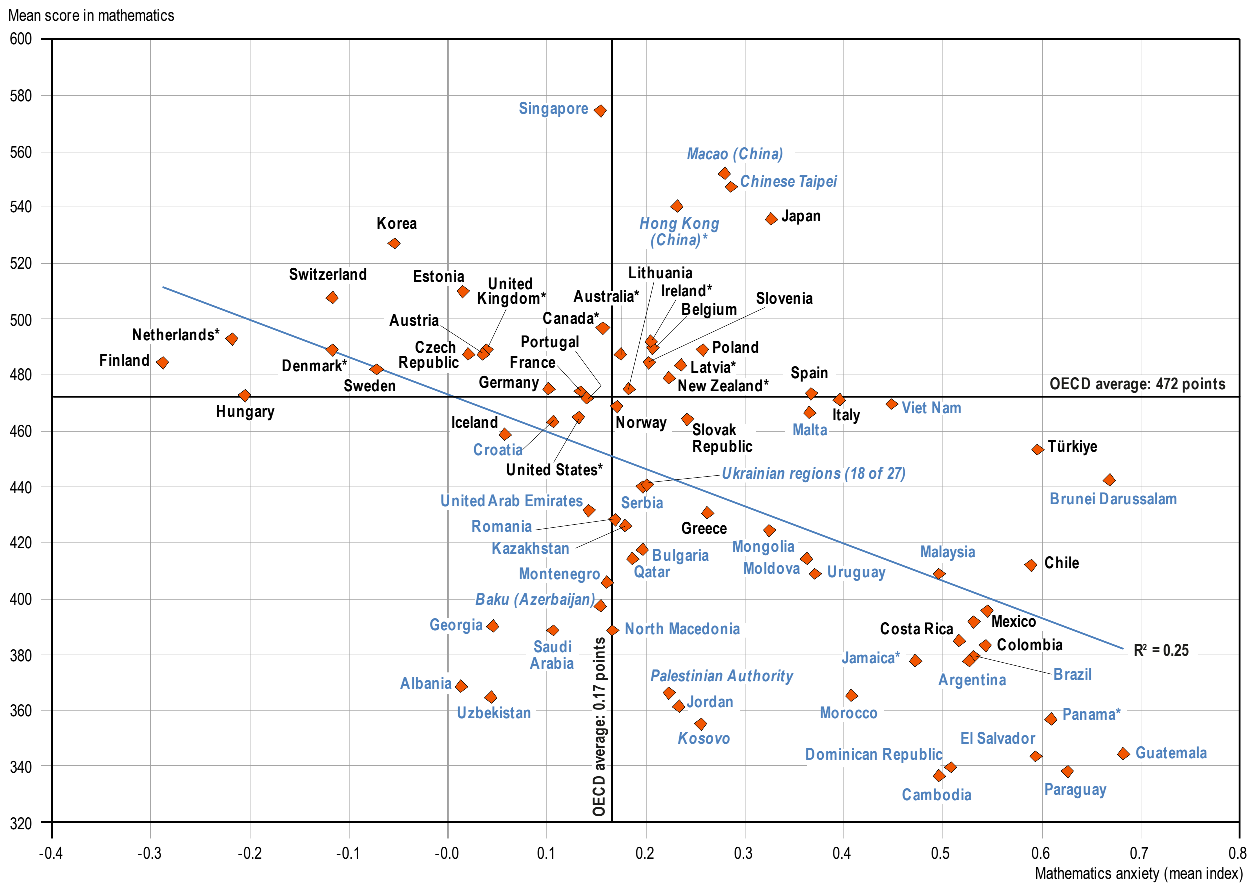
Mathematics anxiety

Mathematics anxiety is a widespread issue that significantly impacts students' academic achievement and long-term engagement with the subject. It is characterised by feelings of stress, tension and apprehension when faced with mathematical tasks, often leading to avoidant behaviour and poor performance (Ashcraft and Kirk, 2001[64]; Richardson and Suinn, 1972[65]). This anxiety can create a self-perpetuating cycle in which students with lower confidence in their mathematical abilities underperform, reinforcing their negative attitudes and increasing their anxiety. Research suggests that mathematics anxiety affects not only day-to-day performance but also long-term decisions regarding further studies or careers requiring mathematical skills (Brown, Brown and Bibby, 2008[66]).

PISA 2022 data reinforce the well-established negative correlation between mathematics performance and anxiety. In every education system that participated in PISA 2022, students with higher levels of mathematics anxiety consistently performed worse than their peers with lower anxiety levels. This relationship holds true regardless of socio-economic status or school characteristics, demonstrating the widespread impact of anxiety on mathematics outcomes (OECD, 2023[33]). On average across OECD countries, a one-point increase in the index of mathematics anxiety corresponds to an 18-point decrease in mathematics performance. Internationally, mathematics anxiety accounts for approximately 25% of the variation in student achievement across countries. This is particularly notable among the 17 countries with the highest levels of mathematics anxiety, all of which performed below the OECD average in mathematics, with 13 of them scoring below 400 points on the PISA scale (see Figure 3.5).

However, Figure 3.5 also shows that top-performing countries exhibit wide variation in levels of mathematics anxiety. For example, while East Asian countries like Japan and Chinese Taipei excel in mathematics, they report higher-than-average levels of anxiety. On the other hand, countries like Denmark, Finland and the Netherlands demonstrate both high performance and lower levels of anxiety.

Figure 3.5. Mathematics anxiety and mean score in mathematics in PISA 2022



Note: Only countries and economies with available data are shown.
Source: OECD (2023[33]) *PISA 2022 Results (Volume I): The State of Learning and Equity in Education*, OECD Publishing, Paris, https://doi.org/10.1787/53f23881-en.

The negative impact is especially pronounced in examination settings where time pressure exacerbates anxiety, contributing to what Ashcraft & Moore (2009[67]) call an "affective drop," where the individual's true mathematical ability is masked by their anxiety. Moreover, mathematics anxiety can result in broader negative effects on students' emotional and psychological well-being. Chronic anxiety around mathematics may contribute to generalised academic stress, affecting overall attitude toward schooling. For many students, their relationship with mathematics becomes one of frustration and avoidance, which can significantly limit their career aspirations in STEM fields and other disciplines requiring quantitative skills (Dowker, Sarkar and Looi, 2016[68]). The role of education systems in addressing mathematics anxiety is crucial. Developing teacher competencies in identifying and managing this anxiety, promoting positive mathematical attitudes, and fostering a supportive learning environment is essential for improving outcomes. One key finding from the PISA 2022 data is the potential role of positive attitudes, such as a growth mindset, in mitigating mathematics anxiety. A belief that abilities can be developed and improved over time, rather than being fixed, has been linked to lower anxiety levels and better performance, suggesting that fostering these attitudes could be a powerful tool in reducing the negative impact of mathematics anxiety (OECD, 2023[33]). Teacher training programmes that focus on emotional and cognitive strategies to reduce anxiety can empower educators to help students break free from the cycle of poor performance and fear of mathematics.

Fear of failure

Fear of failure is defined as the tendency to avoid mistakes, as they may be perceived as shameful or indicative of a lack of innate ability, potentially jeopardising one's future prospects (Atkinson, 1957[69]; Conroy, Willow and Metzler, 2002[70]). This fear stems from the pressure to meet academic expectations, avoid mistakes, and succeed in high-stakes assessments. In mathematics, where precision and correctness are highly emphasised, fear of failure can become particularly pronounced, leading students to avoid challenges and risk-taking in problem solving, which are essential for deep learning.

Additionally, fear of failure is associated with broader psychological effects, such as lower social and emotional well-being (Elliot and Sheldon, 1997[71]) and higher rates of stress, anxiety, burnout and depression (Gustafsson, Sagar and Stenling, 2016[72]; Sagar, Lavallee and Spray, 2007[73]). Research also indicates that fear of failure disproportionately affects girls, who tend to experience more negative outcomes such as reduced confidence and increased anxiety when faced with failure (Alkhazaleh and Mahasneh, 2016[74]; McGregor and Elliot, 2005[75]; Wach et al., 2015[76]; Borgonovi and Han, 2020[77]). PISA 2018 findings also indicate that fear of failure is a much better predictor of academic performance amongst girls than amongst boys (OECD, 2020[78]). Girls who expressed a greater fear of failure scored significantly higher in mathematics and science in PISA 2018 compared to girls with less fear of failure, with differences of five and eight points, respectively. In contrast, boys who expressed a greater fear of failure showed only marginal improvements in their scores (OECD, 2020[78]). The gender gap in fear of failure was particularly noticeable among top-performing students, with girls exhibiting a fear of failure 0.5 units higher than boys at this level, compared to a gap of 0.3 units among low achievers. On the other hand, the PISA results also revealed that fear of failure is negatively associated with life satisfaction (OECD, 2020[78]).

Overcoming barriers: Promoting positive attitudes towards mathematics

Many factors impact attitudes towards mathematics (ATM), some external to schooling and many within educational experiences. The ATM of family members, peers and wider society, particularly about the usefulness and importance of the subject, and the perceived enjoyment of mathematical challenge, strongly impact the attitudes adopted by students. Media also influence the messaging about the worth of learning and engaging in mathematics. According to Kiwanuka et al. (2016[79]) and Mata, Monteiro and Peixoto (2012[80]), factors affecting ATM that are within the sphere of influence of education systems include:

- supportive and knowledgeable teachers who model learning behaviours;
- high teacher expectations for student engagement and learning;
- students' perceptions of personal success;
- connections between mathematics and real-life;
- interaction and collaboration with other students;
- appropriate levels of challenge and support;
- high-quality learning tasks;
- opportunities for personal control of learning, such as goal setting and choice of task.

Furthermore, the design of curriculum and pedagogical approaches can also play a crucial role in shaping students' enjoyment of mathematics. For example, by incorporating mathematical reasoning, problem solving and real-world applications, curricula can significantly enhance students' engagement and enjoyment of the subject. This approach can encourage students to view mathematics as a dynamic and applicable field, fostering a deeper appreciation and a more positive attitude towards the subject.

Certain competencies can also play a pivotal role in helping students overcome the challenges of mathematics anxiety and fear of failure. These competencies are believed to not only improve performance but also shape positive attitudes toward learning mathematics. One of the key competencies that students should possess is a **growth mindset**, which encourages them to believe that effort, practice and persistence can help them develop, improve and succeed over time. PISA 2022 findings show that students with a growth mindset are less anxious about mathematics and perform better, as they view challenges and setbacks as opportunities to grow (OECD, 2023[33]). Moreover, students with a growth mindset tend to fear failure less than those without it (OECD, 2020[78]). Having a growth mindset can foster resilience, making students more likely to persist in the face of difficulties. Other research also indicates that supporting students' beliefs about their competency in mathematics may be more effective for reducing anxiety than focusing solely on achievement value (Li et al., 2021[81]).

Certain teaching strategies have also been found to improve students’ attitudes towards mathematics. Teaching strategies that favour cognitive activation, for example, play an important role in improving students' attitudes toward mathematics. Cognitive activation encourages students to think deeply about mathematical concepts, connect ideas and apply their knowledge to different situations. According to PISA 2012 Results, teachers who engage students in cognitively activating tasks, such as asking them to explain their reasoning, work through complex problems, and approach tasks from multiple angles, help enhance students' perseverance, motivation and confidence. This approach not only boosts performance but also fosters positive attitudes towards mathematics, reducing anxiety and increasing engagement (OECD, 2013[25]).

Attitudes and values for societal well-being

Mathematics education also plays a vital role in fostering attitudes and values that contribute to the well-being of society. Beyond its cognitive and technical benefits, mathematics can instil qualities essential for responsible and engaged citizenship, including integrity, co-operation and a commitment to fairness. By engaging students in real-world contexts and collaborative problem solving, mathematics can cultivate values that empower them to participate thoughtfully and ethically in society.

For instance, mathematics education can play a critical role in fostering active citizenship by equipping students with the skills needed to engage in informed, reflective and responsible decision making. According to Maass et al. (2019[82]), mathematics education that integrates socio-scientific issues and emphasises inquiry-based learning can empower students to address real-world challenges such as environmental concerns, economic inequalities and public health issues, all of which require mathematical literacy and ethical judgement. This approach encourages students not only to develop competencies like critical thinking and problem solving but also to engage with the societal implications of these skills, preparing them to become active, responsible citizens capable of navigating complex social issues through informed mathematical perspectives.

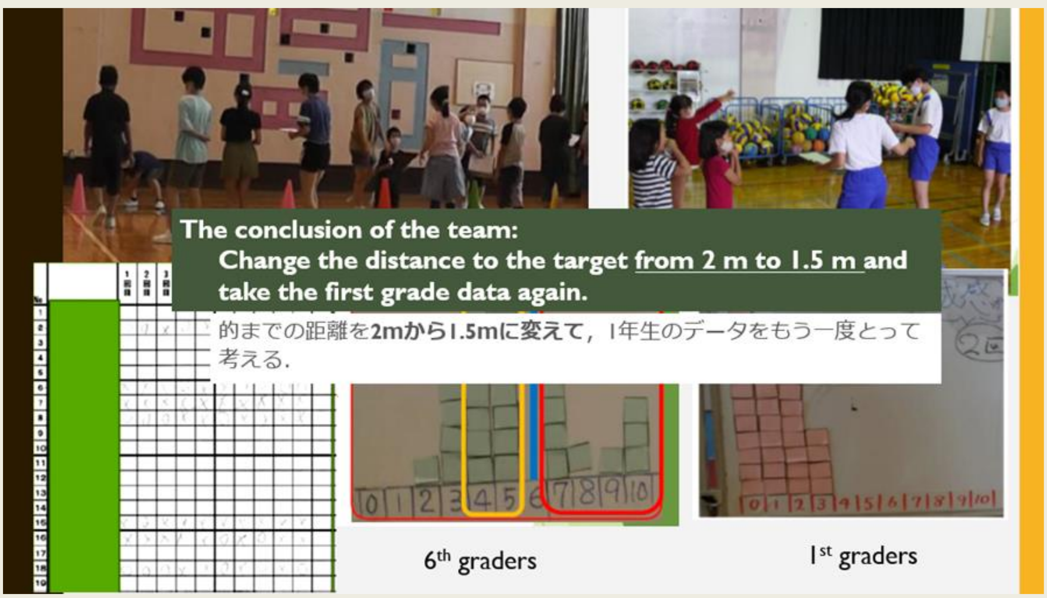
Similarly, mathematics education can contribute to citizenship by enabling students to interpret and critically analyse information prevalent in today's data-driven society (Geiger, Gal and Graven, 2023[83]). Students trained in mathematics can better understand social, economic and political issues, thus participating more meaningfully in civic life. This aligns with the idea of mathematics as a tool for justice-oriented citizenship, where individuals are prepared to question and address inequities and contribute constructively to society. By learning to apply mathematical reasoning to civic issues, students can contribute thoughtfully to democratic processes and promote societal well-being through informed decision making (Geiger, Gal and Graven, 2023[83]).

Box 3.8 highlights one example from Japan on how mathematics education can be leveraged to foster social decision making, empathy and ethical values among students. These cases demonstrate how engaging students in inclusive, collaborative problem solving and value-driven projects within mathematics can further reinforce their role as informed, conscientious citizens.

Box 3.8. Social decision making and consensus building through mathematics at school

At Nippori First Elementary School in Japan, 6th-grade students organised a special after-school activity to create a fun and inclusive exchange event with 1st. graders. One team chose to play the game "Quoits," facing the challenge of adjusting the game's rules to accommodate both younger and older students. **Students used mathematical reasoning to balance the game's difficulty, making it engaging and fair for everyone involved**.

Recognising that the game's existing setup might be too challenging for the 1st graders but too easy for the 6th graders, the team of older students worked collaboratively to adjust the rules using data collection and mathematics to achieve fairness for all participants. Supported by their teacher, they created a mathematics lesson around the activity, setting up a target board with an initial distance of two meters and giving each student ten attempts to hit the target.



After testing the setup, the team analysed the results and noted that the distance made the game disproportionately difficult for the younger students. They decided to reduce the target distance to 1.5 meters and gathered new data to assess the change. The final results showed that 1st graders achieved 3 successful hits out of 10, while 6th graders achieved 7, indicating an improved balance. Reflecting on these outcomes, the students felt that the new rules offered an appropriate level of challenge, creating a fair and enjoyable experience for all. They appreciated how mathematics enabled them to make data-driven adjustments to promote inclusivity.

These students practiced the A-A-R (Anticipation-Action-Reflection) cycle of the OECD E2030 Learning Compass: they anticipated possible solutions, took action by testing a group solution, and reflected on the results, refining the task to ensure fairness across age and skill levels. By using mathematics to guide decision making, the students enhanced their skills in empathy, co-operation and inclusivity. This example illustrates how mathematics can be a tool for fostering democratic values. In mathematically adjusting the game's rules, the students learned to approach challenges thoughtfully and inclusively, building a foundation for co-operative problem solving that promotes fairness and social responsibility.

Source: Nippori First Elementary school, Japan (2023).

Embedding attitudes and values in curriculum is not without risks and dilemmas. Variations in the attitudes and values held by stakeholders in the education system make establishing consensus on a uniform set of important attitudes and values challenging. Countries may experience dissonance between teacher beliefs and the attitudes and values espoused in curriculum statements. The Mathematics Curriculum Document Analysis study (Schmidt et al., 2022[7]) shows that commonly used texts in all participating countries fall short in providing the types of collaborative, realistic applications, and higher-order thinking tasks, that can lead to societal innovation. Dissonance between curriculum standards, including attitudes and values, and resources presents a significant barrier to implementation. Likewise, countries report that assessments often do not reflect a focus on attitudes and values. That is particularly true of high-stakes examinations. When considering how to embed key attitudes and values in mathematics curricula, policymakers are encouraged to simultaneously consider how to align them with pedagogies and assessment. Box 3.9 illustrates an example from Singapore of a close alignment of curriculum and teacher practices in terms of attitudes and values.

Box 3.9. Singapore: Attitudes and values in mathematics curriculum and pedagogy

Values and attitudes in mathematics

In Singapore, mathematics education extends beyond learning outcomes to encompass the process and ecology of learning, emphasising not only content mastery but also mathematical thinking and reasoning. Singapore's approach to mathematics education integrates content knowledge with skills, processes, metacognition and attitudes, which are considered equally important. Attitudes in mathematics include beliefs about its usefulness, interest, enjoyment, confidence and perseverance. These affective dimensions are essential in fostering an appreciation of mathematics and encouraging problem-solving resilience.

Problem solving in mathematics is vital in today’s world, especially in contexts like the COVID-19 pandemic, where society relied on data to make crucial decisions. Mathematical education plays a key role in teaching students how to analyse, interpret and apply data, which is critical in a data-driven society. Students develop logical reasoning and predictive capabilities through data analysis, pattern recognition and decision making. In line with the OECD Learning Compass 2030 emphasis on student agency, Singapore highlights the importance of supporting student learning to be more self-directed.

The development of values and attitudes in mathematics learning goes beyond the curriculum. Pedagogy plays a crucial role in shaping students' experiences and attitudes toward the subject. Student-centred and inquiry-based learning methods encourage active participation and self-directed learning, helping students build confidence and develop a positive attitude toward mathematics. Singapore has shifted from traditional didactic teaching to methods that emphasise inquiry, collaboration and the use of technology, which are more aligned with the ways today's learners – who are digital natives – prefer to engage with content.

Examples of values and attitudes in Singapore’s mathematics curriculum

Incorporating technology and interactive learning tools has become a cornerstone of Singapore’s mathematics curriculum. Initiatives like Learn and Apply Math through Play (LAMP) engage students through games and technology, making mathematics more enjoyable and accessible. Teachers use multisensory tools and ICT to help students visualise and experiment with mathematical concepts, fostering motivation, confidence, and a love for continuous learning. Real-world problems are also a focus, with students at both primary and secondary levels engaging in problem formulation and mathematical modelling to solve practical issues, further enhancing the relevance and application of their learning.

Developing teacher competencies for integrating values and attitudes

Teacher development is pivotal in integrating values and attitudes into mathematics education. Teachers in Singapore are encouraged to view themselves as educators of learners, not just instructors of mathematics content. By modelling values like appreciation, sincerity and honesty, teachers create an immersive environment where values and attitudes are not only taught but also caught. Through this holistic approach, students experience a comprehensive learning process, gaining both mathematical competencies and the attitudes necessary for lifelong learning and problem solving.

Source: Presentation by Oon Seng Tan, Director, Centre for Research in Child Development, National Institute of Education, Singapore, on 27 January 2022 for a workshop on co-producing the OECD Future of Education and Skills 2030 mathematics curriculum analysis publication.

Curriculum flexibility and autonomy in mathematics

Flexibility and autonomy in curriculum design are essential for ensuring education systems can respond to the diverse needs of students and rapidly changing societal demands. Flexibility allows schools and educators to adjust learning goals, content, pedagogy and assessments to meet the varying needs of learners, creating more relevant and personalised educational experiences. Autonomy, on the other hand, empowers local authorities, schools and teachers to make decisions about curriculum implementation, enhancing their ability to tailor education to specific local contexts (OECD, 2024[5]). Curriculum flexibility has been discussed earlier in this report, so this section will focus mostly on school autonomy.

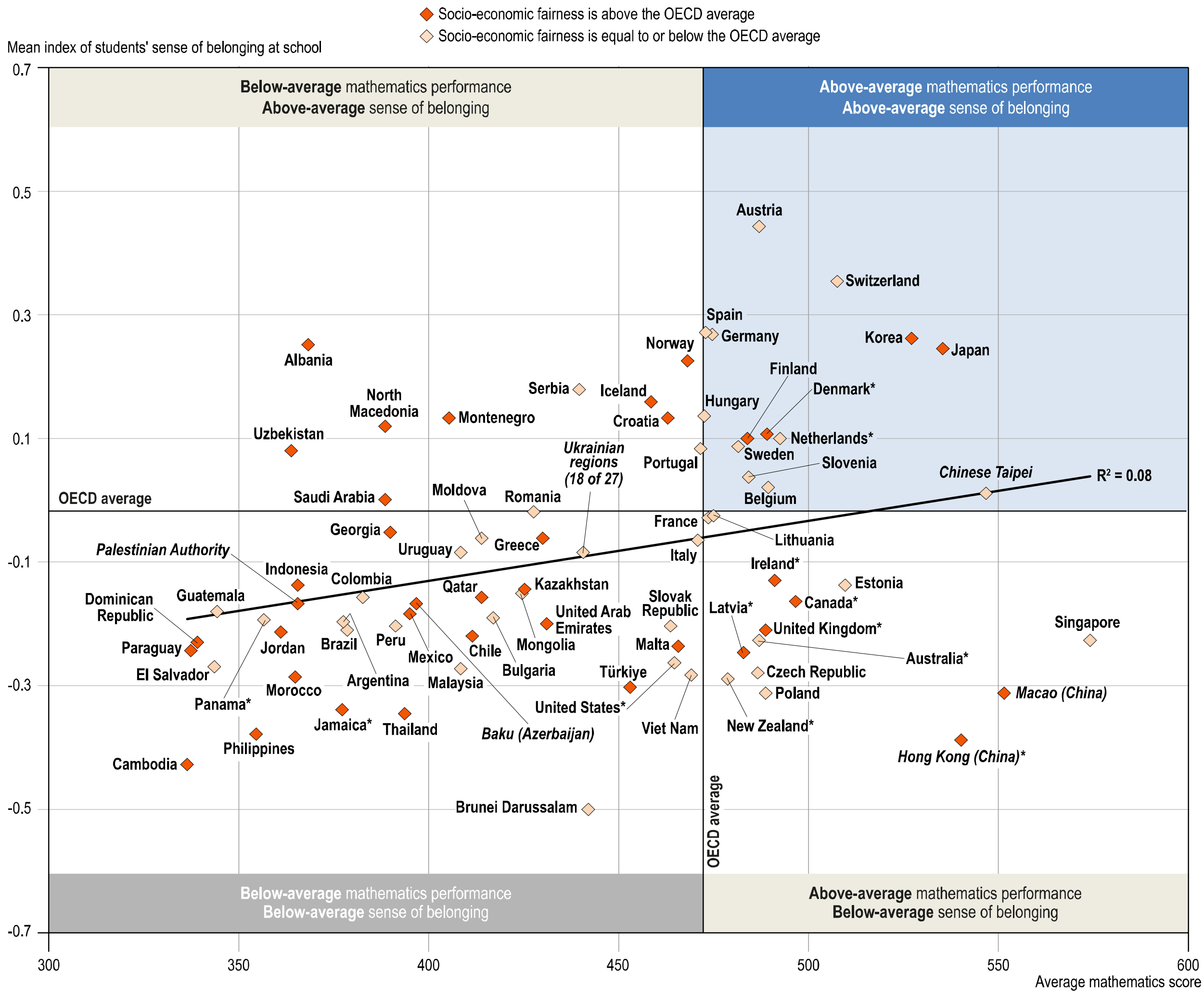
School autonomy over curriculum: A feature of resilient education systems

The latest round of PISA data has identified school autonomy on curriculum as one important factor found in resilient education systems. These are systems that continued to perform well on various fronts in spite of the recent disruption of the COVID-19 pandemic – they maintained high levels of student performance in mathematics while ensuring a good record on equity measures and on students' well-being (Figure 3.6). Resilient systems were able to adapt and respond to unexpected circumstances (e.g. school closures), and provide continued support and learning opportunities to students (leveraging technology for remote learning as needed), thus becoming stronger and better prepared to face adversity (OECD, 2023[18]).

Behind the resilience demonstrated in these education systems is the agility of well-prepared school leaders and educators at the local level who understand the pressing needs of students and can articulate adequate responses. School autonomy, when well thought out, can make systems stronger and more adaptable.

However, school autonomy in itself is insufficient to support positive student learning and well-being outcomes. Striking the right balance between centralised control and school autonomy can be challenging in practice (Ko, 2016[84]).While granting teachers greater autonomy can enable them to tailor their teaching to their students' needs and priorities, excessive autonomy may backfire and overwhelm them, especially when they lack sufficient guidance on how to implement the curriculum (and lack opportunities for ongoing professional development), when they do not fully understand the intentions of the curriculum, or when school autonomy is not part of their local school traditions (OECD, 2024[5]). This is particularly true in mathematics, where teachers need support in integrating flexible approaches that do not compromise the rigour of mathematical content.

Figure 3.6. Performance and equity in mathematics in relation to students' sense of belonging at school



Notes: Socio-economic fairness is measured by the percentage of variation in student performance that is not accounted for by differences in students' socio-economic status. For further information on socio-economic fairness, please refer to Chapter 4 in OECD (2023[33]), *PISA 2022 Results (Volume II): Learning During – and From – Disruption*, PISA, OECD Publishing, Paris, https://doi.org/10.1787/a97db61c-en.
Source: OECD (2023[18]), *PISA 2022 Results (Volume II): Learning During – and From – Disruption*, PISA, OECD Publishing, Paris, https://doi.org/10.1787/a97db61c-en.

Decision making in mathematics curricula

The E2030 MCDA study (the main findings of which were discussed in Chapter 2) conducted a focused analysis on decision making, specifically related to the mathematics curriculum. This analysis, seen in Table 3.1 highlights the roles and responsibilities shared across various education system levels (national, regional, local (school and teachers)) on curriculum decisions across 19 countries/jurisdictions, specifically examining four curriculum facets: learning goals, content of instruction, teaching methods, and examinations. This provides insight into how mathematics curriculum decisions are made across different systems. The percentages on the table represent the relative influence of a particular decision-making actor/level over a given aspect of the mathematics curriculum in a scale that goes from 0% (meaning the given actor has no formal decision-making role over that area) to 100% (meaning the actor in question has final authority or approval over all aspects of a particular curriculum area, e.g. goals for pupils).

On average across the 19 countries/jurisdictions that participated in the study, national authorities exert greatest influence on the **definition of goals for pupils** and on **examinations**; the responsibility for these aspects of the curriculum, however, seems to be widely shared with schools who also carry a strong say – albeit not in a leading role – on these matters. Decisions on the **content of instruction** in mathematics seem to also follow a model of shared responsibility where the national level exerts similar levels of influence as the school level, while recognising the ultimate decision-making influence of individual teachers. Finally, schools and especially individual teachers, have overwhelming control over the **methods of instruction** compared to other actors.

Table 3.1. Relative average influence of different actors on four general curriculum facets in mathematics curricula across 19 countries/jurisdictions

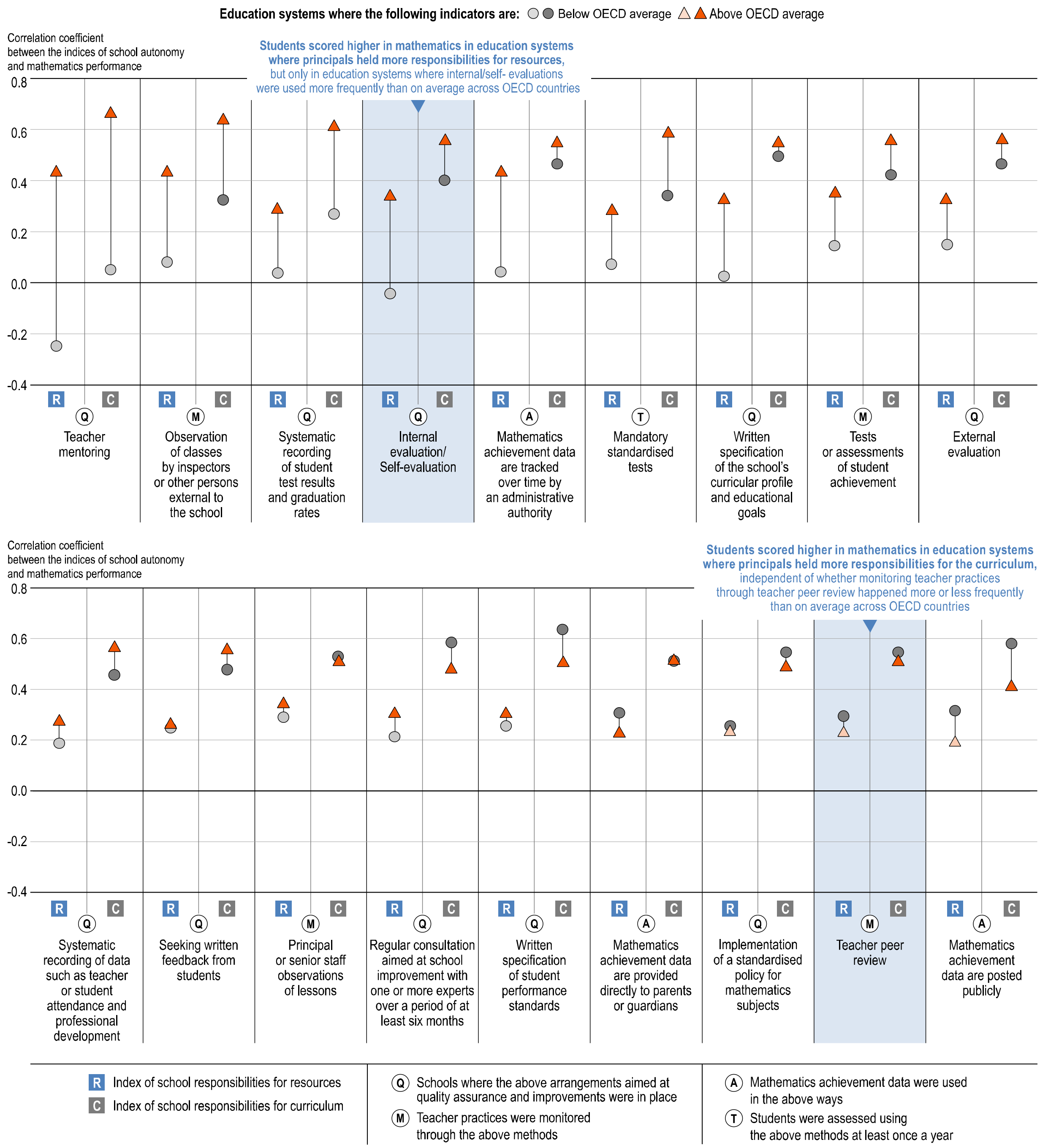
Facet of curricula	National	Regional	School	Teachers, collectively	Teachers, individually
Goals for pupils By overall system completion For intermediate stages For differentiated programme types To be reached in a given grade To apply for a specific school	52%	24%	40%	29%	33%
Content of instruction Course (grade level) offerings Student course assignment rules Course content (syllabi) Auxiliary content outside syllabi	46%	19%	43%	42%	53%
Methods (including textbooks) Textbook selection Instructional methods/techniques	28%	18%	55%	50%	74%
Examinations Content of examinations Examination performance standards School examination standards	55%	16%	30%	40%	41%

Note: This table uses a scale that goes from 0% (no formal role in decision making) to 100% (final authority or approval) to represent the relative influence of each decision-making level/actor over a given aspect of the mathematics curriculum.
Source: Schmidt et el. (2022[7]) "When practice meets policy in mathematics education: A 19 country/jurisdiction case study", OECD Education Working Papers, No. 268, OECD Publishing, Paris, https://doi.org/10.1787/07d0eb7d-en.

These findings are in line with global trends on decision making over various aspects of curriculum in other subject areas (OECD, 2023[18]; OECD, 2024[5]). Individual country variations are also noticeable. In Estonia, Korea and Portugal, schools have greater levels of autonomy over all aspects of the curriculum compared to the average results, and in contrast to Greece and Argentina, for example, where decision making for all aspects of curriculum is largely concentrated at the national level (Schmidt et al., 2022[7]).

The overwhelming convergence across educational systems on the prominent role of teachers as primary decision makers over teaching methods, including the choice of textbooks as well as teaching practices, leaves a lot of room for reflection when considering curriculum reform in mathematics. Given the widespread reliance on textbooks that are often out of date and misaligned with curriculum standards, this shows a gap where policymakers, curriculum designers and teachers can collaborate to better link the intentions of the curriculum to their teaching practices for greater system-level efficiencies (Schmidt et al., 2022[7]).

Figure 3.7. School autonomy over the curriculum: Quality measures associated with higher mathematics performance



Notes: 1. Index of school responsibilities for resources. 2. Index of school responsibilities for curriculum. Q: Schools where the above arrangements aimed at quality assurance and improvements were in place. M: Teacher practices were monitored through the above methods. A: Mathematics achievement data were used in the above ways. T: Students were assessed using the above methods at least once a year.

Notes: Results based on correlation analyses of all PISA-participating countries/economies. Statistically significant correlation coefficients are shown in a darker tone. The variables are ranked in descending order of the differences in the correlation coefficients between the education systems with values "above OECD average" and "below OECD average" in the quality-assurance indicators (indices of school responsibilities for resources and curriculum combined).

Source: OECD (2023[18]), PISA 2022 Results (Volume II): Learning During - and From – Disruption, PISA, OECD Publishing, Paris, https://doi.org/10.1787/a97db61c-en

School autonomy: A conditional strategy

While increased autonomy can empower teachers and school leaders to adapt education to meet local needs, research suggests that autonomy needs to be accompanied by robust accountability systems. PISA 2022 data indicate that education systems with strong quality-assurance mechanisms – such as teacher mentoring, regular monitoring of classroom practices by inspectors, and systematic tracking of student achievement – experience higher average mathematics performance (Figure 3.7) (OECD, 2023[18]). These accountability measures help ensure that autonomy translates into effective, adaptive teaching practices where consistent quality is crucial.

Such of these measures, such as teacher mentoring, feedback, and school internal self-reflection echo other research suggesting that when strategies are well-designed and effectively implemented, teachers who feel supported and empowered with autonomy are better equipped to provide adaptive and appropriate education, particularly as classrooms become more diverse and students have increasingly individualised learning needs (Paradis, 2019[85]).

A flexible curriculum can empower schools and teachers to use their autonomy to modify, adjust and align content with both societal challenges and individual learning needs. Such flexibility allows for the integration of new content and priorities, ensuring the curriculum remains relevant while also forward-thinking, but teachers need to be well prepared and supported for using such flexibility, as they are critical actors in linking curriculum design to implementation (OECD, 2024[5]). Box 3.10 and Box 3.11 exemplify how curriculum flexibility, underpinned by professional development opportunities and adequate resources, can foster a system where mathematics education is responsive to local contexts and adaptable at the school level.

Box 3.10. School autonomy in the Netherlands: Between mathematics curriculum and implementation

The Netherlands provides an example of curriculum flexibility, deeply rooted in its historical commitment to pedagogical freedom and minimal government intervention in school operations. This means that the government prescribes the what, e.g. the goals of education; and schools decide how to realise the mandatory goals. The Dutch Constitution of 1848 enshrined pedagogical autonomy, which extends to the present day. While the Ministry of Education sets legally prescribed standards, schools have the freedom to choose their own teaching resources, curricula and assessment materials. Mathematics education in the Netherlands is heavily influenced by Realistic Mathematics Education (RME), a movement inspired by Hans Freudenthal. RME promotes the idea that mathematics is a real-life activity, not just a set of rules and procedures. This approach emphasises problem solving, active learning, and the connection of mathematics to students' everyday experiences.

The development of mathematics curricula in the Netherlands has been driven by bottom-up principles, allowing for flexibility in implementation. Core principles of RME include activity-based learning, connecting mathematics to real-life situations, guiding students through progressively deeper levels of understanding, and integrating different mathematical concepts into problem solving. These principles were enacted through decades of collaborative projects involving researchers, educators and policymakers, leading to practical strategies for teaching mathematics in classrooms. A notable feature of the Dutch system is its broad and flexible curriculum goals, which do not prescribe specific year-level outcomes. For example, goals like "can do easy mental arithmetic with insight" and "know that fractions and decimals have several meanings" allow teachers the autonomy to adapt their teaching methods to their students' needs and learning pace.

Source: (Vos, 2013[86]; Van Zanten and Van den Heuvel-Panhuizen, 2018[87]; Van den Heuvel-Panhauizen and Wijers, 2005[88]; Freudenthal, 1973[89])

Box 3.11. Adapting the national mathematics and statistics curriculum at Taupō Primary School, New Zealand

In New Zealand, Sarah, a Deputy Principal, has been working with colleagues to adapt the national curriculum to drive learning in Taupō Primary School. This includes a localised curriculum approach to working with *Mana Whenua Ngāti Tūwharetoa* (Indigenous peoples), including their *Cultural Kete* (a collection of narratives provided to the local schools) and integrating the New Zealand Curriculum (NZC).

Data-informed decision making

Taupō Primary School teachers and school leaders use both big and small data to help establish the needs of their learners, which are identified against the NZC learning objectives. Based on data and evidence from student test results, teachers identify the areas that need to be taught.

The NZC specifies eight learning areas: English, the arts, health and physical education, learning languages/*Te Reo Māori* (the Indigenous language of New Zealand), mathematics and statistics, science, social sciences, and technology. The learning associated with each area is part of a broad, general education and lays a foundation for later specialisation.

For mathematics and statistics, achievement objectives are presented in three strands: 1) number and algebra, 2) geometry and measurement and 3) statistics. The NZC states the importance of students seeing and making sense of the many connections within and across these strands. Teachers use the strands and students' test results to determine their own class needs – what their students can and cannot do – and they identify units of work for further development. Teachers have access to exemplars to assist with teaching these units, and they consider how to integrate this teaching where possible.

Curriculum flexibility and autonomy

Once decisions have been made on students' learning needs, teachers and school leaders begin collectively planning, encompassing what *Mana Whenua Ngati Tūwharetoa* (Indigenous peoples) want in the localised and/or national curriculum. The school tries to line up both the local and national curriculum with the needs of their learners, pulling all details together to make a programme for their students. They work with *Iwi* (Māori) as part of the *Kahui Ako* (community of learning) and align the NZC with localised narratives from the *Tūwharetoa Cultural Kete* (the previously mentioned collection of narratives).

In mathematics, for example, Taupō Primary School has been teaching the NZC, including mathematical concepts, through the historical narratives of *Ngati Tūwharetoa*. For instance, in mathematics, the school uses the narratives of two chiefs who arrived in Taupō as a foundation for learning. Students explore these stories through activities like plotting locations on maps and using geometry skills to understand navigation. This blending of cultural stories with mathematics not only enhances learning outcomes but also increases engagement, as reflected in improved effect sizes in mathematics.

Source: Presentation by Sarah Sade, Deputy Principal, Taupō Primary School, New Zealand, on 27 January 2022. OECD Future of Education and Skills 2030 workshop.

In countries where local flexibility and autonomy are prioritised, countries need to balance that autonomy with accountability measures and teacher professional development so they can use their freedom to enhance the links between curriculum design and implementation. If accountability mechanisms become overly stringent, however, they can impose excessive pressure on schools and teachers, stifling innovation and diminishing the flexibility that autonomy is intended to foster (Greany and Waterhouse, 2016[90]). This pendulum between autonomy and accountability highlights the need for a balanced approach that maintains educational rigour while allowing schools the freedom to innovate and respond dynamically to students' needs (OECD, 2024[5]).

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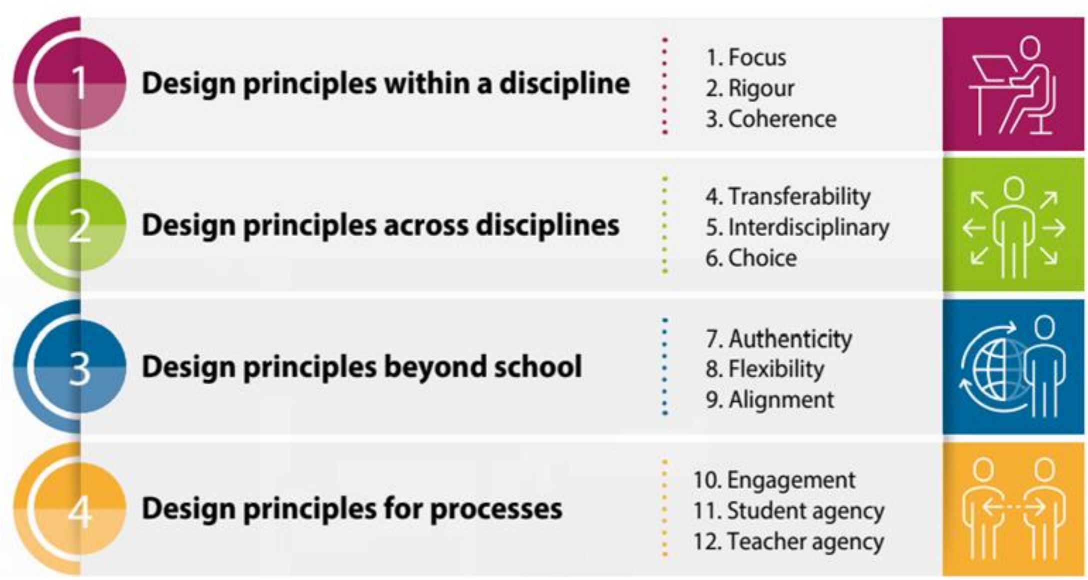
4 Policy implications for mathematics curriculum reform

This chapter outlines 12 policy implications for mathematics curriculum reform, drawn from a set of guiding principles for curriculum design identified by OECD curriculum analyses. These curriculum design principles include those within a discipline, across disciplines, beyond school and for processes. Successful reform requires flexible and future-oriented curricula that not only address the demands of a rapidly changing world but also ensure rigorous, adaptable curriculum redesign, implementation and evaluation.

The preceding chapters have laid a foundation for understanding the uniqueness, challenges and evolving needs of mathematics education. Chapter 1 emphasised the distinct structure of mathematics curricula, traditionally focused on foundational competencies like numeracy and problem solving, but now requiring the integration of 21st-century skills such as critical thinking and digital literacy. Chapter 2 reviewed the development of mathematics curricula over a 25-year period, exposing structural gaps between intended, taught and achieved learning outcomes. Chapter 3 addressed the persistent challenges in mathematics curriculum reform, highlighting issues like curriculum overload, equity gaps and the need for adaptability, drawing on international innovations aimed at making mathematics education more relevant to students' lives.

Policy implications from the OECD's *Future of Education and Skills 2030* (E2030) curriculum analyses highlight that recent mathematics curriculum reforms emphasise teaching core mathematical concepts while fostering higher-order skills such as mathematical thinking, reasoning, creativity and real-world application, often in interdisciplinary contexts. Successful reforms necessitate flexible and forward-thinking curricula that not only address the demands of a rapidly changing world but also ensure rigorous, adaptable curriculum redesign, implementation and evaluation tailored to students' diverse needs. This chapter outlines 12 implications for mathematics curriculum reform, adapted from the E2030 project's set of 12 guiding principles for general curriculum design (Figure 4.1). These principles have relevance across different countries/jurisdictions and are durable over time (OECD, 2020[1]).

Figure 4.1. Design principles for curriculum



Source: OECD (2020[11])*Curriculum (Re)design: A Series of Thematic Reports from the OECD Education 2030 Project*, https://www.oecd.org/content/dam/oecd/en/about/projects/edu/education-2040/2-1-curriculum-design/brochure-thematic-reports-on-curriculum-redesign.pdf (accessed on 26 September 2024).

Design principles within a discipline

Focus: Prioritise core mathematical concepts that provide a deep understanding of essential topics, while minimising content overload.

Conceptual understanding of core mathematical concepts plays a critical role in the development of the necessary foundational knowledge students need to excel in higher-order thinking and in real-world problem solving. Conceptual understanding forms a basis for mathematical literacy, which is critical for academic, personal and professional success. The results of the Programme for International Student Assessment (PISA) consistently show that students with a solid understanding of core mathematical concepts (e.g. number sense, algebraic thinking and geometry) perform better not only in routine problem solving but also in complex, real-world scenarios. Students who grasp core concepts are better equipped to transfer this knowledge to diverse problems or in novel contexts, making them more adaptable learners who can easily build more complex learning on top of this foundational learning (OECD, 2018[2]). As mathematical applications in fields such as data science, artificial intelligence and engineering become increasingly important, a focus on core concepts ensures that students can apply foundational knowledge in innovative and interdisciplinary ways. Curriculum reform should thus focus on building strong conceptual foundations to better prepare students for life and for careers that require flexible thinking and the creative application of mathematics (OECD, 2020[3]).

Rigour: Emphasise depth of understanding rather than just procedural fluency to ensure that the curriculum challenges students to engage in higher-order thinking, problem solving and reasoning.

Research in cognitive science underscores that deep learning of core concepts forms the basis for more advanced cognitive processes like reasoning, critical thinking and creative problem solving. A curriculum that emphasises procedural fluency at the expense of conceptual understanding limits students' ability to engage in meaningful problem solving, as they rely on rote memorisation rather than a deep comprehension of mathematical structures (Bransford, Brown and Cocking, 2000[4]).

Countries with top-performing education systems in PISA, such as Singapore, Finland and Japan, place significant emphasis on deep understanding of mathematical concepts in their curricula. These systems focus not just on what students learn, but how they learn, encouraging inquiry-based approaches that help students develop a robust grasp of core mathematical principles, rather than superficial procedural skills ((National Center on Education and the Economy (NCEE), 2020[5])). When trying to incorporate new content and competencies deemed essential for the 21st century, mathematics curriculum may run the risk of overload. But as findings from the OECD curriculum analyses in this report show, countries are finding strategies to revise curriculum to avoid overload, e.g. by embedding competencies in the teaching of existing content and by focusing on big ideas when selecting content. A well-designed, focused curriculum can offer greater opportunities for in-depth learning.

Coherence: Structure the curriculum so that mathematical ideas build logically and consistently across grade levels and topics, creating strong connections between concepts

Coherence in mathematics curriculum can be understood in terms of vertical and horizontal connections. **Vertical coherence** refers to the logical progression of mathematical ideas through different grade levels. This can support students to build upon previous knowledge and progress from earlier to later grades. **Horizontal coherence** refers to making connections between different mathematical topics within the same grade (to support students in seeing how various mathematical concepts are interrelated) (Peters, 2024[6]; Schmidt, Wang and McKnight, 2005[7]; Morony, 2023[8]). Coherent curriculum can support students to progress in their learning from basic knowledge to deeper understanding, from concrete to abstract concepts, and from connecting specific mathematical facts to broader principles (Schmidt, Houang and Cogan, 2002[9]). It is found to be effective in improving student achievement, reducing achievement gaps, and enhancing conceptual understanding (Schmidt and Houang, 2012[10]). **Clear learning progression**, i.e. well-defined sequences of how mathematical concepts develop over time, is critically important for a coherent math curriculum (Jin et al., 2019[11]; Morony, 2023[8]).

Design principles across disciplines

Transferability: Design curriculum that can encourages students to apply mathematical concepts and skills to new, unfamiliar situations (across different disciplines and/or in real-world contexts).

Transferability refers to students' ability to apply the mathematical knowledge and skills they acquire to novel situations, both within and beyond the classroom. Research shows that students often struggle to transfer learned concepts to new contexts unless explicitly taught how to do so. Therefore, students need opportunities to engage in problem solving that requires them to adapt previously learned concepts to unfamiliar challenges, rather than relying solely on familiar procedural tasks (Bransford, Brown and Cocking, 2000[4]). For example, when students learn algebraic functions, a transferable curriculum might encourage them to apply those functions in fields such as economics, biology or engineering. This ability to extend mathematical reasoning into new domains is crucial for success across a range of academic disciplines and professional fields, from data science to architecture.

As the world becomes increasingly complex and uncertain, the ability to apply learned concepts to new or unfamiliar situations is becoming ever more relevant, and employers increasingly seek workers with transversal skills. A well-designed curriculum should intentionally create space and time for students to explore and connect mathematical ideas to new contexts or disciplines on their own initiative. Allowing this exploratory time fosters the development of flexible problem-solving skills and encourages students to think creatively about how mathematics can be used across various fields and in real-world scenarios. As such, this principle is closely related to “interdisciplinarity” and “authenticity”.

Interdisciplinarity: Promote competency-based, cross-disciplinary learning by linking mathematics to subjects like science, technology, economics and social studies.

Today's global challenges and emerging careers increasingly require interdisciplinary knowledge and key cross-cutting competencies such as problem solving, critical thinking and creativity. Fields related to global challenges, e.g. data science, artificial intelligence, finance, engineering and environmental science, rely heavily on the integration of mathematics with other disciplines. For example, data scientists use statistical models and mathematical algorithms to analyse large datasets across industries like healthcare and marketing. Engineers apply calculus and physics principles to develop solutions to technological problems, while economists utilise mathematical models to forecast trends and inform policy decisions. By promoting competency-based, cross-disciplinary learning in the curriculum, students are better equipped to enter today’s labour market, developing the mathematical literacy needed to thrive in diverse fields of work (OECD, 2020[12]).

British Columbia (Canada) provides an excellent example of interdisciplinarity in their curriculum design. Conceptual ideas, known as “big ideas”, are identified within each discipline, including mathematics, and mapped in a cross-disciplinary table (see Table 2 in (OECD, 2020[3])). For instance, the concept of “change” is explored through the distinct lenses of various disciplines, such as mathematics, art, social science, geography, history and health. Each discipline approaches the concept of “change” using its unique thinking patterns, or so-called “epistemic knowledge” – for example, thinking like an artist or a mathematician. In mathematics, for example, “change” might be understood through the study of rates of change or algebraic functions, while in history or social science, it could involve analysing societal or environmental transformations. This approach not only highlights the interconnectedness of knowledge but also fosters deeper, discipline-specific thinking.

This approach supports the growing emphasis, in particular, on STEM (Science, Technology, Engineering and Mathematics) or STEAM (+Art) education, which integrates multiple disciplines to identify global and local challenges, suggest and act on solutions, to drive innovation and technological progress towards a better future. This not only makes math more relevant but also helps students understand how mathematical thinking is used in other fields to solve complex problems.

Choice: Offer students opportunities to choose areas of focus within mathematics or in new subject areas that align with their interests and future career aspirations.

Providing students with more choice in the mathematics curriculum enhances personalisation and engagement, fostering essential skills for lifelong learning and adaptability and allowing students to align their studies with future career goals. For example, students may opt to explore specialised pathways in mathematics, such as statistics, calculus or data science, based on their interests and professional aspirations.

The *E2030* curriculum analyses highlight another approach to offering relevant choices related to mathematics, via the creation of new subjects, while carefully avoiding curriculum overload. These new subjects can incorporate mathematical concepts when designed effectively. Examples include "career education, work studies and entrepreneurial education" (e.g. Estonia, Poland), "health education, well-being, lifestyle" (e.g. Hungary, Ireland), and "local and global citizenship, peace" (e.g. Northern Ireland, Mexico). Other examples are "environmental education" (e.g. Korea, Norway), "media education" (e.g. British Columbia and Ontario, Canada), and "applied design skills, technologies, informatics" (e.g. Australia, Kazakhstan) (OECD, 2020[3]).

In some cases, countries also leverage “curriculum flexibility and autonomy” to address diverse educational needs and preferences, as seen in New Zealand (Chapter 3), allowing schools to somewhat adapt the curriculum to the interests and aspirations of their students. This flexible approach, when carefully designed with effective accountability and support systems, ensures that students can pursue specialised areas of interest within mathematics, increasing their engagement in and connection to their learning (OECD, 2024[13]).

Design principles beyond school

Authenticity: Incorporate real-world problems and scenarios into the curriculum to make learning more relevant.

Incorporating real-world problems and scenarios into the mathematics curriculum enhances its relevance, boosts student engagement, and prepares learners not only for future careers but also to be informed and capable citizens now and in the future. Using authentic contexts from everyday life and, in particular, those requiring societal decision-making that are meaningful and significant in students’ communities, including their own school, not only help students see the practical applications of mathematics but also foster critical thinking, problem solving and transferable skills that are essential for success in today’s fast-evolving world.

Strategies include the use of inquiry-based learning where students apply mathematical concepts to solve real-world problems over an extended period of hands-on learning; integration of technologies to simulate real-world scenarios and data analysis tasks; collaboration with industry professionals, in particular, professionals using mathematics in various careers; incorporate case studies to show how mathematics is used to solve real-world issues such as environmental challenges, financial issues and urban planning; and facilitation of community-based projects, in which students can engage with their community ties (Jablonka and Bergsten, 2021[14]), including their own school, and learn to identify local problems that can be addressed using mathematical solutions. A curriculum that emphasises authenticity bridges the gap between theoretical knowledge and practical application, making mathematics more meaningful and impactful for students.

Flexibility: Ensure the curriculum is adaptable to different learning styles, paces and needs for all students. In doing so, make conscious efforts to close equity gaps.

Allow for various instructional methods, including digital tools, blended learning and individualised learning plans, to support diverse learners in mastering mathematical concepts. A flexible mathematics curriculum is essential for meeting the varied learning styles, paces and needs of students, while also addressing equity gaps that may hinder some learners' success. Curriculum flexibility provides schools, teachers and students themselves (to some extent) a possibility to adapt learning goals, pedagogies, assessment and learning time to suit the students' needs (OECD, 2024[13]). For example, instead of a one-size-fits-all approach to assessment, flexibility allows for various methods of evaluation, such as project-based learning, portfolios or group assessments, in addition to traditional exams (Hayward, 2012[15]; Gardner et al., 2010[16]). This gives students who may not excel in standardised testing the opportunity to showcase their strengths through alternative means (Hong et al., 2023[17]; Clark, 2012[18]; Ozan and Kıncal, 2018[19]; Gu, 2021[20]; Müller, Mildenberger and Steingruber, 2023[21]).

Within a classroom, students often have varied levels of ability and interest in mathematics; however, all students – regardless of background or ability – should have the opportunity to learn and thrive in mathematics. Adaptive learning technologies can provide customised learning experiences, ensuring that students at all levels – whether struggling or advanced – are challenged appropriately, thereby reducing disengagement and underperformance (OECD, 2022[22]; OECD, 2021[23]).

Strategies include offering multiple pathways with various entry points; using differentiated instruction by adapting teaching methods, content and assessments to meet individual student needs; implementing formative assessment to better understand students' needs, to inform curriculum decisions and provide targeted support; using technology to allow more adaptive learning and teaching, e.g. self-paced learning, online collaborative learning and hybrid learning.

To help close equity gaps and create a supportive, inclusive learning environment, strategies include: incorporating culturally responsive teaching, addressing math anxiety in particular for students with low self-efficacy or a fixed learning mindset in mathematics; using technology appropriately, especially for students who lack access to digital resources at home, including devices, broadband internet, etc. providing targeted support for struggling students; using "Universal Design for Learning" as a checklist, focusing on the "what" (content), "why" (motivation) and "how" of learning (pedagogies and assessment) (OECD, 2021[24]).

Alignment: Align mathematics curriculum, assessment, textbooks and pedagogies.

Alignment between mathematics curriculum, assessment, textbooks and pedagogies ensures that students experience a coherent and unified learning process. For example, when misalignment occurs – such as when teaching focuses on conceptual understanding but assessments primarily test procedural skills – students may become confused and underperform, as they are not adequately prepared for what is being assessed. To address this, possible strategies include: more formative assessments (e.g. with ongoing feedback, student reflection on their learning processes, teacher adjustment of their instruction) (Hayward, 2012[15]; Gardner et al., 2010[16]); using a more holistic evaluation system to better measure students' readiness to apply mathematical concepts in the real world or in cross-disciplinary settings (e.g. focusing on students' ability to reason mathematically, think critically and apply mathematics to unfamiliar contexts rather than just testing computational accuracy and procedural fluency, often assessed through high-stakes testing) (Jablonka and Bergsten, 2021[14]).

Textbooks can also play a critical role in alignment or misalignment, particularly because mathematics is often more abstract and challenging for teachers to design real-world learning materials compared to other subjects. As a result, mathematics teachers are more likely to rely on textbooks for instruction. In this context, the quality and relevance of pedagogies in mathematics can heavily depend on the quality of the textbooks used. The E2030 Mathematics Curriculum Document Analysis (MCDA) textbook analyses revealed a substantial gap between curriculum learning goals and the types of problems included in math textbooks. This gap presents an opportunity for improvement, perhaps with the use of digital textbooks, which can integrate AI and other technologies in a more interactive and connected way. Digital textbooks have the potential to help bridge the gap between learning goals and instructional materials by offering timely real-world applications, promoting key principles like "transferability," "interdisciplinarity," and "authenticity." Such resources can provide dynamic learning experiences that better align with curriculum objectives, making mathematical concepts and problems more relevant and engaging for students.

Design principles for processes

Engagement: Engage students and teachers in the design processes of curriculum, instruction and assessment. In doing so, inclusion and equity should be considered by design.

Engaging both teachers and students in the design of curriculum, instruction and assessment is crucial for creating a more relevant, motivating and effective learning experience. Teachers bring practical classroom knowledge, while students offer insights into their preferences and needs. This collaborative approach not only strengthens the overall learning process but also ensures a sense of ownership of the new curriculum by both teachers and students. This approach also ensures that inclusion and equity are considered from the outset, creating a supportive and accessible educational environment for all learners.

Indeed, British Columbia (Canada) has taken this approach to its curriculum redesign for 2019. It involved teachers, students, as well as parents, universities and business communities in the redesign process. As a result, the 2019 curriculum encourages personalised learning, where students can pursue topics in mathematics that align with their interests and future career aspirations. Mathematical reasoning and problem solving are central, and teachers are encouraged to incorporate real-life contexts into math pedagogy.

While research suggests the aforementioned benefits, some considerations are also suggested to make the process manageable and meaningful: e.g. balancing power dynamics between teachers and students (Enright and O'Sullivan, 2010[25]; Herbel-Eisenmann and Cirillo, 2009[26]); resource allocation, such as time for collaboration (Voogt, Pieters and Handelzalts, 2016[27]); and cultural sensitivity as to how to ensure all students and teachers feel "represented and valued" (Wages, 2015[28]).

Student Agency: Design curriculum to empower students so that they take ownership of their learning, and value their own growth and well-being (not just "doing well" in school).

Designing a curriculum that empowers students to take ownership of their learning and values their well-being fosters both academic success and personal growth. By promoting student agency, the curriculum encourages self-directed learning, intrinsic motivation and a healthy balance between well-being and doing well in academic performance.

To ensure ownership of mathematical learning, curriculum should allow students to, for example, choose problem-solving strategies and explain their reasoning, explore multiple solution paths, and create their own mathematical problem (Swan, 2005[29]). To support students to value their growth and well-being when learning mathematics, curriculum should focus on the process of mathematical thinking and reasoning rather than just getting correct answers, encourage teachers to provide growth-oriented feedback that highlights students' improvement and effort, and design a well-aligned curriculum and low-stakes, formative assessments to monitor progress.

Delegating ownership of learning to students is found to be effective, e.g. reduced math anxiety when students feel in control of their mathematical learning; improved self-image as a competent mathematician; enhanced creativity and critical thinking in problem solving through self-directed learning, and increased persistence in the face of challenging mathematical tasks, when students learn to value their own personal growth in math (Boaler, 2016[30]).

Strategies include: implementing open-ended modelling projects where students apply mathematics to real-world situations of their choice; allowing students to create and solve their own mathematical problems, sharing them with peers; incorporating regular journaling about mathematical thinking, struggles and growth; offering various ways for students to demonstrate mathematical understanding, such as oral explanations, visual representations and written proofs; and implementing regular discussions where students share different problem-solving strategies, fostering meta-cognition and communication (Echazarra et al., 2016[31]; OECD, 2013[32]; OECD, 2023[33]).

In implementing these strategies, research indicates some challenges for consideration, such as striking a balance between the acquisition of foundational skills and the experience of exploration and creativity (Boaler, 2016[30]; OECD, 2023[34]), and changing perceptions about mathematics being a fixed-ability subject (Zhang, Chen and Li, 2023[35]; Thompson and Li, 2023[36]).

Teacher Agency: Empower teachers with professional autonomy and foster collective teacher efficacy to tailor the curriculum to the unique needs of their students.

Empowering mathematics teachers with professional autonomy has shown to improve student outcomes, particularly in terms of engagement and deep learning (Liu et al., 2020[37]; Wei et al., 2019[38]). Involving teachers in decision-making processes, such as curriculum development and assessment design, fosters a sense of ownership and professional fulfilment (OECD, 2016[39]). Teachers feel empowered not only because they can make curriculum decisions in their classrooms but also because their voices are heard at the system level, ensuring that their professional experiences are reflected in broader educational reforms (Sahlberg, 2021[40]).

While teacher autonomy is essential, it must be: i) aligned with system goals, ii) balanced with system accountability, iii) considered for system capacity, and iv) supported by political and economic context (OECD, 2024[13]). Teacher agency is closely related to system capacity.

For teacher autonomy to be effective, it is critical that teachers are equipped with the necessary tools, resources and support. While flexibility grants teachers the freedom to make adjustments, they need ongoing professional development opportunities, access to collaborative networks, and appropriate instructional materials to make informed decisions. Without these supports, autonomy can lead to frustration, as teachers may feel ill-prepared to handle the full responsibility of tailoring the curriculum. High-quality professional learning opportunities provide teachers with strategies for differentiating instruction, integrating technology and applying data-driven decision-making. This (Goddard, Hoy and Hoy, 2000[41])ensures that teachers are not just given autonomy but are also equipped to use it effectively (Hargreaves and Fullan, 2015[42]). For example, research has shown that when teachers are trusted to make pedagogical decisions but are also supported through structured feedback, student learning improves (OECD, 2014[43]; OECD, 2015[44]), and regular formative assessments and feedback loops can help teachers monitor student progress and ensure that their adaptations are leading to the intended learning outcomes (Darling-Hammond and Bransford, 2008[45]; Darling-Hammond et al., 2013[46]; Darling-Hammond, 2018[47]). Also, professional development focused on differentiated instruction, the use of technology and formative assessment boosts teacher confidence in dealing with diverse classroom needs (TALIS 2018).

Teachers who collaborate and share pedagogical strategies are more likely to feel confident in their ability to positively influence student outcomes (TALIS, 2020[48]). Indeed, schools with a culture of collaboration among mathematics teachers perform better in mathematics (OECD, 2020[49]). For example, in Singapore, collective efficacy has been cultivated as a core practice among educators, promoting higher levels of student achievement and teacher satisfaction. Collective teacher efficacy, or teachers' collective belief in their ability to positively affect students, plays a significant role in student outcomes. For collective teacher efficacy to be effective, teachers must share a firm belief that their collaborative efforts are greater than individual efforts, suggesting a link to professional identify as it involves teachers seeing themselves as part of a powerful collective (Goddard, Hoy and Hoy, 2000[41]; Donohoo, 2018[50]).

Finally, there is a strong connection between teacher and student well-being, which is currently under discussion for the development of the OECD Teaching Compass. Students in schools where teachers report high levels of well-being tend to experience lower levels of mathematics anxiety and higher achievement (OECD, 2020[49]). When teachers feel valued, empowered and well-supported, they are more effective in creating learning environments that reduce student anxiety, foster engagement and encourage perseverance, all of which are key for success in mathematics. This holistic approach to education, integrating academic performance and emotional resilience, leads to improved long-term outcomes for both teachers and students.

Teacher autonomy also has a direct impact on teacher well-being. When teachers feel trusted and empowered, they are more likely to experience job satisfaction, reduced stress and a positive work-life balance. This well-being translates into better teaching practices, as motivated and fulfilled teachers are more effective in the classroom. Overall, this teacher agency approach can create more dynamic, responsive and effective mathematics curriculum that benefits students and teachers alike.

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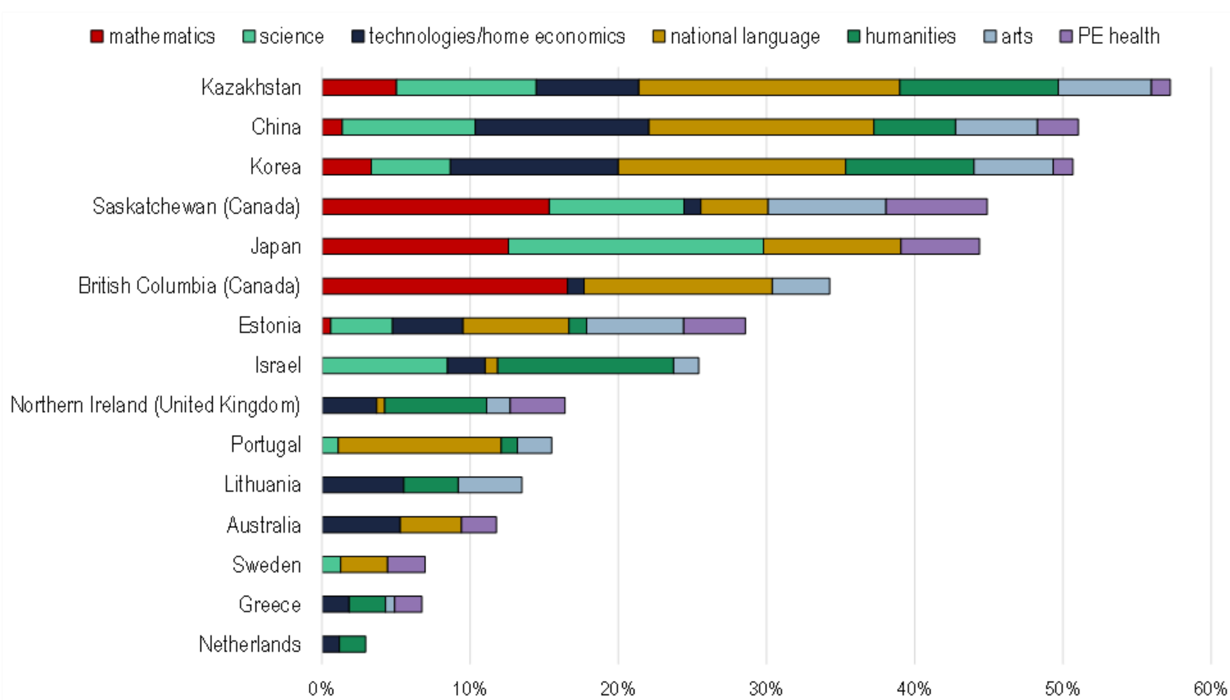
Annex A. Further findings of the Curriculum Content Mapping exercise

Additional findings from our Curriculum Content Mapping analysis are included below and may be of particular interest to researchers and experts who would appreciate a deeper dive into the data behind each of the competencies.

Key concept: Co-agency

Figure A.1. Co-agency in curricula

Distribution of content items in the mapped curricula targeting co-agency (as main or sub target), by learning area



Notes:
1. Year of reference for data collection is 2018.
2. The findings from the CCM analysis in the Netherlands are included here for their research interest. The country did not participate in the CCM main study. The curriculum mapping was conducted on a proposed revision to their curriculum, which was ultimately not approved by the Dutch Parliament and never implemented OECD (2019[1]), Education 2030 Curriculum Content Mapping: An Analysis of the Netherlands Curriculum Proposal, OECD Publishing, Paris, https://www.oecd.org/content/dam/oecd/en/about/projects/edu/education-2040/6-bilateral-support/E2030_CCM_analysis_NLD_curriculum_proposal.pdf.
Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

StatLink https://stat.link/u2wvix

Co-agency refers to "the interactive, mutually supportive relationships that help learners to progress towards their valued goals" (OECD, 2020[2]). Developing co-agency can help to foster teamwork, communication and mutual responsibility among students. In the context of mathematics, co-agency can encourage students to engage in collaborative problem-solving, share different perspectives and work together to tackle complex mathematical tasks. In general, countries/jurisdictions place a varying emphasis on co-agency in their curricula, with **Kazakhstan**, **China** and **Korea embedding** co-agency in over 50% of their curriculum items while Sweden, Greece and the Netherlands integrate it in less than 10% of their curricula (Figure A.1).

In mathematics, in most countries/jurisdictions, co-agency is embedded across several subjects, particularly in national language, arts and technologies/home economics. Only a few countries/jurisdictions, including British Columbia (Canada), Japan and Saskatchewan (Canada), embed co-agency within their mathematics education.

Meta-cognitive foundation: Learning to learn

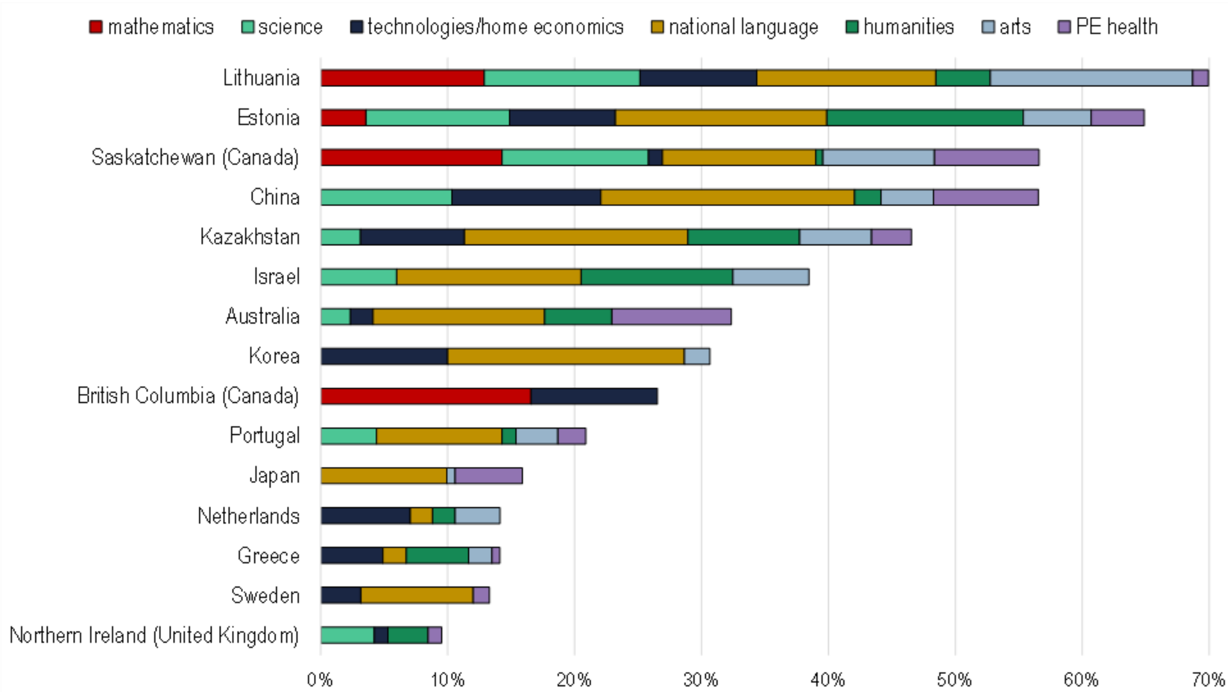
Learning to learn or meta-learning is defined as the awareness and understanding of the phenomenon of learning itself, which enables students to take control of one's own learning. Implicit in this definition is the learner's perception of the learning context, including understanding what the expectations of the discipline are and the demands of a given learning task. Learning to learn is a key competency in modern education, enabling students to develop metacognitive skills, adapt to new challenges, and take responsibility for their own learning process. It equips students with the ability to set learning goals, monitor progress, and adjust strategies based on outcomes, fostering lifelong learning (OECD, 2020[2]). The variation of embedding this important concept in country curricula is quite large, ranging from barely 10% to 70% of mapped curriculum content (Figure A.2).

Especially for mathematics, it is an important competency for fostering resilience and helping students learn to overcome setbacks and continue progressing in their mathematical journey.

Despite the importance of this concept for mathematics, it is barely reflected in any countries' mathematics curriculum, except for **British Columbia (17%), Saskatchewan (14%) (both Canada), Lithuania (13%)** and, to a much lesser extent, **Estonia (4%)**. Most countries/jurisdictions embed learning to learn in national language, technologies/home economics, science and humanities. For example, China (20%), Korea (19%) and Kazakhstan (18%) focus extensively on national language to embed learning to learn in their curriculum.

Figure A.2. Learning to learn in curricula

Distribution of content items in the mapped curricula targeting learning to learn (as main or sub target), by learning area



Notes:
1. Year of reference for data collection is 2018.
2. The findings from the CCM analysis in the Netherlands are included here for their research interest. The country did not participate in the CCM main study. The curriculum mapping was conducted on a proposed revision to their curriculum, which was ultimately not approved by the Dutch Parliament and never implemented OECD (2019[1]), Education 2030 Curriculum Content Mapping: An Analysis of the Netherlands Curriculum Proposal, OECD Publishing, Paris, https://www.oecd.org/content/dam/oecd/en/about/projects/edu/education-2040/6-bilateral-support/E2030_CCM_analysis_NLD_curriculum_proposal.pdf.
Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

StatLink https://stat.link/wdy1l2

Mental and physical foundation: Physical/health literacy

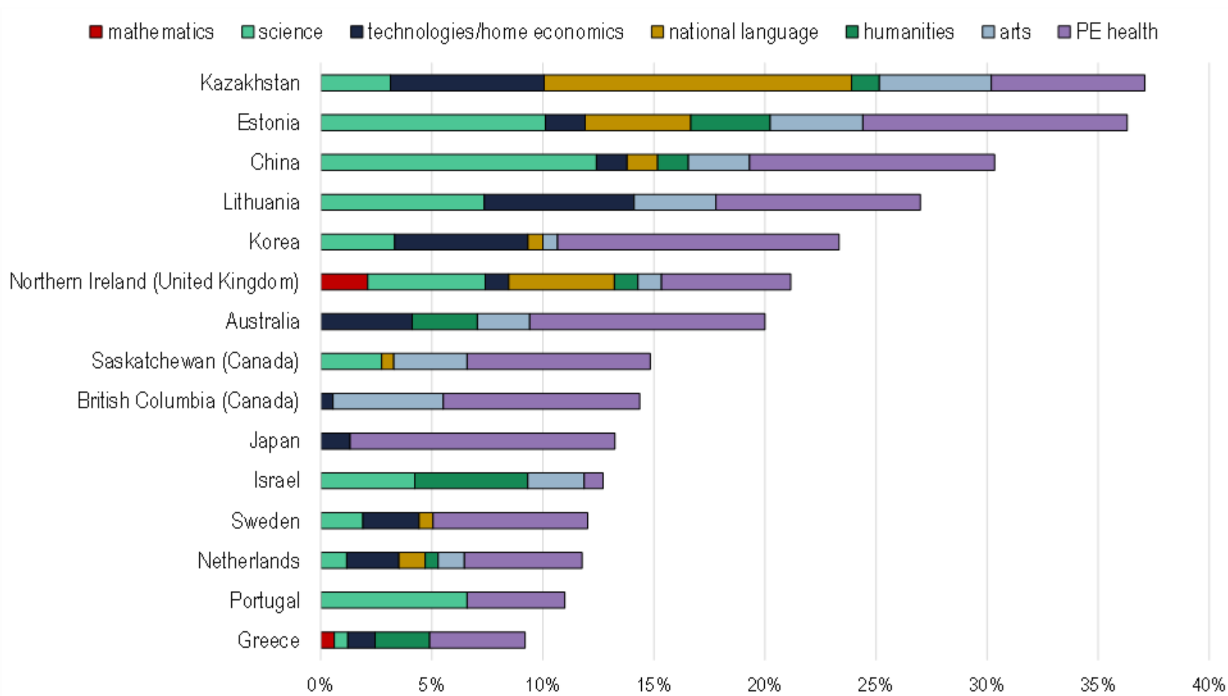
Physical/health literacy is defined as the ability and motivation to integrate physical, psychological, cognitive and social competencies into a healthy and active lifestyle. This involves the acquisition of fitness and movement skills; positive attitudes towards movement and understanding how and why to engage in movement activities. Health literacy tends to be linked to better access and use of health services, and to maintaining health and wellness (e.g. nutrition, mental health, relationships and keeping safe) throughout the life span. Physical/health literate students have the knowledge, skills and attitudes (including motivation) to access, understand, evaluate and apply health information to make appropriate decisions regarding safe and healthy practices and behaviours (OECD, 2020[2]). Countries/jurisdictions integrate physical/health literacy into various subjects (Figure A.3).

While not traditionally associated with mathematics (which is reflected in the Figure A.3, below), these competencies play an important role in math education by supporting students' well-being and enhancing their learning abilities – contextualising math in areas of personal relevance (tracking fitness progress, calculating nutritional values, etc.), increasing interdisciplinary learning and developing problem-solving skills through logical and quantitative thinking.

Almost no countries/jurisdictions in the study embed physical/health literacy within their mathematics curricula – exceptions are found in **Northern Ireland (United Kingdom) and Greece, at 2% and 1%** respectively. As expected, most countries focus heavily on embedding this competency into physical education and health (PE/health), with countries like Kazakhstan (37%), Estonia (36%) and China (30%) embedding physical/health literacy extensively across the curriculum. In addition to PE/health, subjects such as science and technologies/home economics also frequently feature physical and health literacy content. For example, in China, 12% of the mapped curriculum targeting physical and health literacy is embedded within science. Similarly, Lithuania and Estonia integrate health literacy within science, reflecting an emphasis on the scientific understanding of health.

Figure A.3. Physical/health literacy in curricula

Distribution of content items in the mapped curricula targeting physical/health literacy (as main or sub target), by learning area



Notes:
1. Year of reference for data collection is 2018.
2. The findings from the CCM analysis in the Netherlands are included here for their research interest. The country did not participate in the CCM main study. The curriculum mapping was conducted on a proposed revision to their curriculum, which was ultimately not approved by the Dutch Parliament and never implemented OECD (2019[1]), Education 2030 Curriculum Content Mapping: An Analysis of the Netherlands Curriculum Proposal, OECD Publishing, Paris, https://www.oecd.org/content/dam/oecd/en/about/projects/edu/education-2040/6-bilateral-support/E2030_CCM_analysis_NLD_curriculum_proposal.pdf.
Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

StatLink https://stat.link/blmknq

Social and emotional foundation: Self-control

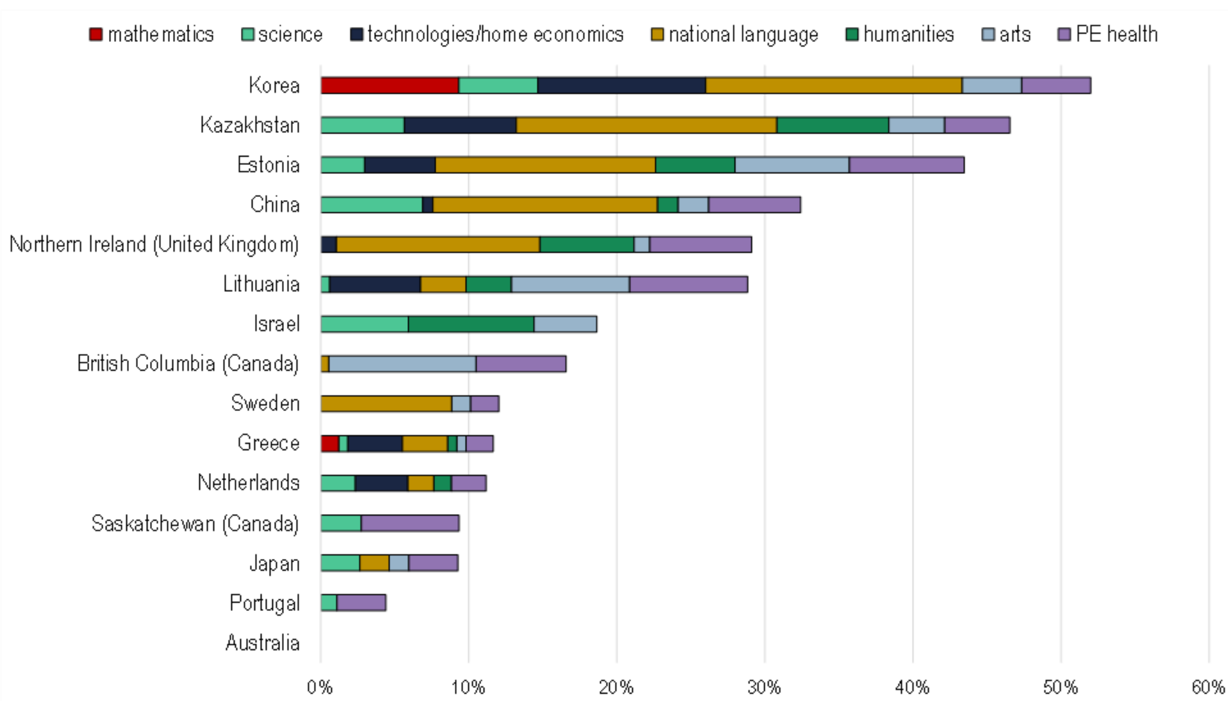
Self-control is defined as the ability to delay gratification, control impulses and manage emotional expression. Self-control is an umbrella construct that bridges concepts and measurements from different disciplines (e.g. impulsivity, conscientiousness, delay of gratification, inattention-hyperactivity, executive function, willpower, intertemporal choice) (OECD, 2020[2]). Self-control is embedded in curricula to varying degrees across countries and jurisdictions (Figure A.4).

In mathematics, students need to resist distractions and maintain focus – making self-control a crucial component of success.

However, mathematics, despite being a subject where self-control is critical, does not show high levels of embedding across most countries, with exceptions being **Korea (9%) and Greece (1%).** Subjects such as national language, PE/health, and science are more likely to embed self-control, as these areas require consistent focus and discipline. For example, Kazakhstan, Korea, Estonia and China all dedicate around 15% of their content items on self-control to their national language curriculum, making it the most prominent subject for this competency.

Figure A.4. Self-control in curricula

Distribution of content items in the mapped curricula targeting self-control (as main or sub target), by learning area



Notes:
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Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

StatLink https://stat.link/zhp3gv

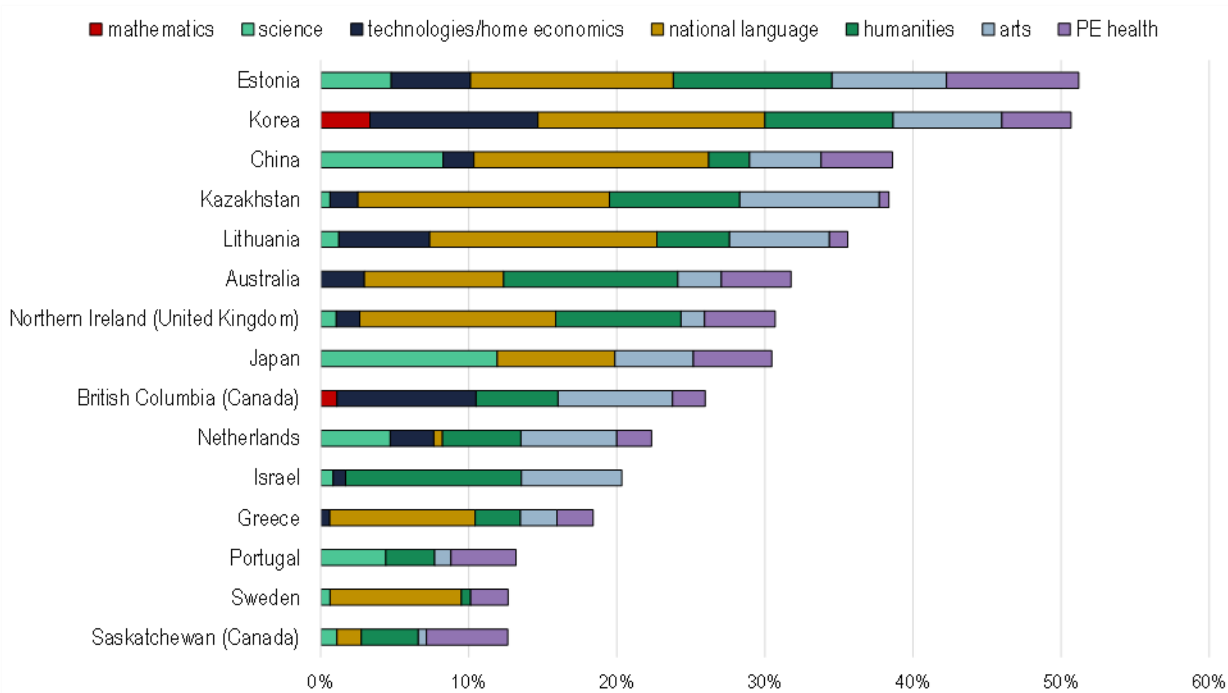
Social and emotional foundation: Empathy

Empathy, defined as the capacity to understand, share and respond with care to the emotions and perspectives of others, is a vital competency for fostering social cohesion and emotional intelligence. It involves not only cognitive skills, such as perspective-taking, but also emotional and social skills, enabling individuals to connect with others, particularly those who are different from themselves (OECD, 2020[2]). Though not traditionally associated with mathematics (which is reflected in Figure A.5 below), empathy plays an important role in the mathematics context by fostering an inclusive, supportive learning environment and improving collaborative problem solving – ultimately promoting socio-emotional growth.

Despite its importance for mathematics, empathy is almost never explicitly embedded within mathematics education in most countries/jurisdictions, with the focus generally being on more traditionally social subjects: only **Korea (3%)** and **British Columbia (Canada) (1%)** embed it, to a minimal extent, in their mathematics curricula. Countries like Estonia (51%) and Korea (51%) embed empathy across more than half of their curricula, with a significant focus on subjects such as national language, humanities and arts. In contrast, countries/jurisdictions like Saskatchewan (Canada) and Sweden integrate empathy into only around 13% of their mapped curricula.

Figure A.5. Empathy in curricula

Distribution of content items in the mapped curricula targeting empathy (as main or sub target), by learning area



Notes: 1. Year of reference for data collection is 2018.
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Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

StatLink https://stat.link/cjn817

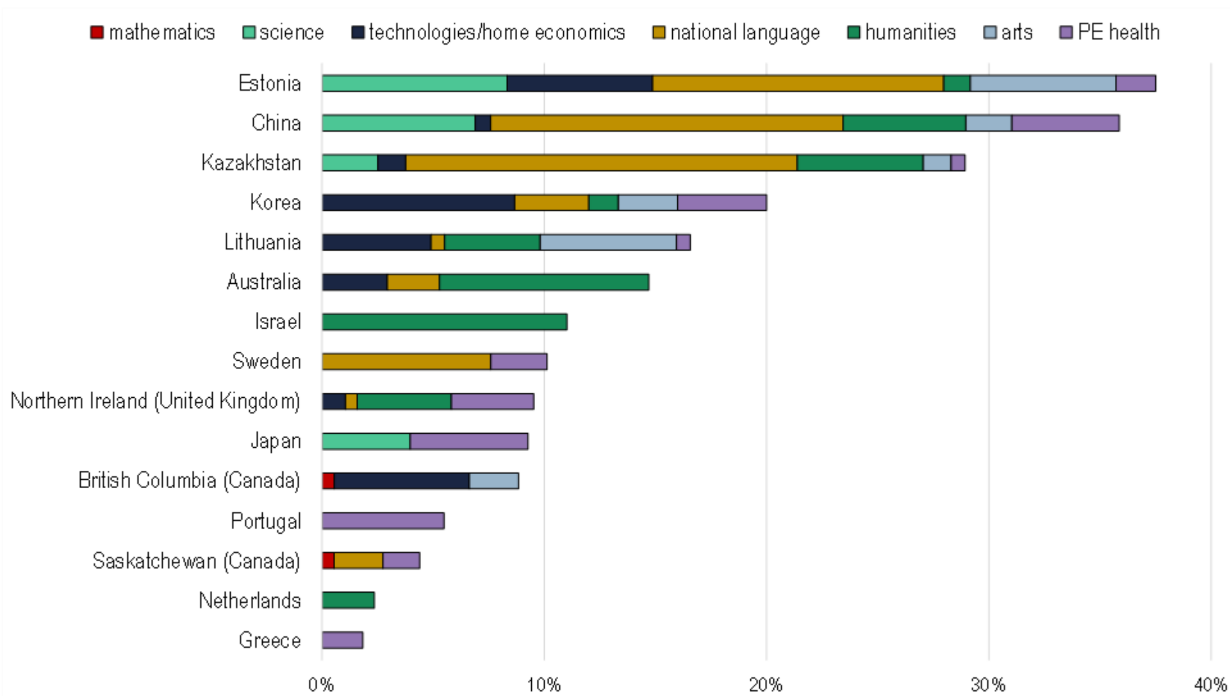
Social and emotional foundation: Trust

Trust is an attitude developed towards individuals and institutions/organisations based on a belief in the reliability and integrity of actions taken or planned. Trust is formed when one is confident that the actions of others are primarily based on good intentions and ethical considerations rather than being aimed to negatively impact individuals or groups. Trust is a multi-dimensional construct which is formed when care, competence and openness are exhibited by individuals and institutions/organisations. The degree of personal and/or societal wellness is closely related to the level of trust held within a community (OECD, 2020[2]). The emphasis on trust varies significantly across countries (Figure A.6).

Trust in mathematics isn't just about believing in one's own abilities; it's about creating a classroom culture where students feel safe, valued and encouraged to explore, make mistakes and grow. This foundation of trust is essential for meaningful, confident and resilient learning in mathematics.

Figure A.6. Trust in curricula

Distribution of content items in the mapped curricula targeting trust (as main or sub target), by learning area



Notes:
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Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

StatLink https://stat.link/kvpz17

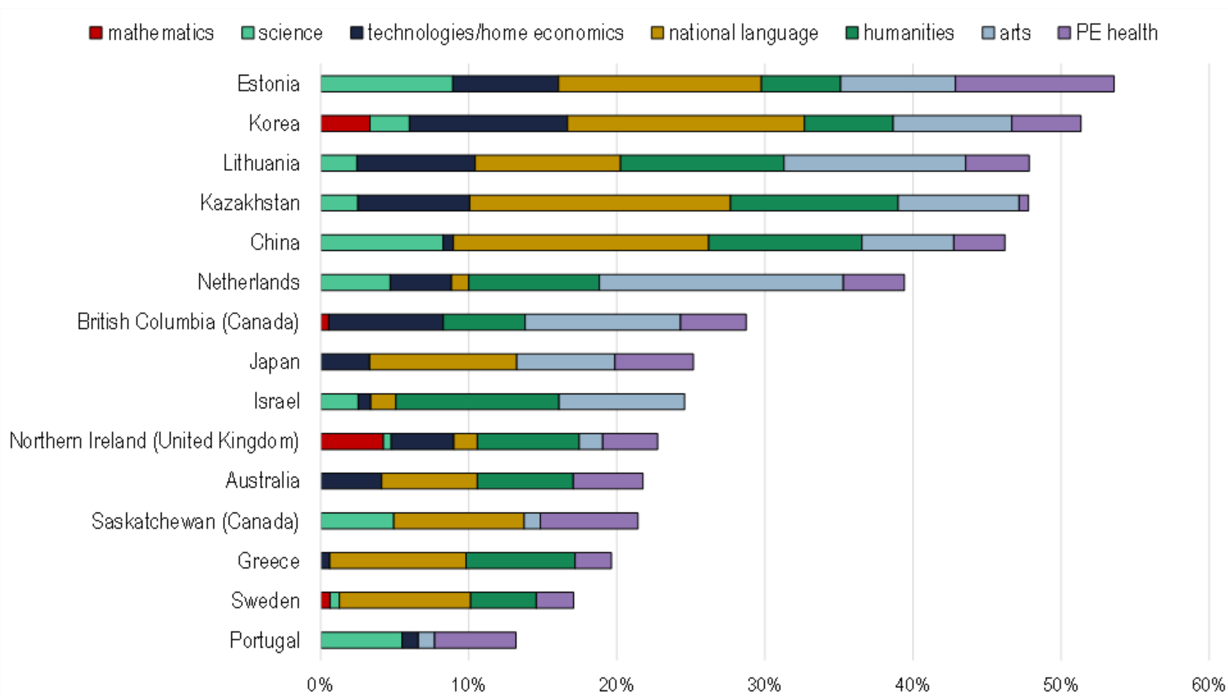
Notably, trust is only rarely incorporated into mathematics education (**British Columbia and Saskatchewan (both Canada) at 1%),** as it is more frequently embedded in subjects traditionally linked to social interactions, such as humanities and national language. Estonia (38%), China (36%) and Kazakhstan (29%) lead in integrating trust-related content into their curricula, with trust being embedded across a wide range of subjects, including national language, humanities, PE health and science. In contrast, countries like Greece (2%) and the Netherlands (2%) place much less focus on trust in their curricula.

Social and emotional foundation: Respect

Respect involves valuing oneself, others, and the environment, with regard for the feelings, rights, and surroundings of individuals and nature. It is shaped by cultural norms and is demonstrated through behaviour and communication. Respect for cultural diversity means appreciating differences among people, while respect for nature reflects environmental ethics (OECD, 2020[2]). Countries embed respect to a varying degree in their curricula (Figure A.7).

Figure A.7. Respect in curricula

Distribution of content items in the mapped curricula targeting respect (as main or sub target), by learning area



Notes:
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Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

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In mathematics, respect plays a role in fostering collaboration, encouraging productive discussions, and valuing diverse perspectives during problem-solving. On the other hand, respect can also be fostered through mathematics education by using heterogeneous grouping and complex instruction, which encourages students to appreciate diverse perspectives and take responsibility for each other's learning, promoting relational equity (Boaler, 2006[3]).

However, respect is almost never explicitly integrated into mathematics, with only **Northern Ireland (United Kingdom) (4%), Korea (3%),** and **British Columbia (Canada) (1%)** showing any inclusion of respect in their mathematics curricula. Subjects such as national language, humanities and arts tend to feature respect more prominently, with for example Kazakhstan and China embedding it 18% and 17% respectively in their national language curricula. Countries/jurisdictions such as Estonia (54%), Korea (51%) and Lithuania (48%) show a high degree of embedding respect across different subjects in their curricula. On the other hand, countries like Portugal (13%) and Sweden (17%) display a relatively lower integration of respect.

Transformative competencies: Conflict resolution/reconciling tensions and dilemmas

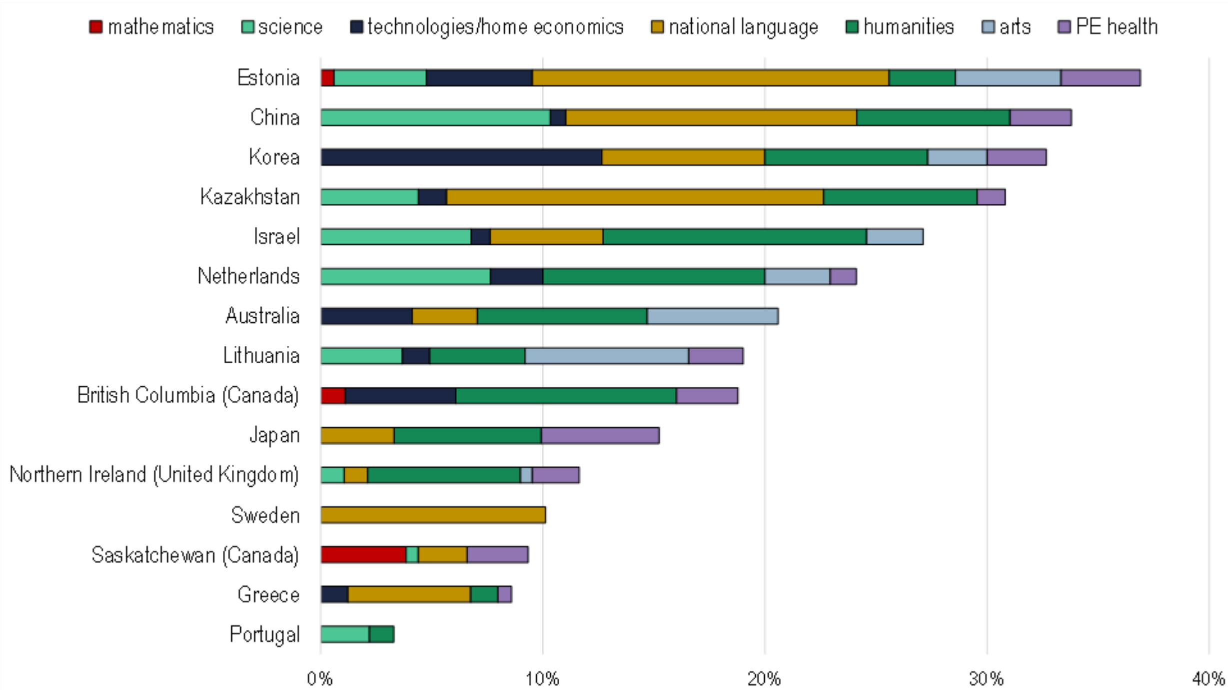
Reconciling tensions and dilemmas – which encompasses the construct of conflict resolution – refers to the ability to navigate complex and often conflicting issues, trade-offs and competing priorities in a constructive, forward-looking manner. It involves acknowledging that many situations do not have simple either-or solutions, and instead require a nuanced approach that integrates diverse perspectives and goals. Conflict resolution requires purposeful listening, clarification of viewpoints, finding common understandings or viewpoints, identifying solutions and evaluating outcomes as methods and processes involved in facilitating the peaceful end of conflict and resolution. (OECD, 2020[2]). Figure A.8 shows that the emphasis on embedding these competencies into curricula varies across countries/jurisdictions.

In mathematics, the skill of reconciling tensions and dilemmas can help students approach problems with a mindset that there might be multiple ways to solve a problem or address a challenge. It encourages reflective thinking and the ability to manage ambiguity, which is particularly relevant in the context of real-world problem-solving where mathematics is applied.

This competency is often integrated across multiple subject areas, including national language, humanities and science, while its presence in mathematics remains limited, with few countries/jurisdictions embedding it in this learning area. Exceptions can be seen in **Saskatchewan (4%)** and **British Columbia (1%) (both Canada)**, as well as **Estonia (1%),** with a close to negligeable share of integration. Estonia (37%), China (34%) and Korea (33%) have the highest percentage of their curricula focusing on reconciling tensions and dilemmas. Countries like Portugal (3%) and Greece (9%) show the least focus on embedding reconciling tensions and dilemmas into their curricula.

Figure A.8. Reconciling tensions and dilemmas in curriculum

Distribution of content items in the mapped curricula targeting reconciling tensions and dilemmas (as main or sub target), by learning area



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Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

StatLink https://stat.link/zvld3y

Transformative competencies: Responsibility

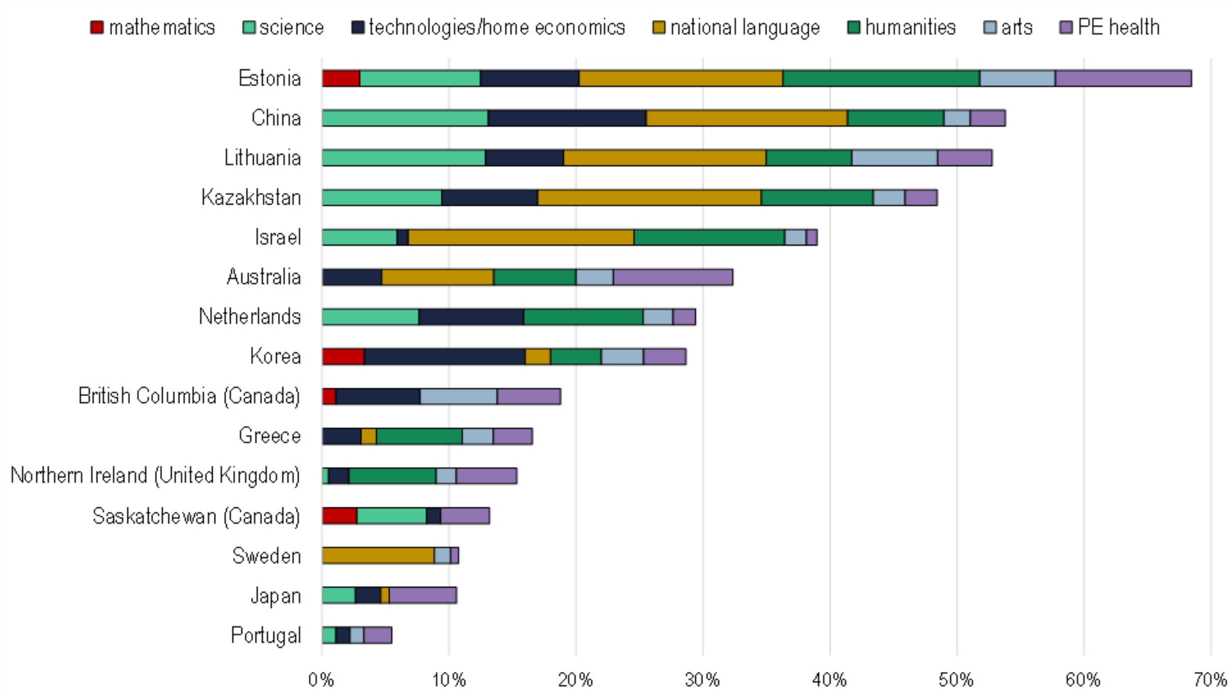
Taking responsibility refers to the ability to act responsibly for a good cause, principles and integrity for individual and collective well-being. A responsible person demonstrates the willingness to accept praise, blame, reward or punishment for an act or omission, and to accept the consequences of their behaviour, they have a commitment to the group and others, they can be depended on, and they have integrity (OECD, 2020[2]). As shown in Figure A.9, there is significant variation in how countries/jurisdictions integrate taking responsibility into their curricula.

In the mathematics context, responsibility plays an important role encouraging students to approach learning with accountability, discipline and sense of ownership – it empowers students to take charge of their learning, approach challenges thoughtfully and develop strong study habits that support their success.

Interestingly, taking responsibility appears less frequently in mathematics across most countries/jurisdictions, with only a few countries/jurisdictions like **Estonia, Korea** and **Saskatchewan (Canada) (all at 3%)** including it in this subject. This trend highlights the general perception that taking responsibility may be more naturally addressed in the context of social sciences, though its relevance in mathematics education – particularly in relation to problem-solving, integrity in data interpretation and accountability for solutions – should not be overlooked. Estonia (68%), China (54%) and Lithuania (53%) lead in embedding taking responsibility across a wide range of subjects, including national language, humanities and science. In contrast, countries like Portugal (5%) and Japan (11%) have a much lower percentage of curriculum items targeting taking responsibility.

Figure A.9. Taking responsibility in curricula

Distribution of content items in the mapped curricula targeting taking responsibility (as main or sub target), by learning area



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Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

StatLink https://stat.link/leno3h

Compound literacies/competencies: Entrepreneurship

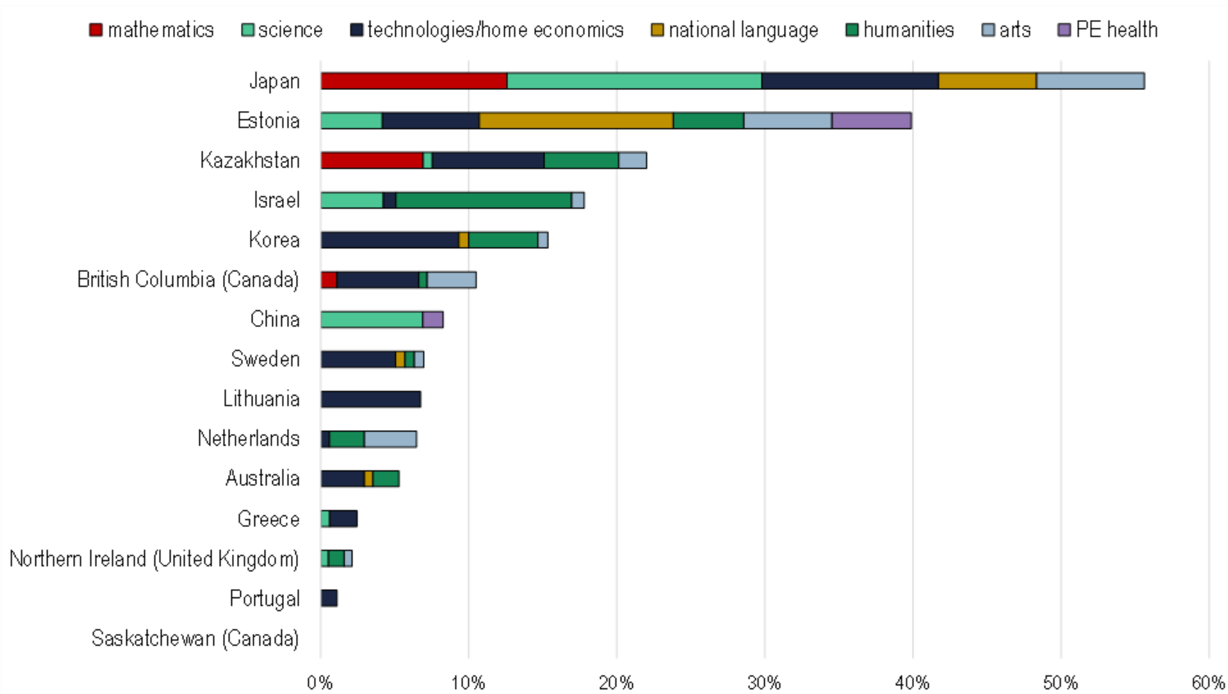
Entrepreneurship is defined as the ability to add value. It involves evaluating situations, organising resources, and creating and developing opportunities for adding value. This value might be a product, service, idea or a solution to address an issue or satisfy a need (OECD, 2020[2]). Most countries/jurisdictions that participated in the CCM do not place much importance on entrepreneurship, with it being embedded in under 10% of their curricula (Figure A.10).

Integrating entrepreneurial competencies into mathematics lessons has been shown to transform the learning environment, giving students opportunities to engage with mathematical concepts in new, creative ways (Lindberg and Nahnfeldt, 2017[4]). This can encourage deeper mathematical discussions, collaboration, and the application of problem-solving skills in real-world contexts. Entrepreneurial competencies help students develop agency in their learning, fostering a mindset where they take initiative, handle complex problems, and apply mathematical reasoning without relying solely on formulaic instructions. This not only enhances mathematical understanding but can also prepare students for the kinds of challenges they may face beyond the classroom.

Given its importance for mathematics, it is surprising that most countries/jurisdictions rather embed entrepreneurship within their technologies/home economics, humanities or sciences subjects, while it appears to a far smaller extent in mathematics. Only three countries/jurisdictions – **Japan (13%), Kazakhstan (7%) and British Columbia (Canada) (1%)** – integrate entrepreneurship within their mathematics education. However, some countries/jurisdictions, such as Japan and Estonia, integrate entrepreneurship more extensively into their curricula, with the competency integrated into 56% and 40% of their mapped curriculum items, respectively, while giving priority to science (17% for Japan) and national language curricula (13% for Estonia).

Figure A.10. Entrepreneurship in curricula

Distribution of content items in the mapped curricula targeting entrepreneurship (as main or sub target), by learning area



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Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

StatLink https://stat.link/3k9amg

Compound literacies/competencies: Media literacy

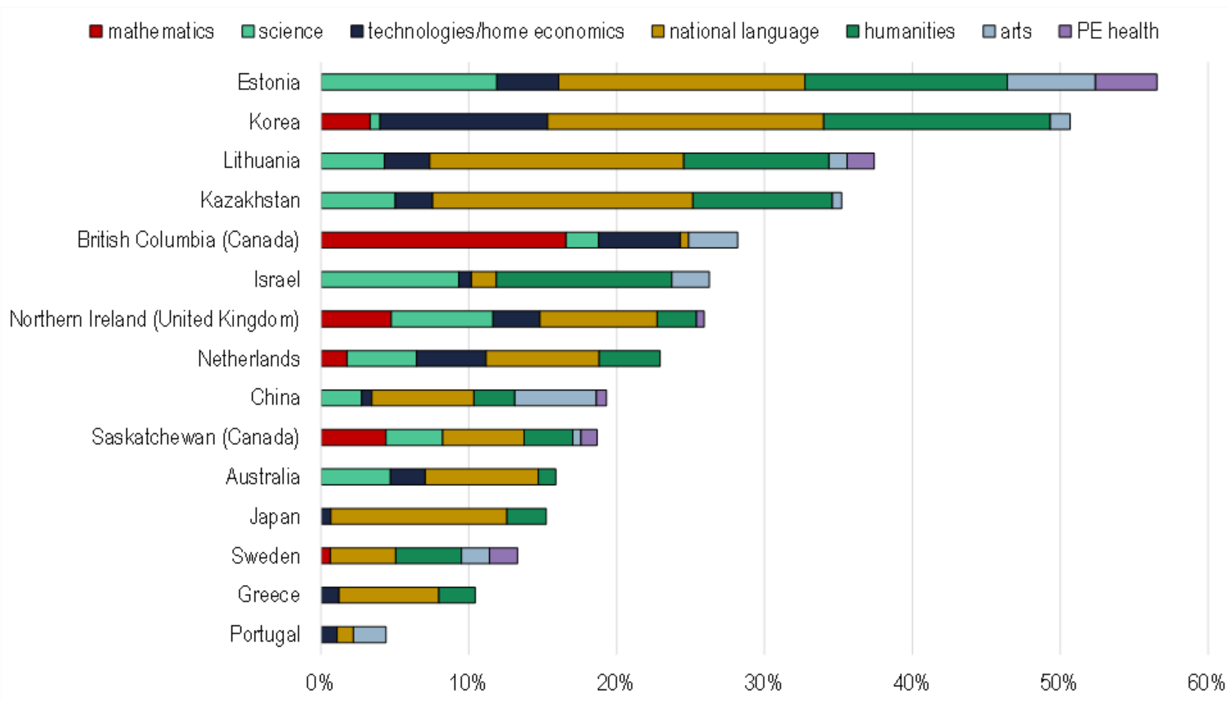
Media literacy is defined as the ability to think critically and analyse what one reads in the media, including social media and news sites. This includes recognising "fake news", or the ability to distinguish what is true from what is not, as well as to be able to assess, evaluate and reflect on the information that is given in order to make informed and ethical judgements about it (OECD, 2020[5]). As shown in Figure A.11, there is significant variation in how countries/jurisdictions integrate media literacy into their curricula.

Media literacy in mathematics helps students not only understand how numerical and visual data function, but also equips them to critically evaluate the information they encounter.

In most countries, media literacy is embedded in subjects such as national language, humanities and technology/home economics. For example, Korea dedicates 19% of its content items in national language curricula to media literacy. However, **British Columbia (Canada) (17%)** stands out as an exception, embedding medial literacy mostly into their mathematics curriculum, followed to a much lesser extent by **Northern Ireland (United Kingdom) (5%), Saskatchewan (Canada) (4%), Korea (3%), the Netherlands (2%)** and **Sweden (1%).**

Figure A.11. Media literacy in curricula

Distribution of content items in the mapped curricula targeting media literacy (as main or sub target), by learning area



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Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

StatLink https://stat.link/ha547p

Compound literacies/competencies: Global competency

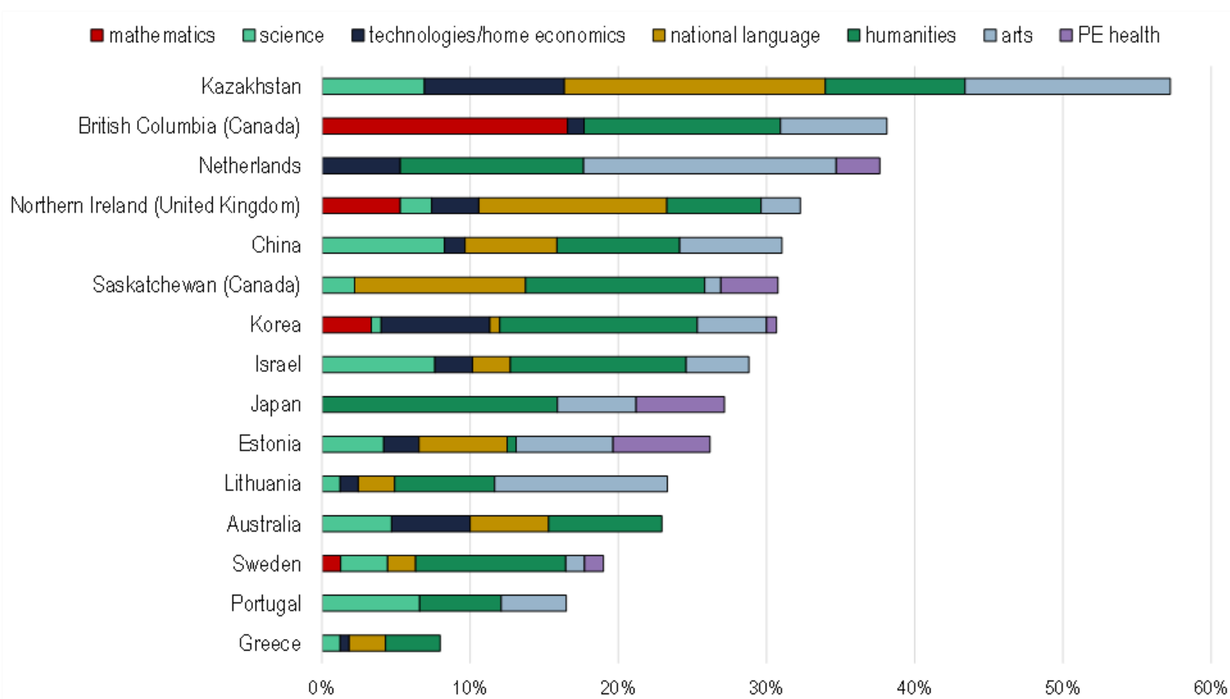
Global competency refers to the ability to explore local, global and intercultural issues, understand and appreciate diverse perspectives, engage in open and effective communication with people from different cultures, and take action for collective well-being. (OECD, 2020[5]). Most countries/jurisdictions embed global competency in less than 30% of their mapped curriculum items (Figure A.12).

For the mathematics context, incorporating global competency into math education cultivates a more holistic view, encouraging students to become globally-minded problem solvers who can effectively apply their skills across diverse contexts. This not only enriches their understanding of mathematics but also prepares them to address complex issues in an interconnected world.

Countries/jurisdictions primarily focus on subjects such as arts, humanities and national language to embed global competency in their curricula. However, as with media literacy, **British Columbia (Canada)** is the outlier, dedicating **17%** of content items in their math curricula to global competency learning. British Columbia is followed by **Northern Ireland (United Kingdom) (5%), Korea (3%)** and **Sweden (1%),** embedding global competency to a much lesser extent into maths, while prioritising national language and humanities (for Korea and Sweden), respectively.

Figure A.12. Global competency in curricula

Distribution of content items in the mapped curricula targeting global competency (as main or sub target), by learning area



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Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

StatLink https://stat.link/1nadf2

Anticipation-Action-Reflection Cycle: Anticipation

The Anticipation-Action-Reflection (AAR) cycle is a process that encourages individuals to anticipate possible outcomes, take informed actions and reflect on the consequences of those actions to foster continuous improvement and learning. This cyclical approach helps individuals and groups navigate complex situations, adjust strategies and enhance their decision-making skills by learning from both successes and failures.

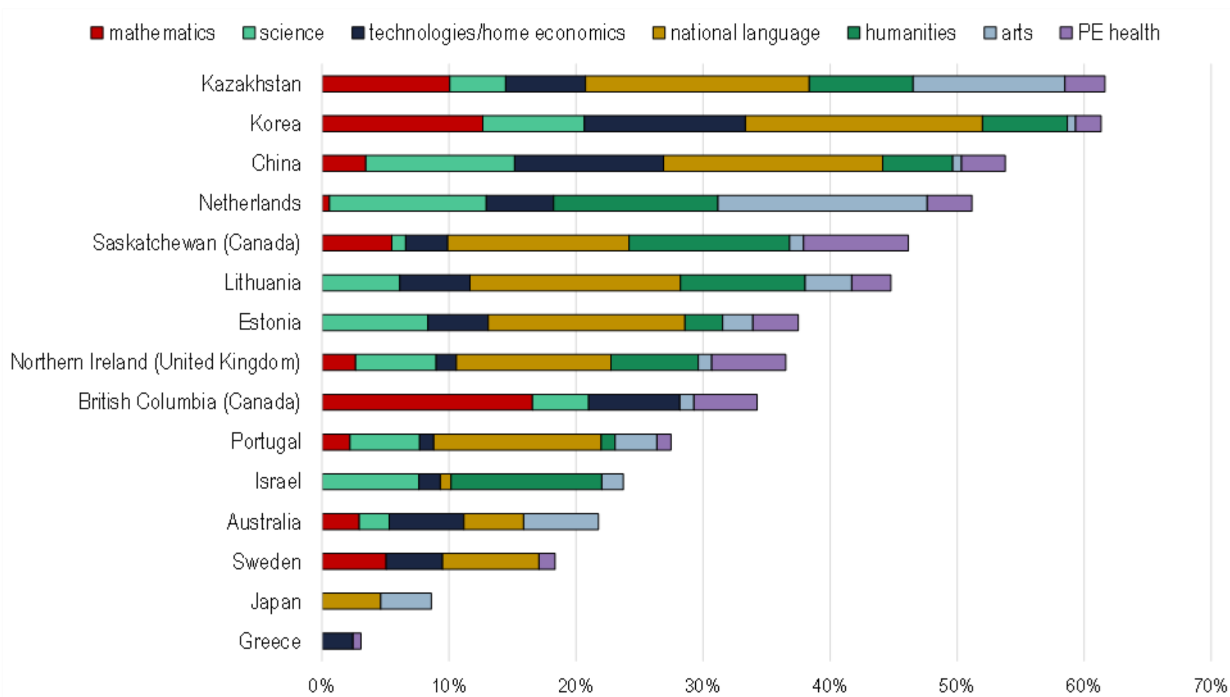
Anticipation, the first element of the AAR cycle, is defined as the ability to foresee or predict the consequences of actions, both in the short- and long-term, while also being able to understand others' intentions and feelings. This competency is crucial for enabling individuals to take responsibility for their decisions, influence outcomes and shape their own futures (OECD, 2020[2]).

Countries/jurisdictions vary in the extent to which they embed anticipation in their curricula (Figure A.13).

From a mathematics perspective, anticipation is a key competency for certain types of data analysis involving predictions, simulations and forecast. It builds students' strategic thinking and fosters their adaptability, all essential skills for both theoretical mathematics and practical applications in everyday life.

Figure A.13. Anticipation in curricula

Distribution of content items in the mapped curricula targeting anticipation (as main or sub target), by learning area



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Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

StatLink https://stat.link/8pzyjk

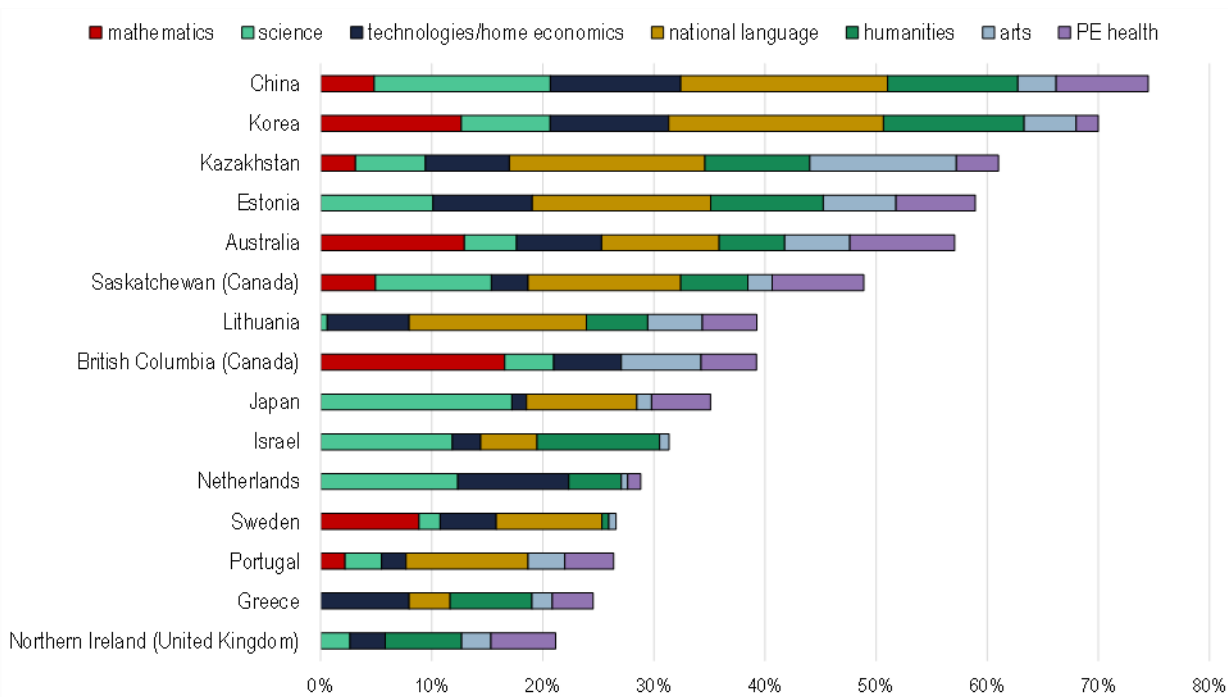
This importance is being recognised by countries/jurisdictions, who put a certain emphasis on embedding anticipation into their math curricula – most countries embed anticipation to at least a certain extent in math, ranging from **1% (the Netherlands) to 17% (British Columbia, Canada).** Interestingly, national language is picked as the priority subject for anticipation for most countries, with for example Korea, Kazakhstan, China and Lithuania dedicating above 15% of their content items in this curriculum area to anticipation. In general, Kazakhstan (62%), Korea (61%) and China (54%) embed anticipation more extensively across multiple subjects, while countries like Greece (3%) and Japan (9%) show significantly lower integration.

Anticipation-Action-Reflection Cycle: Action

Action as a competency involves the ability to act with a willingness and capacity for a defined purpose. It involves the individuals' disposition to act on what they are learning or want to learn or in response to a situation; to utilise acquired skills to act or contribute to a situation or circumstances and to evaluate the impact of one's actions (OECD, 2020[2]). Countries/jurisdictions take a diverse approach to embedding action in curricula (Figure A.14).

Figure A.14. Action in curricula

Distribution of content items in the mapped curricula targeting action (as main or sub target), by learning area



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Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

StatLink https://stat.link/le1acy

In mathematics, fostering action is crucial because it moves students beyond passive learning. By encouraging them to take action in their learning, students actively engage with mathematical concepts, try out new methods of problem-solving, and apply their knowledge to real-world tasks. This hands-on approach helps them develop critical thinking, adaptability and confidence in using mathematics in everyday life, from financial literacy to scientific analysis.

Most countries/jurisdictions embed action within national language, humanities, technologies/home economics or science, with less emphasis in mathematics. However, a few countries/jurisdictions, including **British Columbia (Canada) (17%), Australia** and **Korea (both at 13%),** also integrate action into their mathematics education. In general, China and Korea stand out for integrating action in over 70% of their curriculum items, while prioritising national language curricula to embed action (19% for both). In contrast, countries like Northern Ireland (United Kingdom) (21%) and Greece (25%) place less focus on cultivating action through their curricula.

Anticipation-Action-Reflection Cycle: Reflection

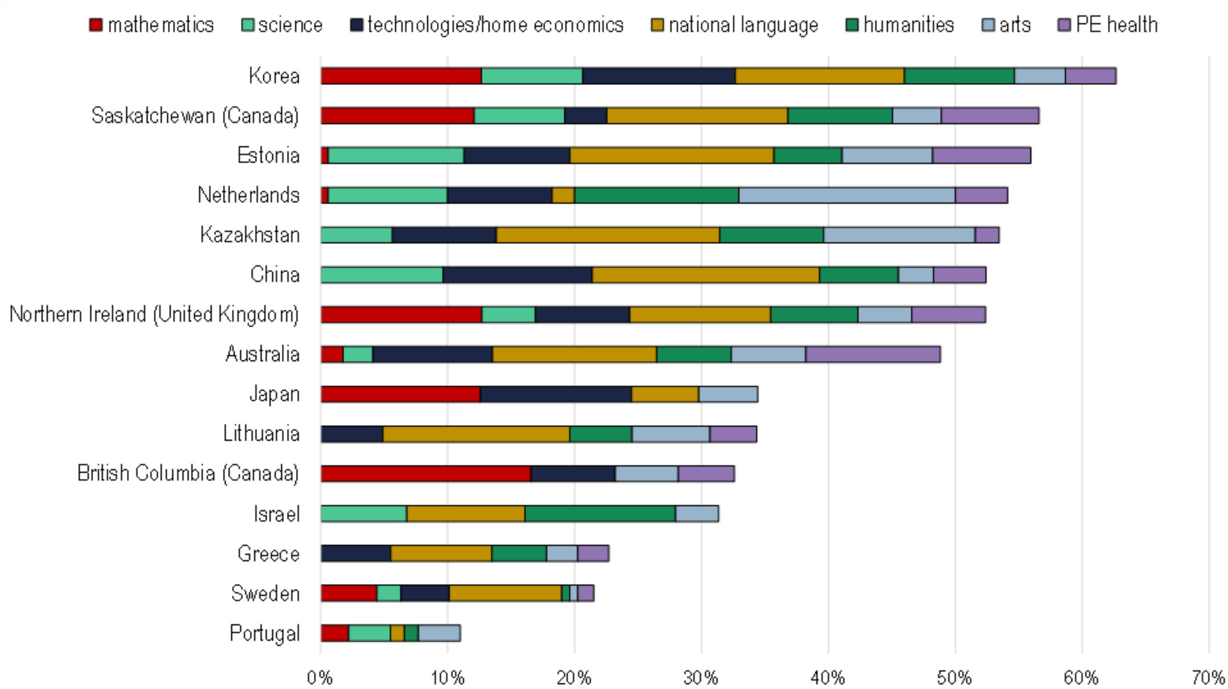
Reflection is the ability to take a critical stance before deciding, choosing and acting, such as by stepping back from the assumed, known, apparent and accepted, comparing a given situation from another, different perspective, and looking beyond the immediate situation to the long-term and indirect effects of one's decisions and actions. This enables individuals to reach a level of social maturity that allows them to adopt different perspectives, make independent judgments and take responsibility for their decisions and actions. The reflective approach is based on a model of human development in which individuals are able to integrate increasing levels of complexity into their thinking and actions (OECD, 2020[2]). Countries/jurisdictions embed reflection in their curricula to a varying degree (Figure A.15).

In mathematics, reflection is essential for students to critically evaluate their problem-solving approaches, understand mistakes, and refine their strategies. It helps them not only to solve mathematical problems but also to think about the reasoning behind their solutions, enabling deeper learning and more effective application of mathematical concepts to real-world situations.

While reflection is most often embedded into national language and technologies/home economics, it is also widely integrated into mathematics, especially in some countries/jurisdictions such as **British Columbia (Canada) (17%), Japan (13%), Korea (13%) Northern Ireland (United Kingdom) (13%),** and **Saskatchewan (Canada) (12%).** In general, countries/jurisdictions embed reflection across a wide range of subjects – even those that emphasise reflection to a lesser degree in their curricula (e.g. Portugal at 11% and Sweden at 22%) have reflection embedded in at least five out of seven learning areas.

Figure A.15. Reflection in curricula

Distribution of content items in the mapped curricula targeting reflection (as main or sub target), by learning area



Notes:
1. Year of reference for data collection is 2018.
2. The findings from the CCM analysis in the Netherlands are included here for their research interest. The country did not participate in the CCM main study. The curriculum mapping was conducted on a proposed revision to their curriculum, which was ultimately not approved by the Dutch Parliament and never implemented OECD (2019[1]), Education 2030 Curriculum Content Mapping: An Analysis of the Netherlands Curriculum Proposal, OECD Publishing, Paris, https://www.oecd.org/content/dam/oecd/en/about/projects/edu/education-2040/6-bilateral-support/E2030_CCM_analysis_NLD_curriculum_proposal.pdf.
Source: Data from the Education 2030 Curriculum Content Mapping (CCM) exercise.

StatLink https://stat.link/7utvz5

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An Evolution of Mathematics Curriculum

WHERE IT WAS, WHERE IT STANDS AND WHERE IT IS GOING

The OECD Future of Education and Skills 2030 report on mathematics curriculum presents first-of-its-kind comparative data on how countries are adapting curricula to meet the demands of the 21st century. The project's unique data illustrate a 25-year evolution of mathematics curricula in various countries, looking at content coverage and the integration of essential 21st-century skills like problem-solving, critical thinking, and data literacy. The findings show how mathematics as a school discipline – a traditionally "hard-to-change" subject given its foundational and hierarchical nature – is undergoing transformation to meet societal and technological demands.

Using a collaborative "co-creation" approach, the report synthesises inputs from a wide range of stakeholders including policy makers, academic experts, school leaders, teachers, NGOs, social partners and, most importantly, students. This broad, inclusive perspective enriches the report with insights on implementation gaps, students' voice, and promising examples on how to embed future-oriented competencies alongside rigorous content into mathematics curriculum.

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