STEM policy in Nordic, other European, Anglosphere and East Asian countries: Objectives and prevalence

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INTRODUCTION

This policy brief was prepared for the Confederation of Swedish Enterprise to identify Science, Technology, Engineering and Mathematics (STEM) policies introduced by Sweden's leading comparator countries. As a highly competitive, advanced European economy, Sweden's comparators identified for this study include other Nordic countries (Finland, Norway, Denmark, Iceland), other European countries (France, Germany), high-performing Anglosphere countries (United States, United Kingdom, Australia) and dynamic East Asia (Japan, South Korea). Rather than focusing on Swedish Government policy priorities and commitments to science, technology and innovation, this policy brief reveals the prevalence of Sweden's comparator country's STEM policies. It highlights STEM-related government policy priorities, STEM policy objectives and focus areas, while also referencing climate, energy, space and security policies that are heavily reliant on STEM skills, knowledge and capabilities. Building on this evidence base, further research will be undertaken to analyse key STEM policies of these comparator countries, to contribute to discussions regarding the development of Swedish STEM policy.

Defining STEM

STEM has been defined as "learning and/or work in the fields of science, technology, engineering and mathematics, including preliminary learning at school prior to entry into the specific disciplines" (Marginson et al., 2013, p. 30). STEM education involves "teaching and learning in the fields of science, technology, engineering, and mathematics … [including] educational activities across all grade levels – from pre-school to post-doctorate – in both formal (e.g., classrooms) and informal (e.g., afterschool programs) settings" (Gonzalez & Kuenzi, 2012, p. i). This signals the vital role for teachers, faculty members and education institutions spanning early years learning centres, schools, vocational or technical institutions, higher education institutions, and research institutes. From a disciplinary perspective, STEM encompasses school mathematics and science (typically biology, chemistry, physics), as well as vocational and higher education STEM disciplines (i.e., science, technology, engineering, and mathematics). In some countries, health sciences are included (e.g., STEM or STEMM); whereas in others they are not. Increasingly, the acronym STEM is considered to encompass additional dimensions (e.g., iSTEM: integrated Science, Technology, Engineering, Mathematics; STEAM: Science, Technology, Engineering, Arts and Mathematics) acknowledging the importance of the humanities, arts and social sciences, and interdisciplinarity.

Scoping the 'policy problem'

This policy brief discusses public policies that explicitly articulate government choices or decisions, applying a narrow definition of policy as "a statement of government intent, and its implementation through the use of policy instruments" (Althaus et al., 2013, p. 246). According to Arvanitis (2002), "science and technology policy covers the public sector measures designed for the creation, funding, support, and mobilization of scientific and technological resources" (p. 2). In this policy brief, 'policy' encompasses diverse formal instruments including *legislation*, *policy* (e.g., policy texts, strategies, plans and roadmaps), *expenditure* and *information* concerning STEM, and science, technology and innovation more broadly.[1] These policies are implemented through multiple government ministries, departments, instrumentalities, governance structures, infrastructure and programs.

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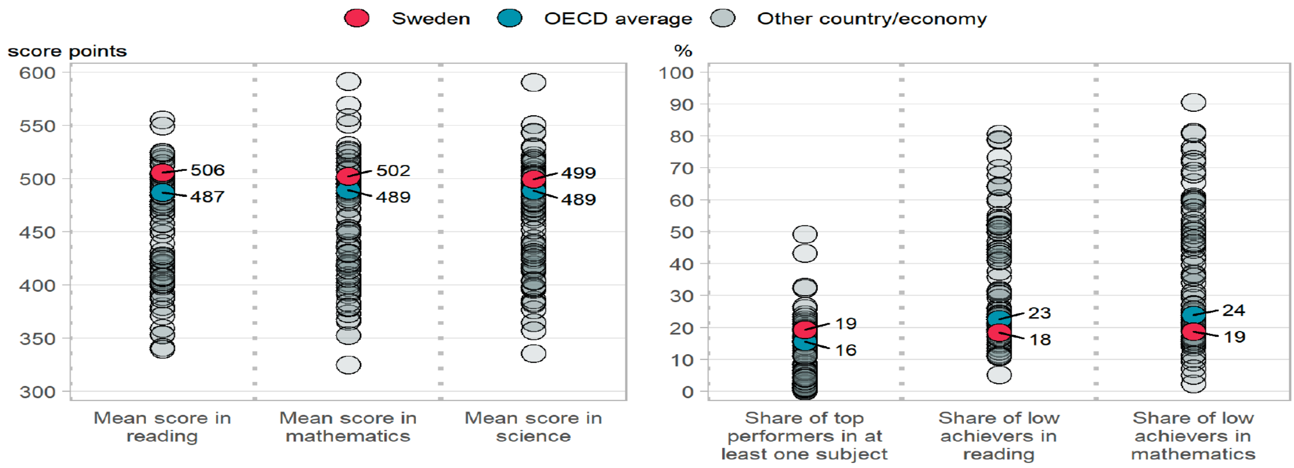
[1] See Capano et al., 2019.

In many jurisdictions, STEM policy has been introduced to address six key policy problems. First, declining participation in school mathematics and science (i.e., interest, enrolment), extending to issues concerning curriculum, pedagogy, and subject integration. Second, declining (or suboptimal) relative national and international educational performance in school mathematics and science assessments[2] (i.e., Programme for International Student Assessment [PISA], and Trends in International Mathematics and Science Study [TIMSS]) (Figure 1).

International educational performance in school mathematics and science

Figure 1: Snapshot of Performance in Reading, Mathematics and Science (PISA, 2018)[3]



Note: Only countries and economies with available data are shown.
Source: OECD, PISA 2018 Database, Tables I.1 and I.10.1.

Third, declining (or inadequate) participation (e.g., enrolments, graduates[4]) in STEM disciplines at higher education level, including under-representation of specific cohorts (e.g., women and traditionally marginalised groups) relative to industry demand for qualified, competent STEM professionals and knowledge workers for continued industry competitiveness (Figure 2).

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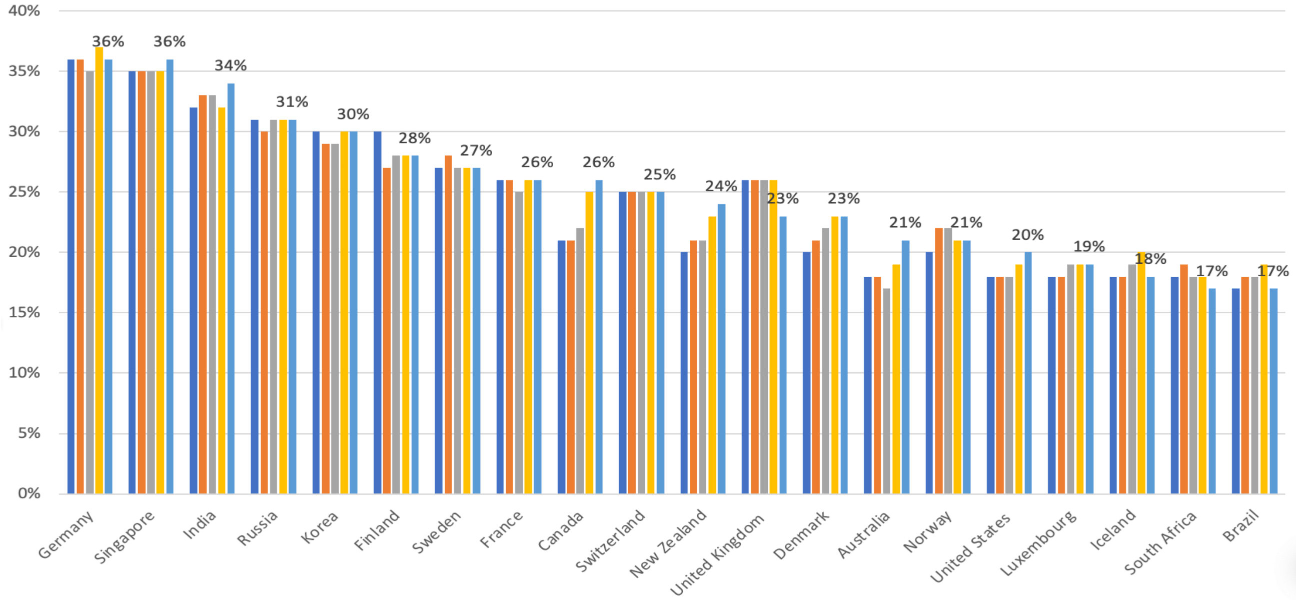
2 According to PISA assessments, the reading, mathematics, and science proficiency of Sweden's 15-year-olds fluctuated over the period 2000 to 2018. During this time, Organisation for Economic Co-operation and Development (OECD) country results remained relatively static; however, trended down between 2012 and 2018. Sweden's decreases from the turn of the century, culminating in the 2012 results (reading: 483; mathematics: 478; science: 485), caused considerable concern (i.e., 'PISA shock'). However, Sweden's PISA results corrected to near pre-2012 levels by 2018, with student's reading, mathematics, and science proficiency scores higher than the OECD mean scores: reading (Sweden: 506; OECD mean: 487), mathematics (Sweden: 502; OECD mean: 489) and science (Sweden: 499; OECD mean: 489). For reading, Sweden's proportion of 'top performers' (defined as achieving level 5 or 6 in PISA) (13%) was higher than the OECD average (11%), and this was the case for both mathematics (13% Sweden; 11% OECD) and science (8% Sweden; 7% OECD). Furthermore, Sweden's proportion of students achieving minimum proficiency levels (defined as achieving level 2 or higher) was higher than the OECD (evidencing a short 'tail', despite increasing differences between students from different socio-economic backgrounds) (OECD, 2019).

3 See OECD, 2019.

4 The percentage of graduates from Swedish higher education STEM programs remained relatively static (ranging from 27-28%) over the period 2016 to 2020. In 2020, Sweden (27%) ranked 7th behind select comparators including Germany (36%), Singapore (36%) and Korea (30%), but ahead of others including France (26%), Denmark (23%) and Norway (21%). During the period 2016-2020, for most comparator countries, the percentage of graduates from STEM programs in higher education fluctuated only minimally, typically without increasing or decreasing more than a few percentage points. Increases by comparators of more than 3% were limited to three Anglosphere countries (Canada, New Zealand, and Australia) and Denmark, each having recorded a comparatively low percentage of STEM graduates in 2016 (UNESCO UIS, 2023). Most countries with a higher percentage of graduates from STEM programs than Sweden (Germany, Singapore, India, Korea) had a larger percentage of engineering, manufacturing, and construction program graduates than health and welfare program graduates. By contrast, Sweden, like most comparator countries, had a higher percentage of health and welfare program graduates (22%) than engineering, manufacturing and construction program graduates (18%) (United Nations Educational, Scientific and Cultural Organisation Institute for Statistics [UNESCO UIS], 2023). See Appendix 1.

Graduation from STEM disciplines at higher education level

Figure 2. Percentage of Graduates from STEM Programs in Higher Education, Both Sexes (%), 2016-2020, Select Comparator Countries

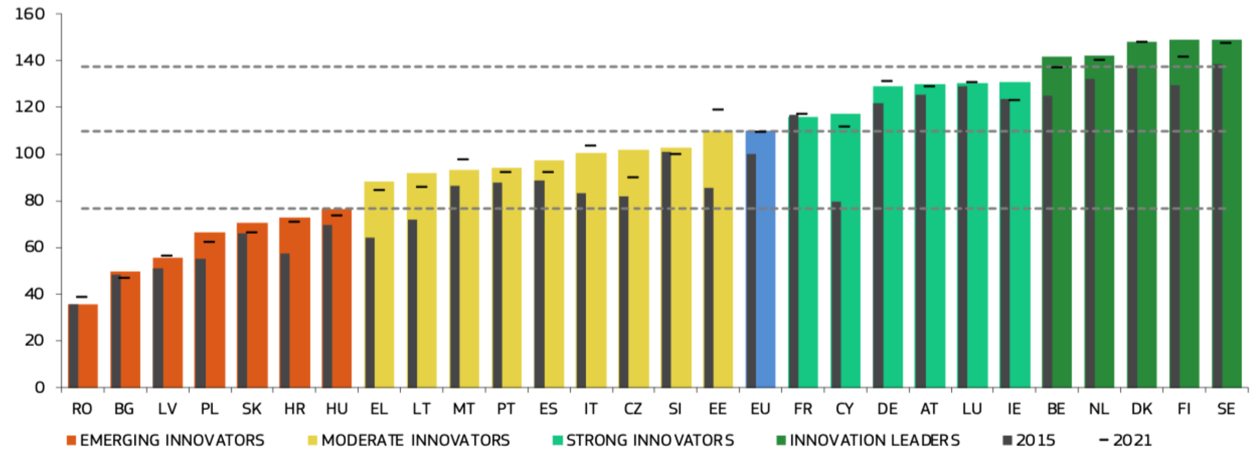


Source: UNESCO UIS, 2023.
Note: Figures are estimated for Russia (2020), Korea (2018), Canada (2017), France (2017), United Kingdom (2017, 2018), Australia (2016), United States (2017, 2018), Luxembourg (2017) and Iceland (2016, 2017)

Fourth, urgent, shifting demands on global science, innovation[5] and education-industry knowledge exchange (i.e., STEM excellence for research) (Figure 3).

Innovation capabilities

Figure 3. Performance of European Union Member States' Innovation Systems (2015-2022)



Source: European Commission, 2022.

[5] The European Innovation Scoreboard 2022 confirms Sweden's performance as Europe's innovation leader (followed by Finland, Denmark, the Netherlands, and Belgium). Sweden's relative strengths include lifelong learning, public-private and international scientific co-publications, employed ICT specialists, and foreign doctorate students. Relative weaknesses include job-to-job mobility of human resources in science and technology, resource productivity, government support for business research and development (R&D), and non-R&D innovation expenditures (European Commission, 2022).

Fifth, capacity to address intractable global and national grand challenges (‘wicked problems’). Sixth, generalised scientific and digital literacy for societal wellbeing (see Congressional Research Service, 2018; Freeman et al., 2019).

STEM policies

The European Commission’s Eurydice network found that by 2010, governments in at least eight European countries had introduced policies that aimed to promote school science education (Eurydice, 2012),[6] while others implemented multiple programs in the absence of an overarching strategic framework. Commissioned by European Schoolnet, which links 34 European Ministries of Education, Kearney (2011) reported that nearly three quarters of the 21 European countries surveyed had a “global approach in place to deal with STEM issues at national level” (p. 7) in the form of a national strategy or centre. Similarly, the study commissioned by Australia’s Chief Scientist, *STEM Country Comparisons: International Comparisons of Science, Technology, Engineering and Mathematics (STEM) Education* concluded that “STEM is a central preoccupation of policy makers across the world” (Marginson et al., 2013, p. 13). Freeman et al. (2019) subsequently acknowledged the extension of STEM policy to STEM-related fields, reporting that recognition of the importance of scientific literacy, STEM skills and high-level STEM research capacity was evident in emerging science and technology, innovation and commercialisation policies.

Concurring with these findings regarding prevalence, the Government of Japan (2021) authoritatively argued that:

> We are at a crossroads of a great age. Science, technology, and innovation policies will continue to be formulated in every country for the foreseeable future in two major directions. … science and technology require wisdom to overcome global crises stemming from the explosive expansion of human activities since the late 20th century. At the same time, each country will accelerate domestic reforms and expansion of future investment in science and technology to strengthen its competitiveness, while competing with other countries in various international proposals and concepts for global cooperation and harmony. (p. 3)

Accordingly, this policy brief explores STEM policy and more broadly defined science, technology, and innovation policies in select countries with a high degree of relevance to Sweden’s industrial capabilities and context to inform future policy deliberations.

In terms of STEM policy objectives, past European policies aimed to:

- promote a positive image of science;
- improve public knowledge of science;
- improve school-based science teaching and learning;
- raise pupils’ interest in science subjects and consequently increase uptake of science studies at upper secondary and tertiary education levels;
- strive for a better gender balance in [mathematics, science and technology] studies and professions; [and]
- provide employers with the skills they need … to maintain competitiveness (Eurydice, 2012, p. 27).

6 Norway, Germany, France, the Netherlands, Austria, Spain, Ireland and the United Kingdom.

Consistent with this, Kearney (2011) emphasised STEM policy objectives concerning young people's perception of STEM, the importance of fostering scientific culture, and supplying scientifically and technologically skilled workers sufficient to meet future industry requirements. Gough (2015) emphasised increasing the number and quality of STEM qualified graduates (i.e., undergraduates), increasing the number of research qualified STEM graduates (i.e., higher degrees by research), increasing overall scientific literacy, and economic competitiveness.

OBJECTIVES AND PREVALENCE OF STEM POLICY IN SWEDEN'S COMPARATOR COUNTRIES

Nordic comparator countries (Finland, Norway, Denmark, Iceland)

Research conducted to prepare this policy brief finds that in advanced Nordic comparator countries, government policy priorities include (amongst others) world-class school education, higher education and research, science-industry knowledge transfer and innovation, and improving capabilities to address global, economic, and societal challenges. Policy prioritisation is also given to sustaining competitive, innovative business environments while emphasising health, wellbeing, safety and security. Technology (including digitalisation, artificial intelligence and data sharing) is considered essential for the ongoing success and transformation of Nordic economies, businesses and society, as well as sustainably protecting the climate, nature and the environment.

The Government of Sweden has also prioritised the life sciences, methane action, the work environment, and cyber security. Many shared Nordic government policy priorities are similar to those set for Sweden's Presidency of the European Union in 2023 (i.e., security, competitiveness, green and energy transitions), as well as issues of importance to the European Union (i.e., skills for future competitiveness and growth, the semiconductor shortage, artificial intelligence regulation, sustainability, biodiversity, climate and digital identity). Most presume excellence in science, technology and innovation, generalised STEM capabilities and extensive research infrastructure and human resources.

These policy priorities are highlighted and addressed in discrete policy texts[7] introduced by Sweden's Nordic comparator countries governing schools, higher education and skills (e.g., Finland's *LUMA [STEM] Strategy*; Norway's *Science for the Future: Strategy for Strengthening Mathematics, Science and Technology 2010-2014*), research and innovation (e.g., Danish *Roadmap for Research Infrastructure 2020*) and technology (e.g., *Finnish Technology Policy*). These policies frequently aim to enhance school education (including science and mathematics), support STEM disciplinary knowledge, research excellence and industry transformation.

These policy priorities are also prominent in emerging climate/nature/environment, energy, space and security policies that are heavily reliant on STEM skills, knowledge and capabilities (Table 1). In pursuing national policy priorities, Nordic (and most other European) countries are actively engaged in global and European science networks, research schemes and projects, and discrete STEM programs.

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7 The Nordic countries have multiple STEM and STEM-related policies, most frequently referred to as 'policies' (Finland, Iceland), 'roadmaps' (e.g., research and innovation, and sustainability) (Finland, Norway, Denmark, Iceland), 'action plans' (Finland, Norway, Iceland), 'strategies' (Finland, Norway, Denmark) and 'white papers' (Norway).

Table 1: Prevalence of Broadly Defined STEM Policies: Select Nordic Countries (Finland, Norway, Denmark, Iceland)

	Finland	Norway	Denmark	Iceland
School, higher education and skills	- *Government Programme* (2019) - *Education Policy Report of the Finnish Government, 2021* - *Entrepreneurship Strategy* (2022) - *LUMA (STEM) Strategy for the Years 2014-2025* (2014)	- *Science for the Future: Strategy for Strengthening Mathematics, Science and Technology (MST) 2010-2014*	- *Life Science Strategy* (2021)	- *2030 Education Policy. The First Action Plan 2021-2024* - *Science and Technology Policy 2020-2022* (2020)
Research and innovation	- *Strategy for National Research Infrastructures in Finland 2020-2030* - *National Roadmap for Research, Development and Innovation*	- *Long-term Plan for Research and Higher Education 2023-2032* (2022) - *Data as a Resource. The Data-Driven Economy and Innovation* (2021)	- *Danish Roadmap for Research Infrastructure 2020* (2021)	- *Action Plan for Public Innovation* (2020)
Technology	- *Finnish Technology Policy* (2021)	- *Digital Strategy for the Public Sector 2019-2025* (2019) - *National Strategy for Artificial Intelligence* (2020) - *Cyber Security – A Joint Responsibility* (2017)	- *Digital Growth Strategy* (2018) - *Strategy for Investments in Green Research, Technology and Innovation* (2020)	
Climate, nature and environment; Energy	- *Government Action Plan* (2019) - *Sectoral Low Carbon Roadmaps* (2021)	- *Norway's Climate Action Plan for 2021-2030* (2021) - *Roadmap – The Green Industrial Initiative*	- *Climate Act 2020*	- *Iceland's 2020 Climate Action Plan*
Space	- *Space Strategy 2025* (2018)	- *The Government's Strategy for Norwegian Space Activities*	- *Denmark's National Space Strategy* (2021)	
Security	- *The Security Strategy for Society* (2017) - *Government Report on Finnish Foreign and Security Policy* (2016)	- Multiple instruments	- *Foreign and Security Policy Strategy* 2022	- *National Security Policy for Iceland* (2016)

Other European comparator countries (France and Germany)

In other advanced European comparator countries (France and Germany) government policy priorities include (amongst others) world-class education, skills development, knowledge and research systems, open science and technology-driven industry growth (e.g., deploying artificial intelligence and robotics). Policy prioritisation is also given to collaboration between education, industry, and research institutions, knowledge and technology transfer, and industrial competitiveness. Research, innovation and technology are considered essential for resolving grand challenges around climate change, energy, safety and security. These priorities are reflected in national policy texts[8] governing schools, higher education and skills (e.g., Germany's *MINT Action Plan* and *National Skills Strategy*), research, innovation and technology (e.g., France's *National Strategy for AI* and Germany's *High-Tech Strategy 2025*). They are also evident in emerging climate/nature/environment, energy, space and security policies that require STEM skills, knowledge and capabilities (Table 2).

[8] These two European countries have multiple STEM and STEM-related policies, which in addition to legislative instruments are most frequently referred to as 'strategies' (France and Germany), 'plans' (including 'investment plans' in France), 'roadmaps' (France) and 'pacts' (Germany).

Table 2: Prevalence of Broadly Defined STEM Policies: Select Other European Countries (France and Germany)

	France	Germany
School, higher education and skills	- *Digital Education Strategy 2023-2027*	- *MINT Action Plan* (2019) - *National Skills Strategy* (2019) - Digital Pact for Schools - *Future Contract for Strengthening Studying and Teaching in Higher Education*
Research and innovation	- *Research Programming Law (2021-2030)* - *Second National Plan for Open Science 2021-2024* (2021) - *Roadmap for French National Research Infrastructure* (2016) - *France 2030 Investment Plan* (2021)	- *Future Research and Innovation Strategy* (2023) - *Open Access Strategy 2020* (2015) - *Internationalisation of Education, Science and Research* (2019) - Pact for Research and Innovation
Technology	- *Government Digital Roadmap* (2008) - *AI for Humanity: National Strategy for Artificial Intelligence* (2018) - *Investment in Clean Aircraft Technologies 2020-2023*	- *High-Tech Strategy 2025* (2018) - *Artificial Intelligence Strategy 2020 Update* (2020)
Climate, nature and environment; Energy	- *National Low-Carbon Strategy* (2022) - *National Climate Adaptation Plan* - *French Green Hydrogen Plan 2020-2030* (2020)	- *National Hydrogen Strategy* (2020) - *Research for Sustainability* (2021) - *Sustainable Development Strategy* 2021
Space	- *French Space Strategy* (2011) - *France 2030 Investment Plan – Space Section 2022-2027*	- *Making Germany's Space Sector Fit for the Future* (2010)
Security	- *National Security Strategy* (2022)	- National Security Strategy under development

Anglosphere comparator countries (United States, United Kingdom, Australia)

In the comparator high-performing Anglosphere countries (United States, United Kingdom, Australia), government policy priorities include, amongst others, foundational scientific or STEM literacy (e.g., digital skills), STEM disciplinary skills and knowledge, science and public-private partnerships for innovation and technology breakthroughs. Policy prioritisation is frequently advanced in response to a perceived 'STEM crisis', citing declining international performance or competitiveness, and industry's unmet demand for STEM skills (Freeman et al., 2019). Prioritisation is also given to enabling rapid technology advances (i.e., artificial intelligence, semiconductors, and quantum technologies), skilled employment, and economic prosperity. United States and United Kingdom policies anticipate global scientific and technological leadership, and for all Anglosphere countries, STEM capabilities underpin national security and defence regimes. Technology advances are considered essential for resolving major challenges related to climate, environment, and health.

These government policy priorities are highlighted and addressed in dedicated policy texts[9] governing schools, higher education and skills (e.g., the United States' *Charting a Course for Success: America's Strategy for STEM Education*; Australia's *National STEM Education Strategy*), research and innovation (e.g., the United States' *CHIPS and Science Act, 2022*; *UK Innovation Strategy*), and technology (e.g., *UK Digital Strategy*; Australia's *National Robotics Strategy Discussion Paper*). These policies frequently aim to enhance science and mathematics pedagogy and performance, build scientific literacy and STEM skills sufficient to meet industry demand for STEM skills, support STEM disciplinary knowledge, global scientific leadership, competitiveness and industry transformation. Such policies are also evident in emerging climate/nature/environment, energy, space and security policies that require STEM skills, knowledge and capabilities (Table 3). In pursuing national policy priorities, Anglosphere countries are actively engaged in global science networks, research projects, and discrete STEM programs.

[9] These three Anglophone countries have multiple STEM and STEM-related policies, most frequently referred to as 'policies' (United States, United Kingdom), 'strategies' / 'strategic plans' / 'strategic agendas' (United States, United Kingdom, Australia), 'statements' (Australia), 'plans' or 'action plans' (United Kingdom, Australia), 'directives' (United States), 'roadmaps' (United States, United Kingdom, Australia), and 'frameworks' (United Kingdom).

Table 3: Prevalence of Broadly Defined STEM Policies: Select Anglosphere Countries

	United States	United Kingdom	Australia
School, higher education and skills	- *Rising Above the Gathering Story* (2007) - *Charting a Course for Success: America's Strategy for STEM Education* (2018) - *Raise the Bar: STEM Excellence for All Students*	- *The UK as a Science and Technology Superpower* (2021) - *Britain's Industrial Strategy. Building a Britain fit for the Future* (2017) - Scotland's *Science, Technology, Engineering and Mathematics: Education and Training Strategy* (2017) - Welsh *Science, Technology, Engineering and Mathematics (STEM) in Education and Training. A Delivery Plan for Wales* (2016) - Northern Ireland's *Success through Skills – Transforming Futures* (2011) and *Skills Strategy for Northern Ireland. Skills for a 10x Economy* (2021)	- *National STEM School Education Strategy 2016-2026* (2015) - *Australia's National Science Statement* (2017) - *Australia's Science and Research Priorities 2015*
Research and innovation	- Research and innovation legislation (e.g., *America COMPETES Act, CHIPS and Science Act, 2022, United States Innovation and Competition Act of 2021*)	- *UK Research and Development Roadmap* (2020) - *UK Innovation Strategy. Leading the Future by Creating it* (2021) - *Science for Wales – A Strategic Agenda for Science and Innovation in Wales* (2012)	- *Australia 2030. Prosperity through Innovation. A Plan for Australia to Thrive in the Global Innovation Race* (2017) - *National Research Infrastructure Roadmap* (2021) - *Research Infrastructure Investment Plan* (2020)
Technology	- *National Artificial Intelligence Research and Development Strategic Plan: 2019 Update* - *AIM Initiative: A Strategy for Augmenting Intelligence Using Machines* (2019) - *Department of Defence Artificial Intelligence Strategy* (2018)	- *UK Digital Strategy* (2022)	- *Blueprint for Critical Technologies* (2021) - *Action Plan for Critical Technologies* (2021) - *National Quantum Strategy Issues Paper* (2022) - *National Robotics Strategy Discussion Paper* (2022)
Climate, nature and environment; Energy	- *Energy Storage Grand Challenge Roadmap* (2020) - *Climate Strategy* (2021) - *Joint Statement between the United States and the European Commission on European Energy Security* (2022)	- *Net Zero Strategy. Build Back Greener* (2021)	- *Climate Change Act* (2022) - *Climate Change Action Strategy. Tackling Climate Change Through Australia's Development Assistance Program 2020-2025* (2019)
Space	- *US Space Policy Directive – 2, Streamlining Regulations on Commercial Use of Space* (2018)	- *National Space Strategy* (2022)	- *Australian Civil Space Strategy 2019-2028* (2019)
Security	- *Interim National Security Strategic Guidance* (2021) - *National Security Strategy* (2017)	- *Global Britain in a Competitive Age: the Integrated Review of Security, Defence, Development and Foreign Policy* (2021)	- *Safeguarding our Community Together. Australia's Counter-Terrorism Strategy 2022* - *National Counter-Terrorism Plan* (2022)

East Asian comparator countries (Japan and South Korea)

In the high-performing East Asian comparator countries (Japan and South Korea), government policy priorities include, amongst other areas, science, technology and innovation, digitalisation, and economic competitiveness. Prioritisation is also given to enabling rapid technology advances, national safety and security, and sustainability and resilience. These policy priorities respond to contemporary social issues including changing demographics (i.e., falling birth-rate and ageing population). Both governments have also prioritised global and national challenges (e.g., climate change, disaster preparedness).

Government policy priorities are highlighted and addressed in policy texts[10] governing schools, higher education and skills (e.g., Japan's *6th Science, Technology and Innovation Basic Plan*; South Korea's *5th Science and Technology Basic Plan, 2023-2027*), research and innovation (e.g., Japan's *Quantum Technology and Innovation Strategy*; South Korea's *Government R&D Innovation Plan*), and technology (e.g., South Korea's *National Strategy for Artificial Intelligence*). East Asian STEM policies aim to enhance higher education science and technology, industry-driven research and development, and innovation (Freeman et al., 2019). This focus is also evident in emerging climate/nature/environment, energy, space and security policies that require STEM skills, knowledge and capabilities (Table 4). As with other advanced economies, Japan and South Korea are actively engaged in global science networks, research programs, and dedicated STEM programs.

Table 4: Prevalence of Broadly Defined STEM Policies: Select East Asian Countries (Japan and South Korea)

	Japan	South Korea
School, higher education and skills	- *6th Science, Technology and Innovation Basic Plan* (2021)	- *5th Science and Technology Basic Plan, 2023-2027* - *Science, Mathematics, and Informatics Education Promotion Law* (2018)
Research and innovation	- *Integrated Innovation Strategy 2022* - *Quantum Technology and Innovation Strategy* (2020)	- *Government R&D Innovation Plan* (2015) - *Basic Framework for Regional Innovation based on Science and Technology Policy*
Technology	- *Declaration to be the World's Most Advanced IT Nation: Basic Plan for the Advancement of Public and Private Sector Data Utilization*	- *National Strategy for Artificial Intelligence* (2019) - *5G+ Strategy to Realize Innovative Growth* (2019)
Climate, nature and environment; Energy	- *Fusion Energy Innovation Strategy* (2023)	- *The Korean New Deal 2.0. National Strategy for a Great Transformation* (2021)
Space	- *Basic Plan on Space Policy* (2020)	- *4th Basic Plan for Promotion of Space Development*
Security	- *National Security Strategy of Japan* (2022)	- *Strategy for a Free, Peaceful and Prosperous Indo-Pacific Region* (2022)

CONCLUSION

This policy brief has identified STEM-related government policy priorities and STEM policies introduced by other Nordic and advanced European comparator countries, high-performing Anglosphere countries and dynamic East Asia to support ongoing dialogue regarding the development of an overarching Swedish STEM policy. STEM policies explicitly or implicitly acknowledge that policy is inherently political, and that achieving government policy aspirations typically relies on STEM or science, technology and innovation more broadly conceived. The Government of Japan (2021), for example, has explicitly acknowledged that "science, technology, and innovation policy … must intend to make a political contribution to resolving … global issues. On the other hand, it is essential for the government to take a domestic perspective on what benefits science, technology and innovation policy will bring to each and every citizen" (p. 3).

Notwithstanding differences in economic, social and historical contexts, as well as policy cultures, it is abundantly clear that commonalities exist in several key government policy priorities. To some extent, despite changes in governments, and varied external and internal drivers, this reflects shared aspirations

[10] These two East Asian countries have multiple STEM and STEM-related policies, most frequently referred to as 'basic plans' (Japan, South Korea), 'policies' (Japan) and 'strategies' (Japan, South Korea).

amongst Sweden's comparator advanced economies for high quality education, research excellence, economic prosperity, societal wellbeing and peaceful resolutions to global challenges related to automation associated with rapid technological advances, climate change, global emergencies such as the COVID-19 pandemic, energy supply and national security.

While Sweden is yet to frame an overarching STEM policy, most identified comparator countries have introduced legislation and policy texts with varied nomenclature (i.e., strategies, plans, roadmaps and budget measures). In the first instance, further consideration can be given to STEM policies deployed in recent years by Sweden's comparator countries, prioritising policies governing school mathematics and science, and higher education STEM disciplines as follows (Table 5).

Table 5: Prevalence of Broadly Defined STEM Policies: Select Nordic Countries (Finland, Norway, Denmark, Iceland)

Country	Notable STEM policy
Finland	*LUMA (STEM) Strategy for the Years 2014-2025* (2014)
Norway	*Science for the Future: Strategy for Strengthening Mathematics, Science and Technology 2010-2014*
Iceland	*Science and Technology Policy 2020-2022* (2020)
Germany	*MINT Action Plan* (2019)
	National Skills Strategy (2019)
United States	*Charting a Course for Success: America's Strategy for STEM Education* (2018)
	Raise the Bar: STEM Excellence for All Students
United Kingdom	*The UK as a Science and Technology Superpower* (2021)
Scotland	*Science, Technology, Engineering and Mathematics: Education and Training Strategy* (2017)
Wales	*Science, Technology, Engineering and Mathematics (STEM) in Education and Training. A Delivery Plan for Wales* (2016)
Northern Ireland	*Success through Skills – Transforming Futures* (2011)
	Skills Strategy for Northern Ireland. Skills for a 10x Economy (2021)
Australia	*National STEM School Education Strategy 2016-2026* (2015)
Japan	*6th Science, Technology and Innovation Basic Plan* (2021)
South Korea	*5th Science and Technology Basic Plan, 2023-2027*

These STEM policies, which have been periodically evaluated and updated over the last decade, typically have seven key objectives:

1. increasing interest in science;
2. increasing participation and performance in school mathematics and science;
3. increasing public knowledge of science, and life-long scientific literacy and digital skills capability;
4. increasing participation and performance in technical and higher education STEM disciplines;
5. increasing research excellence, innovation and commercialisation;
6. enabling research on grand challenges, national policy priorities and other interests;
7. facilitating economic dynamism and competitiveness by ensuring industry demand for STEM knowledge and skills are met (i.e., STEM-specific occupations, and others more generally).

Further research will be undertaken to extract key policy provisions from comparator country STEM policies, to help build the evidence base to inform the development of a Swedish STEM policy. Where STEM policy shifts onto the policy agenda, more focused attention can be given to school and higher education STEM so important for Sweden's sustained societal wellbeing, ongoing industry transformation and economic prosperity.

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APPENDIX 1 – GRADUATES FROM TERTIARY EDUCATION PROGRAMS, BY DISCIPLINE IN SELECT COUNTRIES

Table: Percentage of Graduates from Tertiary Education Programs (both sexes), by Discipline (2020)

	Country	Business, Administration and Law (%)	Education (%)	Social Sciences, Journalism, and Information (%)	Arts and Humanities (%)	Services (%)	**Health and welfare (%)**	**Engineering, manufacturing, and construction (%)**	**Information and communication technologies (%)**	**Natural sciences, mathematics, and statistics (%)**	**Agriculture, forestry, fisheries and veterinary (%)**
Nordic countries	Sweden	16	14	12	6	2	**22**	**18**	5	4	1
	Denmark	26	5	10	11	3	21	12	5	5	1
	Finland	20	7	7	11	5	20	15	7	5	2
	Iceland	21	15	16	10	4	16	8	6	4	1
	Norway	17	16	12	9	5	19	12	5	5	1
Other European	Germany	25	10	7	9	3	**7**	**23**	5	8	2
	France	35	4	8	8	4	13	14	4	8	2
	Switzerland	27	10	7	7	5	16	15	3	7	1
	Luxembourg	37	13	11	10	0	7	8	6	5	0
East Asia	Singapore	28	7	7	9	3	**9**	**21**	9	5	0
	Korea	14	7	6	15	10	**16**	**21**	5	4	1
Anglophone	Australia	37	8	6	9	2	18	9	7	5	1
	Canada	26	5	10	8	6	15	13	5	8	1
	New Zealand	24	9	9	11	4	16	9	7	7	2
	United States	19	6	12	19	6	17	7	5	8	1
	United Kingdom	24	7	16	15	0	14	9	4	9	1
BRICS	Brazil	34	19	5	3	3	17	12	4	2	3
	India	18	10	27	6	0	**5**	**14**	5	15	1
	South Africa	34	19	17	5	1	6	7	3	7	2

Source: UNESCO UIS, 2023.

APPENDIX 2 – STEM AND STEM-RELATED POLICIES IN SELECT COUNTRIES

This appendix provides important supplementary details regarding the prevalence and objectives of STEM and STEM-related policies in select advanced European, high-performing Anglosphere and dynamic East Asian comparator countries to build the evidence-base for Sweden to introduce a coherent STEM policy framework. These comparator countries were selected given their potential relevance to Sweden. This material is intentionally illustrative rather than exhaustive, drawing on publicly available government policy documents from individual comparator countries, supranational organisations (e.g., OECD Science, Technology and Innovation Outlook series and EC-OECD STIP Compass), and scholarly literature. Each sub-section commences by acknowledging key government policy priorities related to, or indeed reliant on, science, technology and innovation. It then proceeds to identify discrete policy texts governing school and higher education STEM, research and innovation, and related fields heavily reliant on STEM disciplinary knowledge, skills and capabilities.

Sweden

Sweden is a highly competitive, advanced economy with an innovative, dynamic business environment evidenced by positioning on the United Nations WIPO Global Innovation Index and European Commission's Innovation Scoreboard. Compared to many other advanced economies, Sweden experiences relatively high equality and social stability, with sustained government and private sector contributions to school and higher education, global science, and research and development. In recent years, Sweden has experienced 'PISA shock' and concern regarding TIMSS scores (e.g., particularly mathematics). Henrekson and Wennström report, in *Dumbing Down: The Crisis of Quality and Equity in a Once-Great School System - and How to Reverse the Trend* (2022), referencing studies by Swedish economists Heller Sahlgren and Hendrik Jordhal, that:

> Sweden's performance in international assessments began to steadily deteriorate. For example, in the TIMSS study, Swedish average results fell by 56 points between 1995 and 2011, which was the largest decline among all participating countries. … Perhaps most alarmingly, the decline was relatively greater for students at the bottom of the ability distribution, who had previously fared comparatively well in the Swedish educational system. Mirroring the development observed for the TIMSS, the Swedish PISA results also progressively worsened until a low point was reached in the 2012 survey. The overall score was well below the OECD average, and in each area of PISA, i.e., reading, mathematics, and science, only three OECD countries performed worse than Sweden. (p. 5)

As with other comparator countries, Sweden has experienced rapid shifts in the industry environment associated with technology advances, digitalisation (supercomputing, artificial intelligence, automation), and demographic changes associated with inbound migration flows. More recently, the COVID-19 pandemic, and national and energy security have necessarily received policy attention from the Government of Sweden. Other notable political priorities include unemployment, high inflation, household finances, migration and integration, climate change, health and medical care, and schools.

The Government of Sweden's commitment to science, technology and innovation is cross-ministerial and cross-agency, reflected in a small number of disparate legislative provisions, 'strategies' and 'plans' spanning several ministries rather than an overarching, coherent STEM policy administered by a dedicated ministry. Existing strategies and plans focus on life sciences, cyber security, energy and climate, and space, supported by numerous programs supporting school mathematics and science, higher education STEM disciplines, industry competitiveness and sustainable development. Relevant policy documentation most notably includes the *Research and Innovation Bill* (2021), *Sweden's National Life Sciences Strategy* (2020), *A National Cyber Security Strategy* (2017), the *Draft Integration National Energy and Climate Plan*, and *A Strategy for Swedish Space Activities* (2017).

In addition to Government of Sweden strategies and plans, schools, universities, trade associations, enterprises, not-for-profit organisations and others have implemented a range of STEM programs and subject-specific initiatives. Companies, industry and other organisations have driven discussion regarding the introduction of a Swedish STEM policy, in part due to concerns regarding STEM skills shortages and demand in diverse sectors (e.g., green transition, energy, housing, transport, welfare). Much activity has been focused on improving student's school mathematics participation and performance. Initiatives have aimed to improve mathematics teaching and develop teaching resources (e.g., *Matematiklyftet* and NT programming), as well as encourage girls' participation in mathematics and science. Schools and universities have also encouraged STEM and technology-based higher education and careers (e.g., *Teknikcollege*), complemented by the work of non profit organisations and professional associations that have promoted careers in science and technology. Trade associations have highlighted the importance of young people having more information regarding tasks, expectations, knowledge and competence requirements of current and future occupations. Indeed, several initiatives have aimed to provide targeted careers advice in recent years. Other initiatives have encouraged increased participation of under-represented groups (e.g., socio economically disadvantaged).

Finland

The Finnish Government has prioritised, amongst other things, world-class education, economic sustainability, safety and security, and educational and labour market equality. These policy priorities are supported by investment in education, research and public-private partnerships that enable innovation and science-industry knowledge transfer. The Government oversees a strong welfare state and encourages a competitive business environment and a research ecosystem that deploys technology to generate wellbeing and economic advantage. Finland also aims to respond boldly to global and national challenges including climate neutrality, demographic shifts, migration, and skills shortages.

Finnish Government priorities for competence, education, culture and innovation are reflected in an overarching programme of the Prime Minister, *Inclusive and Competent Finland: A Socially, Economically and Ecologically Sustainable Society* (2019). This program is supported by a comprehensive suite of policy texts ('reports', 'strategies', 'roadmaps', 'policies' and 'action plans') broadly concerning school, higher education and innovation. Notably, this includes the *Education Policy Report of the Finnish Government, 2021*[11] and the *Entrepreneurship Strategy* (2022). The Finnish Government's *Education Policy Report* (2021) acknowledges that "high expectations are placed on the possibilities of education to solve societal problems, promote sustainable development and improve people's lives" (p. 7). Policies emphasising research and innovation include the *Strategy for National Research Infrastructures in Finland 2020-2030* (including high-performance computing and artificial intelligence) and the updated *National Roadmap for Research, Development and Innovation.* The *Luma (STEM) Strategy for the Years 2014-2025* (2014) promotes school-level mathematics, science and technology for social, ecological and economically sustainable growth.[12] The Finnish Government has also issued thematic policies with a strong science and technology focus, including the *Finnish Technology Policy* (2021), which aims to position Finland as a global technology leader.[13]

As Finland moves towards carbon neutrality with existing and emerging technologies, policy focus has shifted to sustainability, climate and the environment (see the *Government Action Plan*. *Inclusive and Competent Finland: A Socially, Economically and Ecologically Sustainable Society* [2019], Sectoral Low

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11 The Education Policy Report spans early childhood education, higher education, research, liberal education for adults, continuous learning, and arts and cultural education. The report emphasises Finland's strong educational foundation, students' well-being, educational equality and excellence, and research that is socially and economically sustainable. It also supports internationalisation of education and research.

12 Multidisciplinary and STEM-related programs support these high-level policies, including the Academy of Finland's Flagship Program, Innovation Ecosystem Agreements, and bilateral Science and Technology Agreements.

13 This policy is supported by initiatives including the Artificial Intelligence 4.0 Programme, Aurora AI network, Digital Trust Program and the EuroHPC LUMI Supercomputer in Kajaani, Finland.

Carbon Roadmaps for 13 industry sectors and the Sustainable Growth Programme). The Finnish Government has also introduced the *Space Strategy 2025* (2018), highlighting opportunities for the new space economy of small satellites, launching services, applications and data.[14] Finally, the *Security Strategy for Society* (2017) emphasises preparedness for varied disruptions, building on the *Government Report on Finnish Foreign and Security Policy* (2016).

Norway

The Norwegian Government has prioritised science, technology, digitalisation, data sharing, artificial intelligence, carbon neutrality and achievement of the SDGs. These policy priorities are supported by investment in quality education and world-class science. Government seeks increased public sector efficiency, private sector focus on value creation, a more competitive and innovative business environment, an equitable welfare system and a quality research ecosystem.

The Norwegian Government's longstanding STEM policy priorities were signalled in *Science for the Future: Strategy for Strengthening Mathematics, Science and Technology (MST) 2010-2014*[15] which extended earlier national strategies covering the periods 2002-2007 and 2006-2009. The objective of this strategy is "to reinforce pupils' and students' competencies in science subjects, increase the interest in [mathematics, science and technology] and strengthen the recruitment and implementation at all levels, not the least among girls" (Norwegian Ministry of Education and Research, 2010, p. 5). More recently, broad higher education, research and public sector innovation 'white papers' (i.e., reports) have been introduced spanning all disciplines, including the *Long-term Plan for Research and Higher Education 2023-2032* (2022), and *An Innovative Public Sector – Culture, Leadership and Competence* (2020). These plans rely on strengths in STEM, humanities, arts and social sciences, and are supported by numerous programs.[16] As with other countries, Norway's STEM policy changes over time (see the OECD 2022 report, *Towards a New Stage in Norway's Science, Technology and Innovation System*).

Several policies have an explicit science and technology focus, such as the *Digital Strategy for the Public Sector 2019-2025* (2019) and *National Strategy for Artificial Intelligence* (2020), while technology white papers include *Cyber Security – A Joint Responsibility* (2017) and *Data as a Resource. The Data-Driven Economy and Innovation* (2021).[17] Norway's sustainability, climate and environment policy framework is reflected in white papers and roadmaps, including *Norway's Climate Action Plan for 2021-2030* (2021) and the *Roadmap – The Green Industrial Initiative* (2022).[18] The Norwegian Government's space strategy is summarised in *The Government's Strategy for Norwegian Space Activities*,[19] while the country's security policy is elaborated in political, military, diplomatic and international legislative and policy instruments.

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[14] In addition, in the context of the Covid-19 pandemic, in 2021 the Finnish Government issued the Sustainable Growth Programme for Finland: Recovery and Resilience Plan recognising the benefits of global health science, open research and publication, and supporting STEM-related matters including the green transition, digitalisation, and health services.

[15] In 2020, the report, Increased Working Life Relevance in Higher Education recommended increased interaction between higher education and working life, noting contemporary drivers (e.g., digitalisation, technology advances).

[16] These policies are supported by multiple initiatives including the Norwegian Programme for Capacity Development in Higher Education and Research, Research Funding for Industry, and the Industrial PhD Scheme. STEM-focused schemes include International Research or Technology Organisations and Programmes (e.g., ESA – European Space Agency, CERN – European Organization for Nuclear Research, EMBL/EMBC – European Molecular Biology Laboratory/Conference, ESRF – European Synchrotron Radiation Facility and IARC – International Agency for Research on Cancer). Other initiatives include the UTFORSK Programme (with partners in the United States, Canada, South Korea and BRICS countries) and the Panorama Bilateral Cooperation Programme.

[17] The Research Council of Norway funds ICT Research Programmes.

[18] These policies are supported by STEM-related initiatives such as the Environmental Technology Programme, Green Conversion Package, and Longship Carbon Capture and Storage Project.

[19] In addition, Norway participates in the Coalition for Epidemic Preparedness and runs the Norwegian Science Programme on COVID-19.

Denmark

The Danish Government has prioritised high-quality school and higher education, green research and technology development to transition their economy, society and industry towards protecting the climate, nature and the environment. They have invested in space-based technology and infrastructure (e.g., satellites), smart cities, security and preparedness. They have emphasised industry innovation, digitalisation, transformation and competitiveness, and positioned their education and research systems and infrastructure to address global, economic and social challenges.

These policy priorities are reflected in Danish Government policy texts variously referred to as 'strategies', 'roadmaps' and 'technology pacts' including related legislation and 'agreements'. The National Centre for Science Education (Astra), affiliated to the Ministry of Children and Education, was established to enhance science education for children and young people. The Ministry emphasises Denmark's world-class education system, supports lifelong skills development, publishes PISA results and hosts the 2018 report, *The Nordic Approach to Introducing Computational Thinking and Programming in Compulsory Education*. Complementing these policies and programs, the Ministry of Foreign Affairs of Denmark launched the *Digital Growth Strategy* (2018) to encourage computational thinking, improve digital technology competences and strengthen cyber security. This strategy is supported by a suite of programs delivered under the *Danish Technology Pact*. Post-school science, technology and innovation policies notably include the *Strategy for Investments in Green Research, Technology, and Innovation* (2020) that aims to accelerate technology developments to resolve challenges to the climate, nature and the environment. Other policies reliant on scientific knowledge and technological advances include the *Climate Act 2020*, *Denmark's National Space Strategy: Update of Strategic Objectives* (2021), the *Danish Roadmap for Research Infrastructure 2020* (2021) and the *Life Science Strategy* (2021).[20] Denmark's approach to national security is elaborated in the *Foreign and Security Policy Strategy 2022*.

Iceland

The Government of Iceland has prioritised the development of technology to protect the environment, ecosystem and climate, and address the SDGs (see *Iceland's 2020 Climate Action Plan*), while encouraging health and wellbeing. Reflecting Iceland's position comparative to other Nordic countries, the Government of Iceland is particularly focused on strengthening their foundational education systems, as well as Iceland's labour market and economy. The government supports entrepreneurship development and innovation, international cooperation, and the communication of science to challenge misinformation. The Science and Technology Policy Council has highlighted three challenges: environment, biosphere and climate; health and wellbeing; and life and work in a changing world.

These policy priorities are reflected in the Government of Iceland's laws, regulations and policy texts ('action plans' and 'roadmaps') under the Ministry of Education and Children, and Ministry of Higher Education, Science and Innovation. Iceland's policy framework acknowledges the challenges associated with automation, digital technology and artificial intelligence, along with the pressing need for public and private sector innovation. The Government of Iceland supports strengthening basic education and lifelong learning, increasing the number of science, technology, engineering, creative arts and mathematics (STEAM) graduates, and further intelligence regarding industry's evolving skill needs. Iceland's *2030 Education Policy. The First Action Plan 2021-2024* references plans and work components concerning, amongst other things, critical thinking and creativity, teacher certification, and teaching materials. At the higher education level, STEM-related policies most notably include the *Science and Technology Policy*

[20] They are supported by Danish Government initiatives including the National Fund for Research Infrastructure, and programs aimed at enhancing science/education-industry collaboration including the Danish Cluster Programme 2021-2024, technology transfer and intellectual property development and commercialisation. In the post-school system, STEM is supported by the Danish National Research Foundation, the Innovation Fund Denmark, innovation incubators and networks. Alliances such as Engineer the Future, comprising technology companies and education institutions, are working to increase school student interest, and science, technology and information technology graduates.

2020-2022 issued in 2020 by the Prime Minister's Office. This policy aspires for an Iceland that is "a diverse society characterised by welfare, security and equal opportunities. … where research, knowledge, creativity and initiative lead reform, value creation and vibrant business and cultural life. … [and] that uses research and innovation to address societal challenges, enhance quality of life and public health and protect ecosystems, both on land and at sea" (Government of Iceland, 2020, p. 8). This aspirational policy is complemented by the *Action Plan for Public Innovation* (2020)[21] and roadmaps for research infrastructure, and open access to data are under development.[22] Iceland's approach to national security is detailed in the *National Security Policy for Iceland* (2016).

France

The French Government has prioritised, amongst other things, educational equity and excellence, industrial competitiveness, research collaboration, knowledge and technology transfer, commercialisation and open science. Government seeks a strengthened industrial economy involving an innovative scientific and industry environment, for sustainable national, European and international transformation.

French Government policy priorities are reflected in legislation and policy texts ('plans', 'strategies' and 'roadmaps'). At the school level, the Ministry of National Education, Youth and Sports has emphasised measures to address equity and performance gaps, and support digitalisation (see the *Digital Education Strategy 2023-2027*). In addition to laws seeking to enhance France's school education system (e.g., Baccalaureate reform, support of migrant groups, teacher education), national student assessments in mathematics were introduced in 2018, and in the same year, the Scientific Council of National Education was established. At the post-school level, legislation governing scientific research notably includes the *Research Programming Law (2021-2030) (LPR law no. 2020-1674 of 2020),* with innovation enabled through the *Second National Plan for Open Science 2021-2024* (2021).[23] Participation in French, European and global science is supported by the *Roadmap for French National Research Infrastructure* (2016) spanning diverse scientific disciplines.[24]

The French Government has also issued thematic or mission-oriented policies that have a strong technology focus, from the early *Government Digital Roadmap* (2008), followed by the *AI for Humanity: National Strategy in Artificial Intelligence* (2018). They have introduced comprehensive schemes to support 'deep-tech' start-ups and unicorns (e.g., semiconductors, robotics, renewable energy), and more recently, *Investment in Clean Aircraft Technologies 2020-2023*.[25] In other STEM-related sectors, the French Government has long invested in space (see the 2011 *French Space Strategy*), with more recent priorities for different companies and fields highlighted in the *France 2030 Investment Plan – Space Section 2022-2027*. In 2020, the European Space Agency and Centre National d'Etudes Spatiales launched the French European Space Education Research Office to promote STEM education and the elite STEM pipeline. In terms of developing and deploying technological solutions and pursuing carbon neutrality more broadly, the French Government has adopted a *National Low-Carbon Strategy* (2022), *National Climate Adaptation Plan*, and *French Green Hydrogen Plan 2020-2030* (2020). The *France 2030 Investment Plan* (2022) signals increased support for green hydrogen, small nuclear reactors, industry

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[21] Key initiatives include Enhancing Education in the Natural Sciences and Technology (GERT), the Strategic Research and Development Programme (SRDP) for science and technology, the Icelandic Research Fund, and the Kría Iceland Venture Initiative.

[22] Relatedly, the Strategy for Icelandic Healthcare Services to 2030 emphasises health sciences services, education and research. These policies build on key reports including Iceland and the Fourth Industrial Revolution (2019) and Icelandic Society 2035-2040: Economic, Environmental, Regional, and Demographic Developments (2019).

[23] The National Research Agency provides funding for STEM disciplines (amongst others), while diverse French Government schemes that support science, technology and innovation include the Investments for the Future Programme strengthening public-private linkages, the Fund for Innovation and Industry, and funding for the Defence Innovation Agency.

[24] Priority STEM-related scientific fields under this initiative include earth system and environmental sciences; energy, biology and health; material science and engineering; astronomy and astrophysics; nuclear and high-energy physics; and digital science and technologies and mathematics.

[25] The government also administers the National Fund for Technology Transfer and supports Technological Research Institutes.

decarbonisation, hybrid/electric vehicles and chips/semiconductors.[26] The revised *French National Security Strategy* (2022) prioritises, amongst other things, nuclear deterrence and cyber resilience, all reliant on STEM capabilities and technology.

Germany

The German Government has built strong education, knowledge and research systems, encouraging technological and non-technological innovations, while fostering technology transfer, digitalisation, and industry competitiveness. They have also pursued social resilience, diversity and cohesion. The German Government has sought to increase cooperation between education, industry, civil-society and research institutions, as well as transparency (i.e., open science/data/access publications). They seek solutions to grand challenges including climate change, hydrogen energy, healthcare, mobility, safety and security.

The German term for STEM, MINT, stands for mathematics (*Mathematik*), IT (*Informatik*), science (*Naturwissenschaften*) and technology (*Technik*). German Government priorities are reflected in policies ('strategies'), supported by joint programs ('pacts') and analytical reports. At all levels of education, STEM is actively promoted by government, education systems and the learned academies. The objectives of the *MINT action plan* launched in 2019, are "promoting MINT education for children and young people; countering the shortfall of skilled workers in MINT professions; increasing the opportunities open to girls and women in MINT professions; [and] demonstrating to society the great importance of MINT" (Office of the Federal Government, 2023, para. 6). This plan is supported by the national STEM-networking centre (*MINTvernetzt*), STEM clusters and the MINT Alliance, with a variety of schemes (see the 2022 *Milestones in Teacher Education* report). This builds on previous pacts including the National Pact for Women in STEM Careers (2008). The *National Skills Strategy* (2019) focuses on Germany's strong vocational system, encouraging continuing education and technical skills development.

Generic and STEM-related research and innovation policies notably include the *Future Research and Innovation Strategy* (2023), *Open Access Strategy 2020* (2015), *Internationalisation of Education, Science and Research: Strategy of the Federation Government* (2019), pacts (e.g., Digital Pact for Schools, Pact for Research and Innovation, and Future Contract for Strengthening Studying and Teaching in Higher Education) and organisations (e.g., Alliance of Science Organisations).[27] The German Government has also issued strategies with a strong technology and grand challenge focus including the *High-Tech Strategy 2025* (2018) and more recently, the *Artificial Intelligence Strategy 2020 Update* (2020).[28] A new space policy is under development, building on the early strategy, *Making Germany's Space Sector Fit for the Future* (2010). In terms of sustainability, the German Government has introduced several policies and related programs[29] including the *National Hydrogen Strategy* (2020), *Research for Sustainability: A Strategy of the Federal Ministry of Education and Research* (2021) and the *Sustainable Development Strategy 2021* (supported by the Science Platform Sustainability 2030).[30] Germany is developing a new National Security Strategy.

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[26] In response to the COVID-19 pandemic, the French recovery plan supported technologies for innovation, and strengthening resilience. The Alliance for Life Sciences and Health complements this plan, as does the work of the Emerging Infectious Diseases (ANRS) agency.

[27] Many programs support cutting-edge research (e.g., Excellence Strategy). STEM-specific programs include the Exploration of the Universe and Matter Framework Programme, Women in Science, Research and Innovation and health sciences research (e.g., National Decade Against Cancer, German Centres for Health Research). See also the Federal Government Report on International Research Cooperation in Education, Science and Research 2019-2020 (2021) and Federal Report on Research and Innovation (2022).

[28] These strategies are supported by the Civic Coding - Innovation Network AI for the Common Good.

[29] Related programs notably include Research and Innovation for Sustainability, the Innovation for Energy Transition program, the German Energy Transition initiative, and 7th Energy Research Programme.

[30] In response to the COVID-19 pandemic, the German Government emphasised new technologies, digitalisation and agility in global science, supporting research infrastructures (e.g., big-data platforms), collaborations (e.g., University Medicine Network), and vaccine research (BioNTech/Pfizer).

United States

The United States Government has prioritised, amongst other things, foundational STEM literacy, STEM skills to meet technological advances and industry's unmet demand for STEM skills, along with cutting-edge basic research. These policy priorities emerged over time as policy actors identified a 'STEM crisis' amidst declining relative performance on international science and mathematics assessments. Government has also prioritised innovation, scientific and technological leadership, and national security supported by investment in education, research and public-private partnerships enabling scientific discovery, technological breakthroughs, and industry competitiveness in a globalised economy.

The National Science Foundation (NSF) used the acronym STEM in *Rising Above the Gathering Storm* (2007) prepared by the national academies of science, engineering and medicine. This seminal report prioritised science and technology, knowledge-intensive jobs, and technological innovations necessary to address societal challenges, thereby shifting policy actor's focus to STEM. Since then, numerous science, technology and innovation acts, policy texts ('strategies', 'strategic plans', 'directives' and 'roadmaps'), programs and reports recommending actions have emerged. This includes the National Science Board's *National Action Plan for Addressing the Critical Needs of the US STEM Education System* (2007), National Science Board's STEM education recommendations (2009) and *National Governors Association Building a Science, Technology, Engineering and Maths Agenda* (2011).

More recently, *Charting a Course for Success: America's Strategy for STEM Education* (2018) aims to position the United States as the global leader in STEM by building strong foundations in STEM literacy, increasing diversity, equity and inclusion in STEM, and preparing the STEM workforce for the future.[31] The new administration's *Raise the Bar: STEM Excellence for All Students* initiative was launched to strengthen STEM education nationally by helping "implement and scale equitable, high-quality STEM education for all students from PreK to higher education – regardless of background – to ensure their 21st century readiness and global competitiveness" (US Department of Education, 2022, para. 1).[32] Complementing this, the *United States Innovation and Competition Act of 2021* invests in education, research and commercialisation in artificial intelligence, semiconductors, communications, biotechnology and quantum computing.

In terms of research and innovation, budgetary measures support basic and mission-oriented research. Research and innovation-related legislation, rather than policy, includes the *America COMPETES Act* authorised in 2010 (that covers STEM education and research), and more recently, the *Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act* (2022) supporting frontier technologies and research and development focused science.[33] Policies ('strategies') focusing on artificial intelligence include the *National Artificial Intelligence Research and Development Strategic Plan: 2019 Update*, the *AIM Initiative: A Strategy for Augmenting Intelligence Using Machines* (2019) and the *Department of Defence Artificial Intelligence Strategy* (2018).[34] The United States Government has signalled further focus areas, issuing thematic policies and programs that have a strong science and technology orientation (e.g., the *US Space Policy Directive – 2, Streamlining Regulations on Commercial Use of Space* [2018]).

In recent years, as the United States Government moves to address grand challenges by developing, commercialising and using existing and next-generation technologies, policy focus has shifted to sustainability, climate and the environment. Notable policy instruments include the *Energy Storage Grand*

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31 Federal agency STEM programs, investments and activities are reviewed by the Committee on STEM (CoSTEM).

32 The NSF's Directorate for STEM Education, amongst many other agencies, funds diverse science and technology-related initiatives (e.g., Science and Technology Centers, Accelerating Research Translation, Global Centers for interdisciplinary climate and energy research). Other initiatives supporting science include the R&D Workforce Training scheme and Defence Education and Civilian University Research program.

33 The National Academies Committee on Science, Engineering, Medicine, and Public Policy (COSEMPUP) traces developments in science and technology policy in the United States, and publishes studies (see the 2022 report, Protecting US Technological Advantage).

34 Illustrative multidisciplinary and STEM-focused initiatives include the National Oceanic and Atmospheric Administration Technology Transfer Program, and NSF schemes supporting artificial intelligence and machine learning.

Challenge Roadmap (2020), *Climate Strategy* (2021) and *Joint Statement between the United States and the European Commission on European Energy Security* (2022).[35] National security also reflects a key government priority, with the *2021 Interim National Security Strategic Guidance* (building on the 2017 *National Security Strategy*) reiterating the importance of maintaining technological advantage, and diplomatic and military capabilities. This strategy commits to science and technology investment, computing technologies, domestic manufacturing, and strategic objectives concerning the economy, biotech, health, energy and climate matters, again illustrating the ubiquity of STEM and its relevance to so many policies of contemporary interest.

United Kingdom

The United Kingdom Government has prioritised, amongst other things, economic prosperity, security and defence, soft power, and resolving major challenges relating to health and life sciences, along with environmental sustainability. A broadly defined science and technology 'framework' presented to the Prime Minister by Sir Patrick Vallance in 2021 seeks to position the UK as a Science and Technology Superpower, building on previous STEM investment frameworks.[36] The 2021 correspondence foreshadows the development of strategies regarding critical technologies (artificial intelligence, engineering biology, future telecommunications, semiconductors and quantum technologies), while emphasising talent and skills, industry, digital infrastructure and public sector innovation.[37] Complementary policies include the *UK Digital Strategy* (2022).

The individual governments of England, Scotland, Wales and Northern Ireland, and combinations thereof, have long had policy texts ('strategies') governing STEM since the release of the UK-wide 2002 Roberts report (*SET for Success: The Supply of People with Science, Technology, Engineering and Mathematics Skills*). The *Industrial Strategy. Building a Britain fit for the Future* (2017; here, excluding Northern Ireland) emphasises STEM, technical education, innovation for economic competitiveness, jobs and earning power.[38] Scotland's *Science, Technology, Engineering and Mathematics: Education and Training Strategy* (2017) and related set of key performance indicators prioritise STEM learning excellence, resolving equity gaps, inspiring children, and connecting STEM education with labour market needs, building on the *Science, Technology, Engineering and Mathematics (STEM) Evidence Base* (2017).[39]

The Welsh Government's policy, *Science, Technology, Engineering and Mathematics (STEM) in Education and Training. A Delivery Plan for Wales* (2016) builds on resources such as the *Science, Technology, Engineering and Mathematics (STEM) Guidance for Schools and Colleges in Wales* (2012) and *Science for Wales – A Strategic Agenda for Science and Innovation in Wales* (2012). Northern Ireland's Programme for Government 2011-2015 and overarching skills policy launched in 2011 (*Success through Skills – Transforming Futures*) recognises the centrality of STEM skills for economic competitiveness. Recently updated to draw on the *OECD Skills Strategy Northern Ireland (United Kingdom) Assessment and Recommendations* (2020), the new policy, *Skills Strategy for Northern Ireland. Skills for a 10x Economy* was launched in 2021.

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[35] Numerous initiatives support these roadmaps, strategies and agreements, including funding for clean energy through the Advanced Research Projects Agency's STEM Rising program, and Funding for Low-Carbon Biofuels.

[36] See HM Treasury's 2004 Science and Innovation Investment Framework 2004-2014. Examples of evaluations include the report of the House of Commons Science and Technology Committee report, Diversity and Inclusion in STEM: Fifth Report of Session 2022-23 and 2018 report, Delivering STEM (Science, Technology, Engineering and Mathematics) Skills for the Economy Report by the Comptroller and Auditor General.

[37] The framework also highlights notable STEM initiatives (e.g., Skills for Life, Get the Jump, Global Talent, High Potential Individual), and encourages improved research translation, commercialisation and knowledge exchange through innovation clusters.

[38] The objectives of this strategy are now reflected in the United Kingdom's Build Back Better: Our Plan for Growth, highlighting technical skills, literacy, numeracy and digital skills, lifelong learning, as well as science and innovation for economic growth.

[39] As with some other countries, STEM strategies are evaluated (see the 2021 STEM Strategy for Education and Training in Scotland. Third Annual Report).

Additional relevant United Kingdom policies ('roadmaps' and 'strategies') include the *UK Research and Development Roadmap* (2020) and the *UK Innovation Strategy*. Leading the *Future by Creating it* (2021). Furthermore, the UK's *Research and Innovation Infrastructure. Opportunities to Grow our Capability* highlights current capabilities, and future directions, requirements and opportunities for STEM (and the humanities, arts and social sciences), large-scale, multi-sector facilities, and critical enablers (i.e., skills and training, data management and access, infrastructure sustainability).[40] The UK Government has also introduced thematic policies concentrating on priority areas including *Net Zero Strategy. Build Back Greener* (2021) that emphasises green jobs, skills and industries and emissions reduction technologies, and the *National Space Strategy* (2022). Further, *Global Britain in a Competitive Age: the Integrated Review of Security, Defence, Development and Foreign Policy* (2021) highlights the United Kingdom's ambitions as a science and technology power, and discusses resilience reliant in part of STEM-capabilities (i.e., climate change, biodiversity loss, health resilience).

Australia

The Australian Government has prioritised, amongst other things, skill development to meet industry's skills shortages, economic prosperity, and enhancement of current and new technologies ('critical technologies') for economic competitiveness, social cohesion and national security purposes. These policy priorities are supported by programs concerning school science and mathematics, STEM higher education, and industry innovation.

STEM and broader education, science and technology priorities of the Australian Government are reflected in a diverse range of policy texts including 'strategies', 'statements', 'plans', 'action plans' and 'roadmaps', with several currently under review. This suite of texts builds on early policy advice (see *STEM Country Comparisons: International Comparisons of Science, Technology, Engineering and Mathematics [STEM] Education*)[41] and 2014 recommendations of Australia's Chief Scientist to develop a coherent, strategic approach to STEM (see *Science, Technology, Engineering and Mathematics: Australia's Future*). Australia's STEM policies include the *National STEM School Education Strategy 2016-2026* (2015), with related resources (e.g., *National STEM School Education Resources Toolkit*), structures (e.g., STEM Partnerships Forum), reports (see the 2018 *Optimising STEM Industry-School Partnerships: Inspiring Australia's Next Generation*) and programs (e.g., Early Learning STEM Australia, Primary Connections Science by Doing).

In the higher education sector, the *National Science Statement and Australia's Science and Research Priorities 2015* aims to build scientific engagement, excellence, capability and skills, produce new knowledge, improve scientific research activity and improve Australians' lives. These policies also aim to encourage collaboration across disciplines and sectors, in Australia and internationally.[42] They are both currently under review. In 2017, the Government released *Australia 2030. Prosperity through Innovation. A Plan for Australia to Thrive in the Global Innovation Race* while notable recent releases include the *National Research Infrastructure Roadmap* (2021) and *Research Infrastructure Investment Plan* (2020). Supporting statements include the *National STEM Strategy 2019-2023* by the Engineers Australia professional association and the *Women in STEM Decadal Plan* (2019) by two Australian learned academies.[43]

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40 These policies are supported by a large number of programs.

41 At the time the STEM Country Comparisons research project was undertaken Australia had no overarching strategic STEM policy. Rather, STEM and STEM-related objectives were reflected in school and teaching quality policy, language, literacy, numeracy and generic skills policy; university, research and development, innovation and knowledge-transfer policy; as well as labour market and vocational education and training policy.

42 In some instances, Australia's learned academies also articulated vision statements for specific STEM disciplines, including Mathematical Sciences in Australia. A Vision for 2025 (2016) by the Australian Academy of Science.

43 Many government schemes support multidisciplinary and STEM-specific research and innovation, including the Research and Development (R&D) Tax Incentive, Cooperative Research Centres, and Industry Growth Centres.

The Australian Government has also issued thematic policies and programs that have a strong science and technology focus. For example, the *Blueprint for Critical Technologies* (2021), *Action Plan for Critical Technologies* (2021), *National Quantum Strategy Issues Paper* (2022), *National Robotics Strategy Discussion Paper* (2022).[44] The government also introduced the *Climate Change Action Strategy. Tackling Climate Change Through Australia's Development Assistance Program 2020-2025* (2019), and more recently, *Climate Change Act* (2022). They have also introduced the *Australian Civil Space Strategy 2019-2028* (2019) and *Safeguarding our Community Together. Australia's Counter-Terrorism Strategy 2022*.

Japan

The Government of Japan has prioritised, amongst other things, science and technology, digitalisation, economic competitiveness, and national safety and security. These policy priorities respond to contemporary social issues including Japan's changing demographics (i.e., falling birth-rate and ageing population) and declining international competitiveness in science and technology. The Government of Japan has also prioritised sustainability and resilience, with much effort concentrated on pursuing solutions to national and global challenges (e.g., climate change, disasters).

Rather than a discrete STEM policy, the Government of Japan's STEM priorities have, since 1996, been legislated in five-year plans governing science and technology. The *6th Science, Technology and Innovation Basic Plan* (2021), covering the period 2021-2025. Such plans are derived from the *Basic Act on Science, Technology and Innovation*. This plan extends for the first time to non-STEM disciplines (humanities, arts and social sciences)[45] and acknowledging the centrality of innovation.[46] The objective of the plan is to facilitate a "sustainable and resilient society that ensures the safety and security of the people" (2021, p. 11). The plan is supported by other texts, including national curriculum guidelines. The government's prioritisation of research and innovation is reflected in multiple policy texts ('strategies', 'declarations' and 'plans') including the *Integrated Innovation Strategy 2022, Quantum Technology and Innovation Strategy* (2020), and *Vision of Quantum Future Society. Future Society to be Realized through Quantum Technology and Strategies for its Realization* (2022).[47] In 2020, the Government released the *Declaration to be the World's Most Advanced IT Nation: Basic Plan for the Advancement of Public and Private Sector Data Utilization*.

Japan's approach towards sustainability, carbon neutrality and nuclear energy innovation is illustrated in various legislative provisions and policies, including the recently released *Fusion Energy Innovation Strategy* (2023).[48] Their green innovation strategies promote technological solutions including renewable and nuclear energy, carbon capture, and hydrogen. Japan's *Basic Plan on Space Polic*y (2020), complementing the *Basic Space Law (Law No. 43 of 2008)* and related legislation (*Remote Sensing Data Act, Space Activities Act*, *Space Resources Act*) and updated recently, positions science and technology-based space systems (e.g., providing positioning information and images, and enabling communication) as central to Japan's security, economy and societal wellbeing. The updated *National Security Strategy of Japan* was released in 2022.

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[44] These texts are supported by various programs (e.g., National Artificial Intelligence Centre, CSIRO's Data61, Cyber Security Skills Partnership Innovation Fund).

[45] The plan elaborates that, "This means that the Science, Technology, and Innovation Policy has become a policy that contributes to the comprehensive understanding of human beings and society and to the solution of problems, not only through the promotion of science and technology, but also through the convergence of knowledge that is the fusion of knowledge in the humanities and social sciences and knowledge in the natural sciences that creates social value" (2021, p. 8).

[46] These policies are supported by programs including University Fellowships Towards the Creation of Science and Technology Innovation.

[47] See also the Social Principles of Human-Centric AI (2021).

[48] Multiple government programs are available, including the Development of Technology for CO2 Separation and Capture program, Support for Carbon Neutrality in the Maritime and Port Fields, and the Research and Development Programme for Promoting Innovative Clean Energy Technologies Through International Collaboration.

South Korea

The Korean Government has prioritised, amongst other things, science, technology and innovation, digital and economic transformation, national security, energy and environment. The Korean Government has also focused effort on pursuing solutions to national and global challenges (e.g., climate change, resource exploitation, world order).

Since the 1960s, the Korean Government has issued five-year economic development plans. More recently, five-year science and technology basic plans have emerged (see the *5th Science and Technology Basic Plan, 2023-2027*). Since the second iteration, these plans have emphasised STEAM education (science, technology, engineering, arts and mathematics) reflecting South Korea's high academic achievement, but low confidence and interest in school science and mathematics (i.e., the 'PISA paradox') (Kim & Lee, 2022). In South Korea, STEAM education incorporates 'arts' (i.e., fine arts, language arts, liberal arts, and physical arts) and supports the integration (i.e., convergence) [49] of knowledge from different disciplines.[50] The vision of South Korea's fifth plan is to "solve national and social issues" and "enhance [science, technology and innovation] capacity" (section 3), emphasising recovery, inclusiveness, survival, and innovation. These plans are complemented by other legislative and policy instruments, including the 2018 *Science, Mathematics, and Informatics Education Promotion Law*. This act aims to promote STEAM education as essential "to prepare for the change of the industrial environment, so as to contribute to enhancing national competitiveness and to national and social development by contributing to cultivating multidisciplinary persons of talent to lead our future" (2017, Article 1).

The Korean Government's prioritisation of research, innovation and technology is reflected in multiple policy texts ('plans' and 'strategies'), including the *Government R&D Innovation Plan* (2015), *National Strategy for Artificial Intelligence* (2019), *5G+ Strategy to Realize Innovative Growth* (2019) and *Basic Framework for Regional Innovation based on Science and Technology Policy*. South Korea's approach to carbon neutrality is illustrated in numerous legislative provisions and policies. The updated *The Korean New Deal 2.0 National Strategy for a Great Transformation* was released in 2021, encompassing the digital new deal, green new deal, and stronger social safety net.[51]

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[49] Kim and Lee (2022) explain that "convergence of different disciplines and fields is needed to solve problems; several disciplines must be integrated together, as the traditional academic sub-disciplinary paradigm has become obsolete and unable to address modern issues" (p. 1).

[50] South Korea's approach is 'integration-oriented', recognising that real-world problem solving typically requires "connecting and utilising knowledge gathered from various academic fields. Thus, STEAM education … requires the integration of two or more subjects among S, T, E, A, and M" (see Hong, 2019, p. 211-212).

[51] The report, How we Fought COVID-19: A Perspective from Science & ICT elaborates the contribution of science, technology and innovation to Korea's COVID recovery efforts.