Literature Review on AI Education Programs and Guidelines from Leading Countries and International Organizations

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Submitted to:
The Eddie and Jules Trump Family Foundation

October 2024

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List of Acronyms and Abbreviations:

1. **AI** - Artificial Intelligence
2. **ML** - Machine Learning
3. **OECD** - Organization for Economic Co-operation and Development
4. **IMF** - International Monetary Fund
5. **NSF** - National Science Foundation
6. **UNESCO** - United Nations Educational, Scientific and Cultural Organization
7. **K-12** - Kindergarten to 12th grade
8. **CS** - Computer Science
9. **ICT** - Information and Communication Technology
10. **MOE** - Ministry of Education

Executive summary

This report provides an overview of the current landscape of AI education. The review highlights the growing need for AI literacy among future citizens, scientists, and developers, as emphasized by international organizations. Additionally, the report explores AI education strategies of leading countries and concludes with an analysis of UNESCO's international AI curricula mapping.

The leading global economic and educational organizations – OECD, IMF, NSF, and UNESCO – recognize AI's growing impact on economies, societies, and the workforce, emphasizing the need for AI education, and stressing that AI literacy is essential for both individuals and the economy.

AI education should be offered at a foundational level accessible to all students (Basic AI Education) while providing more advanced, specialized layers of learning for students on scientific and technological tracks. This strategy ensures inclusivity while allowing students with a greater interest in AI to pursue in-depth studies.

AI education should cover AI literacy, which includes three main components: AI foundations, Contextualized problem-solving with AI skills, and Societal and Ethical aspects of AI. Curricula-wise, these aspects should be treated both as a disciplinary area as well as contextualized AI-enhanced problem-solving skills integrated into existing subject matters.

To prepare students effectively for the AI era, it is crucial to build foundational skills, including literacy, critical thinking, and computational thinking, as these are essential for AI literacy. Students must develop the ability to critically evaluate text, assess the accuracy of AI-generated information, and identify misinformation. Incorporating computational thinking, coding, and digital proficiency is also vital for equipping students with the necessary skills to navigate and utilize AI technologies effectively.

Teachers will continue to be the most important actors driving K-12 education, and it is thus essential to prepare them to the AI era. The educational process must continue to emphasize human interaction and collaboration between teachers and learners. Thus, it is a priority to strengthen teacher training institutions and develop capacity-building programs that prepare educators to teach AI concepts and work effectively in an AI rich educational environments.

Leading countries are aligning with international organizations' standards and releasing AI education policy papers. According to global AI rankings, the United States, Canada, Singapore, the United Kingdom, China, South Korea, and Israel are at the forefront of the AI field. These countries have followed the recommendations of international organizations and have published national AI education policies. However, integration into the school curricula varies significantly, and implementation faces considerable challenges.

Countries vary substantially in incorporating AI education into their curricula. For example, in Canada, AI programs are primarily offered through non-profit organizations in a decentralized manner. The United States lacks a unified AI curriculum, but initiatives like AI4K12 help promote AI education across states and school districts by providing curricular support, guidelines, and resources for educators. Singapore and the United Kingdom primarily offer extra-curricular online AI courses at various proficiency levels for school students and teachers. To date, only South Korea and China have introduced nationwide, standard AI curricula, with advanced programs in targeted schools aimed at preparing future scientists and developers.

Additional challenges in implementing a successful AI curriculum include insufficient collaboration, inadequate infrastructure, and the need for research-based evaluation. In order to the develop and deliver a successful AI curriculum a wide-ranging collaboration between stakeholders such as educators, industry experts, and policymakers is necessary. An additional challenge identified is the absence of adequate infrastructure, including reliable internet access, computers, and other resources, which can interrupt the implementation of the new curriculum. Lastly, curriculum development and delivery must be followed by research-based evaluation to effectively assess its success in meeting young students' educational needs.

Israel's 'AI National Strategy' recommends integrating AI education into the national curriculum from elementary through high school, addressing different proficiency levels. However, the current implementation is limited to elective units for CS majors. Locally organized high school programs are offered in a decentralized manner, primarily through collaborations between municipalities, industry, and NGOs. Scaling existing tech-oriented programs and implementing future plans for middle school face significant challenges due to a severe shortage of qualified teachers. Therefore, a national investment is needed to drive teacher preparations programs. Moreover, the current curriculum is highly technological but lacks key components of AI education, particularly in areas such as AI ethics, human-centered AI, and the social implications of AI. The curriculum should be more flexible to target various proficiency levels (future citizens, scientists, and developers).

1. Introduction

Over the past few years, we have witnessed a technological revolution fueled by remarkable progress in artificial intelligence (AI). The transformative power of AI is already reshaping various sectors, with the global AI market projected to reach USD $407 billion by 2027[1]. Recognizing these far-reaching implications, many countries have prioritized growth and innovation in these cutting-edge fields. Since AI is a scientific and technological domain, its advancements depend on skilled human resources, underscoring the need to prepare future generations for the AI era through proper education. However, AI education for elementary and secondary students remains in its nascent stage and is largely decentralized (Sanusi et al., 2023; Schaper et al., 2023) . In Israel, the "National Strategy for Israel", initiative calls to invest in AI education for all K-12 students, emphasizing this as a matter of strategic importance, particularly because Israel's national security and economy heavily rely on its technological capabilities (Berry et al., 2021; Isaac et al., 2020).

To date, AI education in Israel's formal education system has been offered only to a fortunate few high school students who major in computer science (CS) through elective learning units (Cohen et al., 2020; Hazan et al., 2020; Perach & Alexandron, 2024) (Additionally, there are non-formal after-school programs and local initiatives that are difficult to track). However, Israel still lacks a comprehensive approach to AI education. The purpose of this report is to review international frameworks and guidelines, as well as leading national initiatives and curricula, to establish a knowledge base that can assist in developing a national AI education program.

2. Background

The term 'artificial intelligence' was coined by Marvin Minsky and John McCarthy in a workshop during the summer of 1956 that was based on the conjecture that "every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it"[2]. They approached AI as "limited problems that appeared to require intelligence to solve" (Russell & Norvig, 2020). Over time, the definition of AI has expanded, and transformed. A notable definition was later proposed by Herb Simon, an influential scholar in AI who was awarded both a Nobel Prize and a Turing Award. According to Simon, Programs are called intelligent if they

[1] Report Linker, "Global Artificial Intelligence (AI) Industry," reportlinker.com, July 1, 2021, https://www.reportlinker.com/p05478480/Global-Artificial-Intelligence-AI-Industry.html?utm_source=PRN.
[2] https://www.aaai.org/ojs/index.php/aimagazine/article/view/1904/1802.

exhibit behaviors that would be regarded intelligent if they were exhibited by human beings (Simon, 1996). This AI concept encompasses both 'weak AI,' which is trained to perform a specific task, and 'strong AI,' which functions in a variety of contexts (Stolpe & Hallström, 2024; UNESCO, 2022). For the purposes of this review, we adopt Simon's viewpoint of AI as systems that exhibit behavior that would be considered intelligent if performed by humans. A broader discussion of the nature of AI is beyond the scope of this review.

The broadness of AI's definition also extends to its interpretation in education. According to "The Council of Europe's intergovernmental project on Artificial Intelligence and Education"(Holmes et al., 2022), AI education is a broad term that includes three distinctive subject areas. The first area is AI *for* education, namely, applications of AI to improve teaching and learning, a vast area of research that targets applications such as adaptive/personalized learning environments, intelligent tutoring systems, computerized assessment, and learning analytic tools. This area is associated with well-established academic communities: AI in Education (AIED), Educational Data Mining (EDM), and Learning Analytics. The second is learning *with* AI, which centers on using AI tools such as ChatGPT to gain and build knowledge. The third is learning *about* AI, namely, referring to AI as a subject matter. The review focuses on the two latter subjects, learning with AI and learning about AI (AI *for* education is out of the scope of this report). Both 'learning *with* AI' and 'learning *about* AI' are still in their infancy and are in the process of definition. We adopt the broad perspective offered by UNESCO's AI Competency Framework for School Students (UNESCO, 2022a) and refer to them together as *AI Literacy*.

According to UNESCO, everyone should achieve some level of AI literacy, which means having competency in AI, including knowledge, understanding, skills, and value orientation (UNESCO, 2022b). Within this AI literacy framework, three main categories are included: AI foundations, AI skills, and AI ethics[3](Stolpe & Hallström, 2024; UNESCO, 2019), which are explained below.

AI foundations refer to understanding the basic mechanisms of AI. Historically, these include both classical AI (rule-based systems) and machine learning (ML). Today, however, AI is dominated by the ML paradigm, which refers to machines that can learn from data without explicit programming. ML includes several subcategories: Supervised Learning, which uses labeled data to learn a mapping function and make predictions; Unsupervised Learning, which identifies patterns in unlabeled data; and Reinforcement Learning, which optimizes actions based on rewards. The big

[3] We note that UNESCO's updated framework refers to four aspects, which we classify into these three categories.

leap in the field is attributed to the advancements of Artificial Neural Networks, a supervised learning model that includes layers of interconnected nodes that can learn and represent very complex functions (L. Hosch, 2024).

AI skills refer to the ability to use AI applications to solve various tasks. These skills encompass a range of levels, from basic familiarity with AI tools to more advanced AI capabilities for solving complex tasks. This would include understanding of how to model problems in ways that can be solved by AI, choosing the appropriate application for the problem, applying the AI tool to solve the problem, and the ability to validate the results (Chiu et al., 2024; Long & Magerko, 2020a). As AI becomes increasingly integral across various fields such as healthcare, finance, education, and more, these skills are essential for future citizens, scientists, and developers at different competency levels (OECD, 2021b). The AI applications, include, for example, chatbots and Large Language Models (LLMs), AI image detectors, recommendation systems, personal assistants, auto-correct applications, spam filters, and many others.

AI ethics, the third component of AI literacy, covers vital issues such as fairness, equality, privacy, transparency, and human agency (Bengio et al., 2024). This domain examines AI systems from a broader ethical, moral, social, and cultural perspective. This includes for example examining how the choice of training data can cause model to be biased against certain populations, tackling copyright concerns, ensuring transparency and accountability in how decisions or predictions are determined and preventing malicious use of AI for fraud and the production of fake news. Dealing with AI ethics involves developing critical thinking abilities and requires students to identify various stakeholders, understand their interests, and investigate the values and outcomes from a broader perspective (Carolus et al., 2023; Long & Magerko, 2020a).

Within AI literacy for K-12 [4], distinctions have been made between two main target populations: AI for All, which refers to the essential knowledge and skills that every future citizen should possess to understand and navigate a world increasingly shaped by AI ; and AI for Future Developers, which delves deeper into the foundations of AI for those who will create and lead AI innovation in the future (Black et al., 2024). In line with the calls that science education should reflect the integration of AI into scientific research (Erduran, 2023), **there is a growing realization that a third target population should be defined: Future Scientists, namely, students who are in an educational path that is scientific-oriented**. While this review covers all three target groups (general citizens,

[4] Hereafter we use the term AI literacy in the context of K-12 education.

future scientists, and future developers), its primary emphasis is on advancing AI education for future scientists and future developers.

In terms of time scope, this review prioritizes papers and reports published after 2021, a year in which a significant leap in AI education was recognized (Ng et al., 2023). Naturally, research about AI education lags behind applications in the field but is needed in order to develop effective pedagogical approaches and drive the field forward (Long & Magerko, 2020b; Ng et al., 2024; Schaper et al., 2023; Wang & Lester, 2019). This review addresses this need and contributes to the global understanding of AI education.

As noted above, there is broad agreement on the need for AI literacy, but there are various interpretations and numerous ways to translate this understanding into concrete curricula (Long & Magerko, 2020b). Furthermore, different countries and international organizations are at varying stages of maturity in their ability to characterize and implement such educational programs (UNESCO, 2022b). To explore this landscape, this study aims to review and analyze forecasts and recommendations from international organizations, leading national AI education policies, and national AI curricula worldwide.

Specifically, it is guided by the following questions:

1. What are the main forecasts and recommendations for AI education from leading international organizations?

2. What are the national AI K-12 educational policies of leading AI countries, and how do these policies address the AI literacy framework and integration with other disciplines? Who are the delivering associations, who is the target audience, and what is the scope within each country?

3. How do government-endorsed AI curricula, as mapped by UNESCO, differ in their formats, target audience, interdisciplinary connections, incorporation of AI Literacy, and learning outcomes?

The rest of this review includes four sections. The first section addresses the first question by analyzing relevant reports and recommendations from leading international organizations. Although not all of these organizations are educational organizations by definition, their recommendations have broad implications for K-12 education. The second section examines leading countries' strategies for AI in secondary education. The third section explores published AI curriculum frameworks worldwide. The final section discusses and draws conclusions from the previous three sections, addressing challenges, knowledge gaps, and future opportunities for AI education.

3. *International organizations*

In the following section, key forecasts and recommendations from leading international organizations have been collected to understand their approach and perspectives on the role of AI education and what it should include. The OECD, IMF, NSF, and UNESCO were selected due to their global influence. Data collection focused on research reports, committee reports, and official policies available through these organizations' websites that are available in English.

Methodology

The section was analyzed using qualitative content analysis (Shkedi, 2003) to identify recurring themes and highlight the recommendations of each organization. The analysis has also examined its organization's reports with respect to the following aspects:

- Anticipated outcomes of AI on the global market.
- The critical skills needed for the future workforce.
- Recommendations for enhancing general education in secondary schools including mathematics, literacy, computer science, science, etc.
- Recommendations for addressing secondary schools' AI education in three different proficiency levels: future citizens, future scientists, future AI developers.

Organization for Economic Co-operation and Development (OECD)

In 2021, the OECD published a two-part study titled "AI and the Future of Skills"(OECD, 2021a, 2021b) which evaluates a broad spectrum of abilities that AI systems can perform, focusing on essential skills for the commercial workforce. The study's main results show that AI performs at or above human levels in many cognitive tasks while performing more limitedly in general skills. Two years later, the OECD released a continuous report titled "Is Education Losing the Race with Technology?" (OECD, 2023) which investigates the advancements of AI in literacy and numeracy and their potential to compete with and transform the commercial market. The report demonstrates that AI can outperform large portions of the population in reading and math, suggesting that workers will likely face growing competition from machines in these skill domains.

The OECD's educational recommendations are broad, covering multiple disciplines and skills. The first recommendation is to strengthen students' literacy skills, with an emphasis on their ability to

evaluate and reflect on texts. This skill would provide an important advantage over machines and enable students to manage the information overload of the digital age, assess the accuracy of AI sources, and evaluate fake news and misinformation. The second recommendation is that schools should integrate digital skills into their curricula, with emphasis on computational thinking, coding, and proficiency with digital tools. The third educational recommendation focuses on teachers. Teachers need additional professional training to integrate AI tools into their teaching and guide students in using these technologies responsibly.

The final aspect of the recommendations focuses on AI literacy for the future workforce, scientists, and developers. It suggests that educational systems should include AI literacy in their curricula to ensure students understand AI's fundamental principles and applications. This includes teaching foundational concepts such as ML, data analysis, and ethical considerations related to AI technology. For future scientists, it is recommended that AI education be integrated across various subjects, including mathematics and science. This approach helps students appreciate the relevance of AI in multiple fields and fosters a holistic understanding of its applications. Regarding future developers, *the emphasis should be on critical thinking and ethical reasoning*. This focus enhances their awareness of the societal and moral implications of AI, preparing them to contribute responsibly to the advancement and application of AI technologies.

Key recommendations regarding AI Education	
For all future citizens	• **Educational systems should include AI literacy in their curricula.** • **Ethical considerations related to AI technology should be included.**
Future scientists	• **AI education should be integrated into STEM subjects.**
Future developers	• **Scientific and technological focus on ML and data analysis.** • **Critical thinking, moral reasoning and ethical judgment should be emphasized for those who will research and develop AI systems.**

International Monetary Fund (IMF)

According to the IMF forecast[5], the global economy is about to undergo a major transformation driven by AI, potentially matching the impact of the Industrial Revolution. Nonetheless, the full scope of AI's effects on societies and economies remains uncertain. This uncertainty is particularly apparent in employment, where AI can boost productivity in certain jobs while simultaneously posing a threat to others. According to evaluations, almost 40% of global employment is exposed to AI, with advanced economies at greater risk but also better prepared to exploit AI benefits than developing economies. Under most scenarios, AI will likely worsen overall inequality among nations. In advanced economies, about 60% of the jobs are exposed to AI due to the prevalence of technology-based roles and the emerging capabilities of AI (Cazzaniga Mauro et al., 2024).

Factors such as education level, age, and gender may affect people's ability to adapt to AI technologies. Forecasted gaps between men and women in the labor market reveal that women are more likely to be employed in high-exposure occupations, which means they will be more prone to adopting AI in their day-to-day jobs. Additionally, educational background significantly influences the ability to adjust to AI. Workers with postsecondary education are able to transition to roles with high AI complementarity, while those without it face reduced mobility. Differences between older and younger workers also play a crucial role. Younger workers, being more adaptable and familiar with new technologies, are better able to leverage AI opportunities, while older workers may struggle to adapt to new AI technologies, leaving them disadvantaged. This dynamic has the potential to exacerbate socio-economic gaps as younger, more educated workers benefit from AI advancements, leaving behind older and less educated individuals. (Cazzaniga Mauro et al., 2024).

According to Pizzinelli's occupational ranking, job risks and benefits can be forecasted based on two factors: AI exposure and complementarity (*Figure* 1). The AI Occupational Exposure (AIOE) index, created by Felten, Raj, and Seamans in 2021, measures how much AI can be used in different jobs by comparing AI applications with human skills (Felten et al., 2021). Pizzinelli and his team expanded the AIOE index by introducing a supplement complementarity index. This index expands the AIOE by considering factors like how critical an occupation's decisions are and the consequences of errors. If a job has high AI exposure but low complementarity, there's a higher chance AI will replace the job, leading to job losses and lower wages. Conversely, high exposure

[5] https://www.imf.org/en/Blogs/Articles/2024/06/25/mapping-the-worlds-readiness-for-artificial-intelligence-shows-prospects-diverge

with high complementarity means workers could benefit from AI through increased productivity (Pizzinelli et al., 2023). For example, in telemarketing, AI might take over repetitive tasks like answering common customer inquiries, potentially replacing some tasks rather than assisting. In contrast, AI can assist surgeons with diagnoses, enhancing their productivity without threatening to replace them.

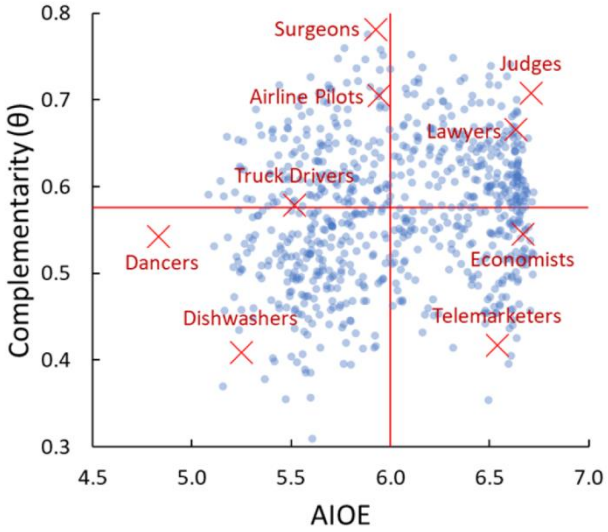


Figure 1. Conceptual diagram of AI occupational exposure (AIOE) and complementarity (θ). Adapted from Cazzaniga Mauro et al. (2024).

To fully exploit the potential of AI, the IMF recommends broader investments in human capital and technological innovation. First, for future citizens, they suggest tracking educational parameters such as expected years of schooling, average adult literacy, the skillset of graduates, and digital skills. Promoting digital literacy, including basic computer skills and coding, is essential to prepare individuals for the digital age. Additionally, it is crucial to ensure that graduates have the necessary skill set, and that education is equitable for all. For future scientists, there should be a concerted effort to increase the number of sciences, technology, engineering and mathematics (STEM) graduates, with a focus on boosting female participation in these fields. By concentrating on these areas, the IMF believes we can better prepare our societies for the advancements and challenges posed by AI. Education for future AI-induced science is an essential advantage for all economies.

Lastly, the IMF recommendations address education for future developers and its necessity. The IMF emphasizes that leading economies have a significant advantage for next-generation AI development. Innovation and economic integration, along with regulation and ethics, are considered "second-generation" elements that can maximize the economic impact of AI. By

leveraging the human capital of future AI developers and providing essential high-quality education and ethical perspectives we can offer a significant advantage to local technology development and therefore to the local economy.

Key recommendations regarding AI Education	
For all future citizens	• **Promote digital literacy.** • **Ensure all citizens have the necessary skill set with emphasis on equity in education.**
Future scientists	• **Integrate AI-induced science education into curricula.** • **Concerted effort to increase the number of sciences, technology, engineering, and mathematics (STEM) graduates.**
Future developers	• **Leveraging the human capital of future AI developers.** • **High-quality education and ethical perspectives are essential.**

National Science Foundation (NSF)

The NSF, a major U.S. federal funder, supports a vast number of AI-related research and education projects. Their motivation for AI investments is to ensure that the United States remains a leader in the field while also promoting worldwide innovation. One prominent initiative, the National AI Research Institutes program[6], launched in 2020, connects over 25 institutions and focuses on various aspects of AI research, including trustworthy AI, ML foundations, agricultural systems, and more. Another worth noting initiative, in late 2023, under NSF funding, the Directorates for Computer and Information Science and Engineering (CISE) and STEM Education (EDU) launched the EducateAI initiative[7]. This initiative supports AI educational experiences nationwide and encourages computing education programs for preparing preK-12 and undergraduate students for

[6] https://new.nsf.gov/funding/opportunities/national-artificial-intelligence-research
[7] https://new.nsf.gov/news/nsf-launches-educateai-initiative

AI careers. During the last year, the NSF presented the AI Education Act offers expanded scholarships and professional development opportunities for AI training.

In late 2019, the NSF funded a workshop titled "Building Capacity for K-12 Artificial Intelligence Education Research" (Wang & Lester, 2019) aimed at initiating a national K-12 AI research program. The workshop focused on formulating a K-12 AI research agenda and encouraging collaborations for K-12 AI education. The workshop highlighted the necessity for students to understand AI systems' inner workings, enabling them to evaluate AI models and their societal impacts. It also emphasized the importance of a well-rounded AI education that includes both technical skills and soft skills like effective collaboration. Key takeaways for AI curricula content include AI transparency and recognizing AI's problem-solving capabilities and limitations. One more important takeout that is relevant to all levels of AI proficiency is ensuring AI knowledge is integrated into various subject matters.

The workshop stressed the importance of involving multiple stakeholders, such as parents, schools, teachers, and informal education communities, to advance comprehensive K-12 AI education. It highlighted the necessity of researching teaching practices to identify effective pedagogical approaches for teaching AI concepts. Additionally, the participants underscored that teachers need professional development to effectively implement these pedagogical approaches in their classrooms, thereby creating engaging and culturally relevant learning environments for their students.

Key takeaways for AI Education
• **Recognizing AI's problem-solving capabilities and limitations is an important skill.** • **AI transparency should be included in AI curricula.** • **AI proficiency should be integrated into various subject matters** • **To enhance AI education, it is crucial to involve multiple stakeholders, including parents, schools, teachers, and informal education communities.** • **Research is needed to identify effective pedagogical approaches for teaching AI concepts.** • **Teachers need extensive professional development in order to deliver effective AI education.**

The United Nations Educational, Scientific and Cultural Organization (UNESCO)

In 2019, UNESCO hosted the Beijing Consensus Conference on AI and Education, marking the first milestone in the organization's AI education strategy (UNESCO, 2019). The conference brought together 500 international representatives from over 100 UNESCO member states to address the rapid development of AI and its impact on education systems. The consensus highlighted the need for coherent AI strategies integrated with existing education policies, new and appropriate teacher training, and AI literacy for all citizens. The conference also underlined that the core of the educational process must continue to be human interaction and collaboration between teachers and learners. It specifically affirmed that machines could not replace teachers. In addition, it is a priority to strengthen teacher training institutions and develop appropriate capacity-building programs to prepare teachers to work effectively in an AI-driven educational environment. UNESCO also announced the establishment of the 'AI for Education' platform[8], an open-source resource providing AI literacy training to educators and leading the responsible adoption of generative AI in the education ecosystem.

In December 2020, UNESCO organized the International Forum on Artificial Intelligence and the Futures of Education (UNESCO, 2021). Building on the Beijing Consensus, the forum recommended that UNESCO explore the role of AI in education and consider issues such as the integration of AI skills into The UNESCO ICT Competency Framework for Teachers (ICT-CFT) and education's role in developing competencies for the AI era. The first prominent conclusion from the forum is that AI must be included in school curricula for young citizens. The Forum argues that engaging young people with the design and implementation of AI systems empowers them to achieve higher levels of AI competence. It was highlighted that AI literacy should be integrated into both school curricula and lifelong learning programs so that all citizens can understand how to interact with AI systems and make informed decisions.

The forum's second emphasis was on enhancing cognitive skills to prepare for the AI era. This involves a focus on computational thinking and digital learning abilities, enabling students to thrive in an AI-induced world. Reinforcing a sense of social responsibility is also crucial. According to the forum's recommendations, students should develop self-discipline, teamwork, and ethical standards to understand the concept of a community with a shared future that is open and inclusive. It is stressed that these competencies are needed not only for future developers but also for all citizens to ensure the responsible and ethical use of AI technologies. Additionally, for future

[8] https://www.aiforeducation.io/

scientists and developers, improving higher-order competencies such as critical thinking, contextual problem-solving methodologies, and the ability to reflect and introspect are essential. These higher-order abilities will enable students to explore and innovate using AI tools and, in the future, develop new AI technologies considering a broader perspective.

In 2021, UNESCO conducted a global survey on government-endorsed K-12 AI curricula. Subsequently, in 2022, UNESCO published a report titled *'K-12 AI Curricula: A Mapping of Government-endorsed AI Curricula'*, which detailed various aspects of these curricula, including competencies, structure, and content mapping (UNESCO, 2022b). This research will be analyzed and presented in the chapter titled *'Evaluation of International AI Curricula.'*

During Digital Week 2023, the organization presented the first draft of AI competency frameworks for school teachers and students. The final version of the frameworks was published during Digital Learning Week in September 2024 (Miao & Shiohira, 2024). The AI competency frameworks provide a structured progression, focusing on aspects such as a human-centered mindset, ethics of AI, AI foundations, and application. Additionally, for students there is a special competency category for AI system design, targeting future AI developers (*Figure 2*).

Competency aspects	Progression levels		
	Understand	Apply	Create
• Human-centred mindset	• Human agency	• Human accountability	• Citizenship in the era of AI
• Ethics of AI	• Embodied ethics	• Safe and responsible use	• Ethics by design
• AI techniques and applications	• AI foundations	• Application skills	• Creating AI tools
• AI system design	• Problem scoping	• Architecture design	• Iteration and feedback loops

Figure 2. Draft AI competency framework for school students (AI CFS). Adapted from Miao and Shiohira (2024)

Key recommendations regarding AI Education	
For teachers	• **Machines cannot replace teachers in the educational process.** • **Teachers (in- and pre-service) should be prepared to the AI era through professional development and training.**
For all future citizens	• **Enhance computational thinking and digital and self-regulated learning skills.** • **Coherent AI strategies should be integrated with existing education policies.** • **AI literacy education is essential for all citizens.** • **Students need skills to work and live with AI, including social responsibility.**
Future scientists and developers	• **Emphasis on contextual problem-solving methodologies.** • **Students need skills to develop AI, including critical thinking.**

4. *National AI Educational Policies of the Leading Countries*

According to the IMF "AI Preparedness Index"[9] and Tortoise's "Global AI Index"[10] certain countries are leading the AI field in terms of development, research, human capital, infrastructure, etc. Most of these leading countries also published a national AI education policy. In the following section, we will examine the official AI education policies of the United States, Canada, Singapore, the United Kingdom, China, South Korea, and Israel. This review focuses on national plans for AI secondary education, including their duration and consistency across different population sectors.

Methodology

This section was analyzed using qualitative content analysis (שקדי, 2003) to identify national AI education strategies, the official, most up-to-date AI education policy of each country has been examined to answer the following guiding questions:

- Which organizations are responsible for implementing the AI education programs (e.g., Ministry of Education, commercial entities, or NGOs)?
- Who are the target audiences in terms of age and (scientific) orientation?
- Are there distinct programs for different proficiency levels such as future citizens, future scientists, and future developers?
- What is the integration with other STEM disciplines, if any?
- What is the duration and scope of the AI education programs?
- What challenges are identified in the implementation of these programs?

It is important to note that the analysis primarily reflects declarations and intentions, as information on actual implementation is not readily available. Additionally, the official information is often incomplete with respect to the questions above.

[9] https://www.imf.org/en/Blogs/Articles/2024/06/25/mapping-the-worlds-readiness-for-artificial-intelligence-shows-prospects-diverge

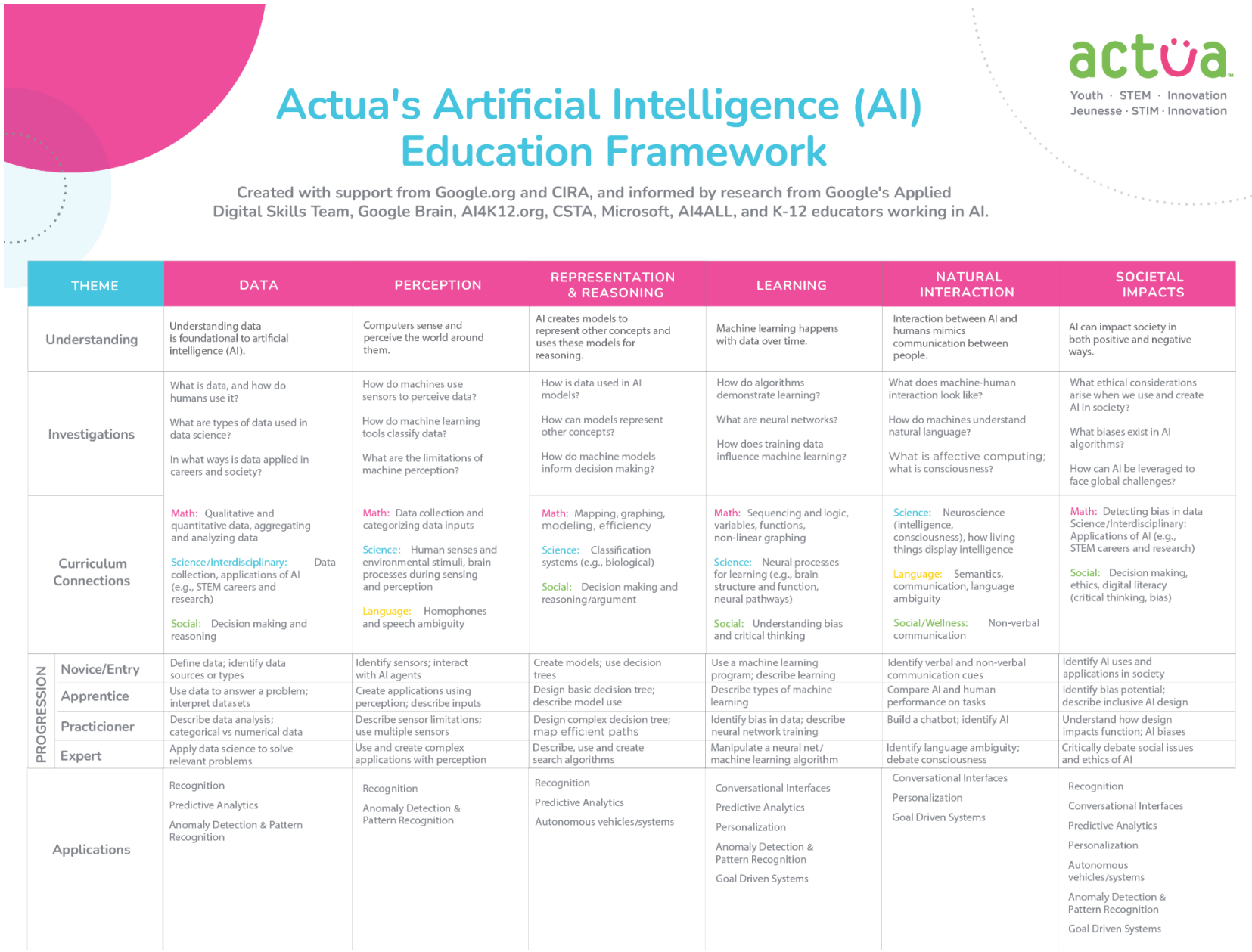
[10] https://www.tortoisemedia.com/intelligence/global-ai/#rankings

Canada

In Canada, the federal government has committed more than $2 billion to develop Canada's AI ecosystem and allocates substantial funding resources to AI education. However, Canada's AI education is highly decentralized, with no official organization overseeing the curriculum. Curriculum development and delivery fall under the jurisdiction of the provinces and territories, leading to distributed and voluntary AI programs offered in different parts of Canada. Various non-profit organizations (NGOs) offer different AI education programs, among the most prominent being Canada Learning Code (CLC)[11], Actua[12], and Kids Code Jeunesse[13]. These organizations provide programs for different target audiences, ranging from future citizens to high proficiency courses, and cover diverse content. For example, *Figure 3,* represents Actua's AI Education framework (ACTUA, 2020). The mentioned organizations frequently collaborate with industry giants like Google, Microsoft, and Amazon for funding and expert support. They also work with American AI education organizations such as AI4K12 and AI4ALL for curriculum support (*Talent for the Future: AI Education for K-12 in Canada and South Korea*, 2021).

The main challenges in Canada's AI education include its decentralized nature and the shortage of skilled teachers. Similar to AI education, CS education is not mandatory at the secondary school level in Canada. There is a lack of uniformity in curriculum themes, for example, some programs include ethical perspectives, while other programs do not. The primary discipline integrated with AI programs is computer science, with the same NGOs also providing computer science education. The second challenge is the shortage of qualified teachers. This issue is exacerbated by competition with industry for skilled professionals, making it difficult to meet the growing demand for qualified educators (*Talent for the Future: AI Education for K-12 in Canada and South Korea*, 2021).

[11] https://www.canadalearningcode.ca/
[12] https://actua.ca/
[13] https://www.kidscodejeunesse.org/



Actua's Artificial Intelligence (AI) Education Framework

Youth · STEM · Innovation
Jeunesse · STIM · Innovation

Created with support from Google.org and CIRA, and informed by research from Google's Applied Digital Skills Team, Google Brain, AI4K12.org, CSTA, Microsoft, AI4ALL, and K-12 educators working in AI.

THEME		DATA	PERCEPTION	REPRESENTATION & REASONING	LEARNING	NATURAL INTERACTION	SOCIETAL IMPACTS
Understanding		Understanding data is foundational to artificial intelligence (AI).	Computers sense and perceive the world around them.	AI creates models to represent other concepts and uses these models for reasoning.	Machine learning happens with data over time.	Interaction between AI and humans mimics communication between people.	AI can impact society in both positive and negative ways.
Investigations		What is data, and how do humans use it? What are types of data used in data science? In what ways is data applied in careers and society?	How do machines use sensors to perceive data? How do machine learning tools classify data? What are the limitations of machine perception?	How is data used in AI models? How can models represent other concepts? How do machine models inform decision making?	How do algorithms demonstrate learning? What are neural networks? How does training data influence machine learning?	What does machine-human interaction look like? How do machines understand natural language? What is affective computing; what is consciousness?	What ethical considerations arise when we use and create AI in society? What biases exist in AI algorithms? How can AI be leveraged to face global challenges?
Curriculum Connections		Math: Qualitative and quantitative data, aggregating and analyzing data Science/Interdisciplinary: Data collection, applications of AI (e.g., STEM careers and research) Social: Decision making and reasoning	Math: Data collection and categorizing data inputs Science: Human senses and environmental stimuli, brain processes during sensing and perception Language: Homophones and speech ambiguity	Math: Mapping, graphing, modeling, efficiency Science: Classification systems (e.g., biological) Social: Decision making and reasoning/argument	Math: Sequencing and logic, variables, functions, non-linear graphing Science: Neural processes for learning (e.g., brain structure and function, neural pathways) Social: Understanding bias and critical thinking	Science: Neuroscience (intelligence, consciousness), how living things display intelligence Language: Semantics, communication, language ambiguity Social/Wellness: Non-verbal communication	Math: Detecting bias in data Science/Interdisciplinary: Applications of AI (e.g., STEM careers and research) Social: Decision making, ethics, digital literacy (critical thinking, bias)
PROGRESSION	Novice/Entry	Define data; identify data sources or types	Identify sensors; interact with AI agents	Create models; use decision trees	Use a machine learning program; describe learning	Identify verbal and non-verbal communication cues	Identify AI uses and applications in society
	Apprentice	Use data to answer a problem; interpret datasets	Create applications using perception; describe inputs	Design basic decision tree; describe model use	Describe types of machine learning	Compare AI and human performance on tasks	Identify bias potential; describe inclusive AI design
	Practicioner	Describe data analysis; categorical vs numerical data	Describe sensor limitations; use multiple sensors	Design complex decision tree; map efficient paths	Identify bias in data; describe neural network training	Build a chatbot; identify AI	Understand how design impacts function; AI biases
	Expert	Apply data science to solve relevant problems	Use and create complex applications with perception	Describe, use and create search algorithms	Manipulate a neural net / machine learning algorithm	Identify language ambiguity; debate consciousness	Critically debate social issues and ethics of AI
Applications		Recognition Predictive Analytics Anomaly Detection & Pattern Recognition	Recognition Anomaly Detection & Pattern Recognition	Recognition Predictive Analytics Autonomous vehicles/systems	Conversational Interfaces Predictive Analytics Personalization Anomaly Detection & Pattern Recognition Goal Driven Systems	Conversational Interfaces Personalization Goal Driven Systems	Recognition Conversational Interfaces Predictive Analytics Personalization Autonomous vehicles/systems Anomaly Detection & Pattern Recognition Goal Driven Systems

Figure 3. Actua's AI Education Framework. Adapted from ACTUA (2020).

South Korea

In South Korea, AI education initiatives have seen significant advancements since 2021, and are prevalent throughout the entire school trajectory from elementary to high school[14]. The South Korean Ministry of Education (MOE) has developed AI-related course materials for distribution to k-12 schools across the country. Spotlighting middle school, as shown in *Figure 4*, the Seoul Education Office has developed plans to integrate AI education nationwide with explicit emphasis on AI-based competencies, digital literacy and AI ethics.

Figure 4. Seoul Education Office, AI education development plan for middle schools. Adapted from Talent for the Future: AI Education for K-12 in Canada and South Korea (2021)

[14] https://enews.sen.go.kr/news/view.do?bbsSn=170640&step1=3&step2=1

In high schools, two distinct trajectories have been established: regular high schools for future citizens, and exemplary schools for future scientists and developers. Starting in 2021, all regular high schools require a mandatory Information Technology (IT) course for first-year students. Additionally, second and third-year students are offered two AI-focused courses, AI Basics and AI Mathematics, along with a range of AI-related elective courses. Exemplary schools require an IT course for both middle and high school students. Furthermore, exemplary schools offer AI-related clubs at all educational levels, from elementary to high school (*Talent for the Future: AI Education for K-12 in Canada and South Korea*, 2021).

The content standards for the Korean AI curriculum cover three domains (*Figure 5*) (UNESCO, 2022b):

1.Understanding AI, with sub-domains 'AI and society' and 'Intelligent agents'.

2. Principles of AI and its application, with subdomains 'Data', 'Recognition', 'Classification, exploration and reasoning', and 'Machine learning and deep learning'.

3. The social impact of AI, with sub-domains 'AI influence' and 'AI ethics'.

Figure 5. Curriculum Standards, Republic of Korea. Adapted from UNESCO (2022).

By 2024, the Seoul Education Office plans to transform ten vocational high schools (a.k.a. career-focused schools) in Seoul into specialized high schools that intensively teach either AI or big data. Despite these efforts, AI education in South Korea faces challenges, including a shortage of AI-specialized teachers and insufficient emphasis on AI ethics across different educational levels. Moreover, evidence suggests that the delivery and implementation of AI education must become more systematic and unified to align with the country's long-term AI education goals(Lee et al., 2022).

Singapore

In 2019, Singapore introduced its National AI Strategy, emphasizing the importance of AI knowledge from being a mere opportunity to a necessity. The strategy highlights that in addition to experts all citizens must be proficient in AI to fully leverage its potential among all sectors, including industry, health, sciences, public services, and education (*Figure 6*). To achieve this, Singapore is committed to embedding basic computing skills and computational thinking throughout the education path. The goal is to grow 'bilingual individuals' proficient in both AI and their respective fields. AI education is targeted throughout the education path, starting from foundational AI concepts in early education to advanced AI competencies in higher education (*Singapore National AI Strategy 2.0 (NAIS 2.0)*, 2023; *Singapore National AI Strategy -2019*, 2019).

AI Singapore (AISG)[15] has launched the 'AI Student Outreach Programme,' aiming at promoting AI literacy and proficiency among students from age 7 to university level. Supported by Singapore's Ministry of Education, the program offers free resources for Singaporean students to learn about AI at different proficiency levels, from beginners to developers. Courses can be taken individually, as part of a school class, or with a group of friends. Additionally, the program offers developer conferences and student internships for students in higher proficiency courses.

[15] https://learn.aisingapore.org/

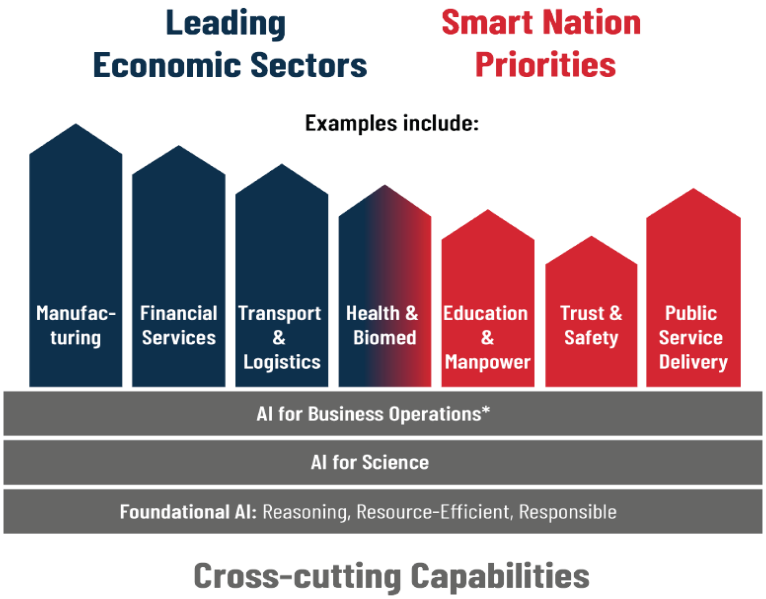


Figure 6. Vision for AI education, Singapore. Adapted from Smart Nation Singapore, Ministry of Communications and Information (2023).

The United States

The United States does not have a unified national curriculum for AI or CS education. Instead, national organizations and initiatives provide guidelines and resources to help states and school districts create AI education programs. This decentralized approach allows for flexibility to meet local needs; However, it also leads to diverse educational experiences across the country. Key initiatives include the AI4K12 initiative established by the Association for the Advancement of Artificial Intelligence (AAAI) and the Computer Science Teachers Association (CSTA) on 2018. AI4K12 is funded by the NSF and led by Professor David Touretzky, Professor Christina Gardner, and Deborah Seehorn. It addresses the need for AI education alongside CS education and offers resources and support for incorporating AI into the curricula (AI4K12.org, 2021; UNESCO, 2022b).

AI education, as outlined in the Five Big Ideas (Touretzky et al., 2019, 2023), aims to help individuals understand AI mechanisms, societal impacts, and limitations. As shown in *Figure 7*, key concepts include understanding how computers perceive the world using sensors, how AI agents maintain and use world representations for reasoning, and how machines can learn representations from data (Machine Learning). Students should also grasp the challenges of making AI interact with humans and the ethical implications of AI applications on society. Recognizing both the potential

and benefits of AI alongside the ethical responsibilities associated with AI is crucial for students comprehensive understanding of the AI domain.

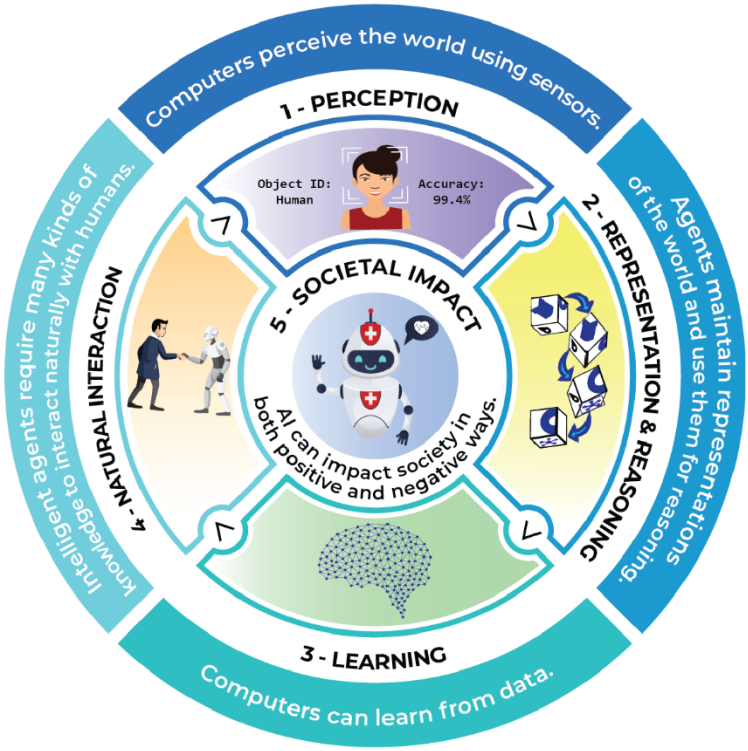


Figure 7. The Five Big Ideas in AI. Adapted from AI4K12.org. [16]

The United Kingdom

The United Kingdom is a leading nation in the AI landscape, with the government recognizing AI as a critical discipline and making strong commitments to promoting AI education nationwide. The UK's AI Council Roadmap emphasizes the importance of inspiring those not yet engaged with AI, encouraging children to explore its potential, with the goal of building a diverse, AI-literate workforce (*UK National AI Strategy*, 2021).

In the UK, the National Centre for Computing Education (NCCE)[17] works to promote AI education programs and make them widely accessible, offering a variety of AI courses for both educators and students in grades 7-12 to reach the widest demographic. AI education in the UK focuses on

[16] https://ai4k12.org/
[17] https://teachcomputing.org/artificial-intelligence

addressing the skills gap in the labor market through initiatives like online bootcamps[18]. These programs offer a range of AI-related skills and provide solutions to bridge gaps in AI knowledge within the workforce.

However, the UK faces challenges in implementing a unified AI curriculum. Currently, there is no single AI curriculum or standardized guidelines for K-12 education across all regions, nor is there any mandatory AI content within K-12 CS curricula. Updating national educational standards to reflect the latest advancements in AI is a recognized need (UK National AI Strategy, 2021).

China

In 2017, China's MOE introduced an IT curriculum for high schools, aimed at helping students understand what AI is, how it works, and the social issues related to it. The curriculum is implemented in 225,000 schools across the country, reaching over 180 million students. It consists of 10 modules: 2 mandatory and 8 electives. The elective modules include AI courses such as "Basics of Artificial Intelligence" and "Data Management and Analysis." Although the curriculum was nationally mandated, provinces were able to adjust its implementation based on population demographics, available resources, and educational needs (UNESCO, 2022b).

In 2024, the MOE further expanded AI education by announcing a list of 184 primary and secondary schools selected as AI education bases, aimed at promoting the development of AI education[19].

The programs use various teaching methods, including direct instruction, blended and remote learning, group work, project-based learning, and hands-on activities. To prepare teachers to deliver these programs, the National-Level Teacher Training Programme focuses on Information Science and Technology, including AI. The training is held twice a year during school holidays, and all teachers must attend at least once every three years. Schools and teachers have the flexibility to choose which technologies to use in the classroom, ensuring students gain experience with a wide range of tools and applications (Song et al., 2022; UNESCO, 2022b).

[18] https://www.skillsforcareers.education.gov.uk/pages/training-choice/skills-bootcamp
[19] https://english.www.gov.cn/news/202402/23/content_WS65d85f47c6d0868f4e8e44a7.html

Israel

According to the “National Strategy of Israel”[20] (2020), a crucial component for securing Israel’s leadership in AI is the integration of AI education across the entire school learning trajectory. The proposed "National Strategy" suggests including AI as part of the core subjects in the national curriculum, starting from elementary school and continuing through high school at different proficiency levels. This includes referring to AI both as a subject matter and as cross-cutting skill that should be integrated into almost every discipline. The curriculum also includes an ethical component to address the unique challenges posed by AI, ensuring that students develop technical proficiency alongside ethical awareness and critical thinking (Isaac et al., 2020).

In practice, (formal) AI education in Israel is now available mainly through two elective paths available only to CS majors[21] (Cohen et al., 2022). One is an elective, 90-hour ML unit which is one of the available options for the internal assessment component within the CS major, contributing 30% to the final grade[22]. The unit covers both theoretical and practical ML. The second path is through the AI specialization track in software engineering. It is an extensive 450-hour specialization in ML that CS majors can take in addition to the 450-hour (five units) CS major[23]. This specialization is taught at a high academic level and includes a spectrum of theoretical and practical subjects outlined in the official published curriculum, with assessment that is based on a final project in applied ML.

In its current state, AI education in Israel is characterized by its high academic and technological level, aiming to a small, self-selected group of technology-oriented high school students. Its implementation is constrained by an acute shortage of qualified teachers, and due to that both paths are available only to a small portion of students. To address this, blended learning models have been introduced alongside traditional learning to supplement teachers' knowledge and make the program more accessible in crisis instances (Perach & Alexandron, 2022). With respect to broader outreach of AI education, Israel still lacks a national plan for AI education.

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[20] https://en-cyber.tau.ac.il/home/NationalInitiativeForSecuredSystems

[21] In Israel, high-school students are required to extend their studies in at least one subject (in addition to mandatory subjects such as Mathematics, English as second language, etc.). This it referred to as ‘Major’ or ‘Track’. Possible tracks include Chemistry, Biology, Physics, and CS, as well as Art and Humanities subject matters.

[22] chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://meyda.education.gov.il/files/CSIT/MachinLearning-Ver1%204.pdf

[23] chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://meyda.education.gov.il/files/CSIT/deep-learning.pdf

Summary of findings

The leading country review offers a comprehensive view of AI education strategies globally.

First, the organizations responsible for implementing AI education programs vary across countries. For example, in Canada, programs are implemented by NGOs such as CLC and Actua. In contrast, China and South Korea rely on their respective MOEs, while Singapore delivers AI education through online courses provided by the governmental organization 'AI Singapore'.

Second, the target audiences for AI education range from elementary to high school students. Countries like South Korea, Singapore, and the United States target all educational levels, while others, such as Israel and China, focus on secondary education.

Third, national AI education strategies range from introductory courses aimed at future citizens to advanced courses for future scientists and developers. For example, AI4K12 in the United States offers resources for all proficiency levels. South Korea's national curriculum includes introductory AI courses for all students, alongside advanced options for future scientists and developers. Israel is unique in the sense that its in-curriculum AI education programs target exclusively future developers.

Fourth, regarding integration with other disciplines, most examples show a combination with computer-related fields. For instance, Israel and Canada integrate AI education with CS, South Korea combines its AI curriculum with digital literacy, and China with Information and Communication Technology (ICT) education.

Lastly, the diverse strategies present different challenges in implementing AI education. The first challenge is the shortage of skilled teachers, as noted in the strategies of Canada and Israel. Another challenge is the lack of a national AI education strategy, as seen in Israel and the United Kingdom. Finally, while China and South Korea have national AI curriculum, they face difficulties in fully implementing their programs.

5. Analysis of national AI Curricula worldwide

While the previous sections centered on AI education recommendation and agendas of international organizations (Section 3), and on the AI education policies of AI leading countries (Section 4), this section delves into the question of what the actual content included in international and national initiatives is, namely, *the curricula*. However, most of the country-level curricula are difficult to access due to language barriers, copyright walls, or simply because they are not shared. Therefore, this section draws mainly on UNESCO's 2022 mapping of government-endorsed AI curricula (UNESCO, 2022b) in order to examine key aspects such as content themes, learning outcomes and goals, target audiences, and overall scope.

Methodology

UNESCO's curricula report was based on two surveys. The first was distributed to representatives of 193 UNESCO Member States, and the second to over 10,000 private- and third-sector actors. The surveys asked the respondents to report on AI curricula for students in K–12 general education. The inclusion criteria consisted of government-endorsed AI curricula from countries that responded to the survey and provided sufficient evidence for evaluation. Additionally, the AI curricula had to focus on AI literacy and include specific AI learning content. Overall, 29 countries were included. These countries vary considerably in their level of AI adoption, from leading AI nations such as China, Germany, and South Korea, to countries such as India and Portugal, which are at early stages in this regard.

Influential non-governmental curricula, such as AI4K12[24] and DAILy[25], were also included as benchmarks for comparison, especially regarding content themes and learning outcomes.

The analysis was guided by the following questions:

- Who is the target audience for the curricula?
- What is the scope of the different curricula (in terms of hours, format, etc.)?
- What are the prevalent content themes of the different curricula?
- What are the expected learning outcomes across different curricula?
- What interdisciplinary connections exist between AI curricula and other subjects?
- What challenges and limitations are present in the current global AI curricula?

The methodology will provide a comprehensive overview of the AI curricula landscape worldwide.

[24] https://ai4k12.org/

[25] https://raise.mit.edu/daily/

Analysis of the Report

The target audience for the various AI programs differs across countries. The inclusion criteria selected only curricula for K-12 students in the general public education system. In the included countries, all AI curricula for primary schools were part of K-12 AI education, which also included programs for the secondary education level. However, most countries focus on AI education for secondary grades. Furthermore, all of the non-governmental AI curricula included in the study, as a benchmark, are intended for secondary school students. Additionally, several government-endorsed AI curricula are designed for all students, while others are elective or restricted to specific schools or classes. Exact details on these distinctions are not available.

The formats of the different programs varied, as shown in *Figure 8*, with three main models identified. The first is the *discrete* format, which refers to an independent program (school subject) within the national or local curriculum framework. The second is the *embedded* format, where AI curricula are included as an added component within existing national curricula, most commonly in ICT or CS. The third model is the *interdisciplinary* format, which involves AI learning through project-based learning involving multiple subject areas. The overall scope of the programs differs, with total time allocations ranging from a few hours to about 900 hours, spread across 1st to 12th grades. The median time allocation for all programs is 21 hours/year.

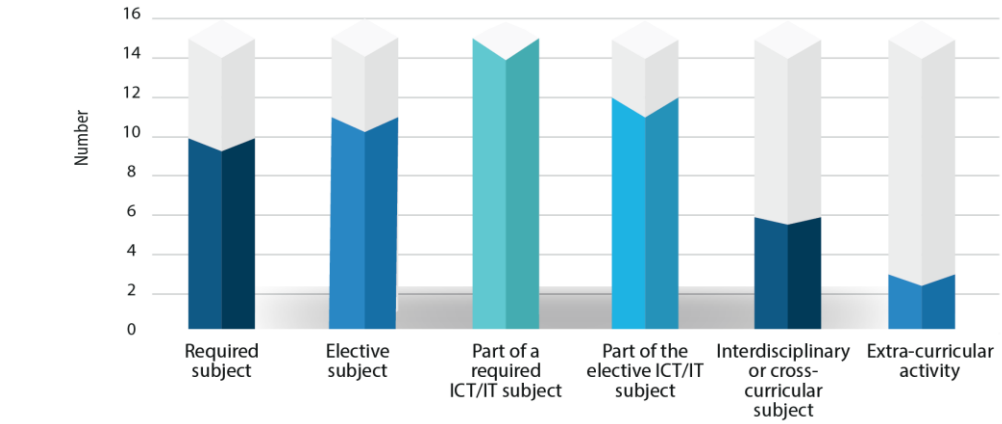

Figure 8. Number of AI curricula by type (n = 27, multiple responses possible).

Adapted from UNESCO (2022).

The interdisciplinary connections within AI curricula often emphasize mathematics as the primary subject . Participated countries highlighted that developing AI curricula requires a strong foundation in relevant subject areas, with mathematics being the most cited example. There is a recognized need for alignment between mathematical principles and expectations around coding and

algorithms. Approaches to this integration vary across countries. For example, Portugal has embedded AI learning outcomes into its mathematics curriculum under "computational thinking". Similarly, China aligns its ICT and AI curriculum with grade-specific mathematics requirements.

The content analysis reveals several prevalent categories of AI topics. First, AI foundation topics include algorithms and programming, data literacy, and contextual problem-solving. This category covers the basic understanding of AI and data literacy principles. Another main category is understanding, using, and developing AI, which focuses on AI skills such as working with neural networks, generative AI, large language models (LLMs), and computer vision. Additionally, many curricula emphasize the ethical and societal impacts of AI. Students are expected to deal with ethical challenges, such as bias and privacy, and recognize AI's broader social implications. A complete elaboration of these topics can be found in the appendix (*Figure A1*).

As shown in *Figure 9*, time allocation across different curricula reveals differences in the distribution of focus. Overall, on average, AI foundations take 41% of the total time allocated, with algorithms and programming receiving the largest share, followed by nearly equal time dedicated to data literacy and contextual problem-solving. Ethics and social impact capture 24% of the content on average, however, 19% of country curricula do not include AI ethics at all, and 43% do not cover AI's social implications. Additionally, AI skills, referred to as "understand, use and develop AI", make up 25% of the curricula, with a primary focus on understanding and using AI technologies and models.

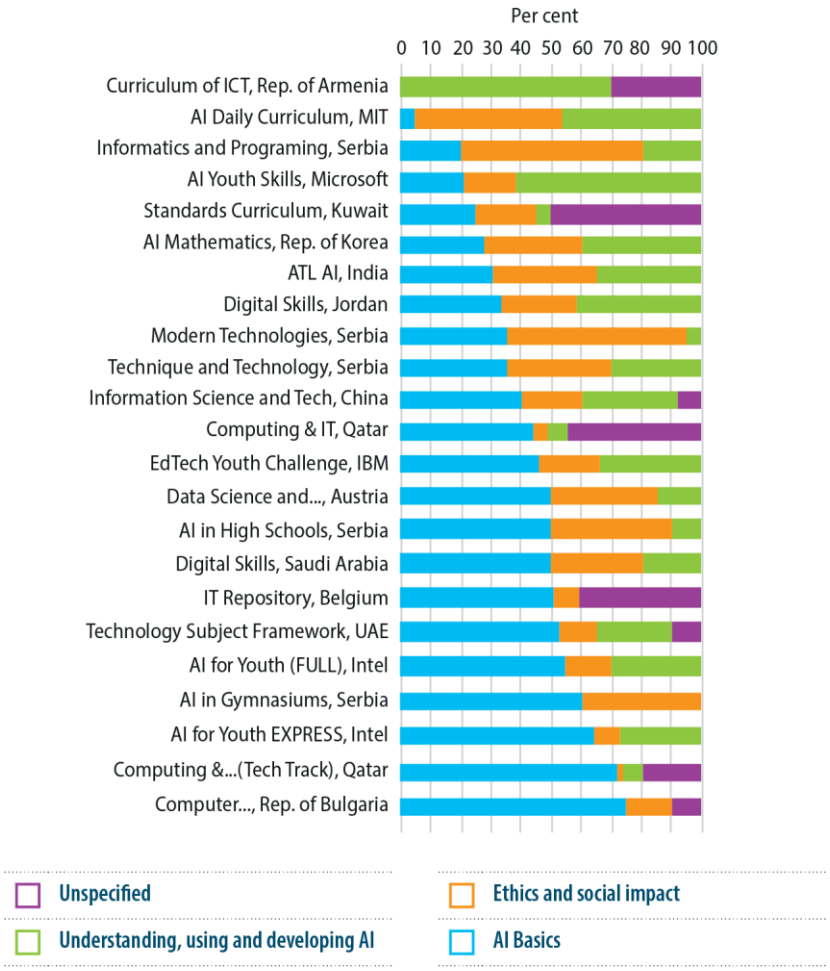

Figure 9. Allocation of curriculum time by topic area (n = 23). Adapted from UNESCO (2022).

The learning outcomes are typically divided into three main areas: knowledge, skills, and values and attitudes. These outcomes can be applied across different education levels, including elementary, middle, and high school. **Knowledge** encompasses AI literacy, with some curricula also incorporating CS. These outcomes are mapped to nine domains, 26 subdomains, and over one hundred specific learning objectives. For example, students are expected to understand the basic structure of a table in a spreadsheet and grasp the principles of data collection and simple analysis. In addition, they are expected to recognize the key components of AI, such as datasets, learning algorithms, and predictions. Furthermore, students are expected to reflect on concepts like algorithmic bias, the creation and use of natural language processing (NLP), and the environmental impacts of technology. The reference to basic data literacy skills (e.g., data tables) as part of 'AI knowledge' underlines the reliance of AI foundations on more fundamental skills that students are expected to master, as well as the broad interpretation that the term 'AI literacy' often receive.

Skills outcomes are spread across ten topic areas, detailed to eighty specific skills. These include organizing collected information through data labeling, as well as manipulating data for calculations. Other skills involve creating charts using spreadsheets and designing workflows for training are also specified. Additionally, non-academic skills, such as protecting personal data and privacy and utilizing algorithms for creative outputs such as art and music are also included.

The **values and attitudes** outcomes of AI curricula are organized into fourteen categories, covering 15 specific outcomes within the personal, social, and human domains. These outcomes include the ethical dimension of developing and implementing strategies for solving real-life problems using AI technology. Soft skills like effectively collaborating as part of a team and demonstrating tolerance for diverse ideas and perspectives are also included. Lastly, there is an emphasis on agency and accountability. Students are expected to understand that humans create, control, and are accountable for ML systems, while recognizing the risks and challenges posed by this emerging technology. A full list of the learning outcomes is available in the appendix (*Figures A2-A4*).

Summary of findings

In conclusion, this evaluation of AI curricula reveals a rich landscape shaped by diverse formats, content themes, and learning outcomes. While most curricula focus on AI for secondary education, they vary in levels of proficiency. The common thematic areas include AI foundations, understanding and using AI, and AI ethics and social implications. These themes are mapped into multiple learning outcomes in the domains of knowledge, skills and values and attitudes. They include technical competencies such as organizing data and utilizing classification, alongside soft skills like collaboration and debating abilities. Another key learning outcome focuses on ethical perspectives and reflections on AI's impact on society.

Challenges and recommendations

According to UNESCO, several issues must be addressed to ensure the success of AI curricula. One significant challenge is the limited evidence regarding quality and effectiveness. To advance AI education, research is needed to guide curricula development, teacher training, and instructional design. Another key point is that AI education should not rely on a single technology. Instead, it is crucial to diversify the skills being developed across various platforms and providers. Countries like Austria and China advocate for a "technology-agnostic approach", meaning the curriculum is not tied to specific brands, devices, or programming languages. This approach ensures two key

outcomes: first, that teacher training is grounded in theory, offering a strong understanding of principles that can be applied across different technologies. Second, when specific hardware or software is used, both teachers and students are exposed to multiple options and different providers of AI tools, stretching their perspectives, and increasing flexibility.

Teachers are the center of the education process and a key factor in the success of new AI curriculum. Therefore, developing resources and training for teachers should be a priority. Additionally, pilot studies should be carried out and must seek feedback from teachers and students. Moreover, collaboration among a wide range of stakeholders is necessary. AI curriculum development and implementation should involve a partnership between industry experts, academics, third-sector organizations, teachers, and government officials.

Discussion

This report provides a comprehensive overview of the current state of AI education in the K-12 field from multiple perspectives, including international organizations, country strategies, and analyses of worldwide curricula.

To begin with, the OECD, UNESCO, NSF, and all analyzed countries' policy papers stress the critical need for AI education, starting from a young age. These entities recognize AI as a transformative force that will impact the workforce, economies, personal lives, and education systems. To prepare for an AI-powered world, various actions and recommendations have been outlined. The OECD and IMF suggest that, in addition to AI literacy, students must strengthen their critical thinking, reading, writing, and digital literacy skills. For future scientists and developers, there is an emphasis on incorporating AI-related science into all STEM fields, alongside ensuring high-quality education in both general and AI-specific subjects.

With respect to related domains, AI education can be integrated into ICT education or CS. However, in many countries, such as Israel, Canada, and the United States, ICT and CS education are not accessible to all students, and the same applies to AI education. Mathematics is another key subject closely linked to AI. As highlighted in the "Evaluation of International AI Curricula" chapter, there is a recognized need for alignment between the level of mathematics and AI education, with Portugal and China serving as examples. Additionally, digital literacy plays an important role. Digital literacy is a concern for various countries, including South Korea and Canada, as well as international organizations such as the NSF, UNESCO, and the OECD.

Overall, related fields, such as mathematics, CS, data literacy, and digital literacy should be prioritized alongside AI literacy in future education programs worldwide, including Israel. While these skills are essential for the entire population, they will also provide a competitive advantage for future scientists and developers, which is key for strengthening the local economy's resilience.

To address the need for AI education, one of the most immediate and significant matters is the role of educators. UNESCO stresses that teachers cannot be replaced by machines and that the core of the education process remains the human connection between students and teachers. Therefore, teachers are pivotal to the implementation and success of AI curricula, a point emphasized by international organizations, country strategies, and worldwide curricula overviews throughout the paper.

While all the international and national initiatives declare teachers as having a central role in implementing the programs, the reality is that the shortage of qualified teachers is a limiting factor in scaling up AI education programs. Thus, international organizations like the OECD, NSF, and UNESCO focus on teachers' professional training. Investing in teacher training is essential to providing effective and up-to-date educational content and to guide students in using AI technologies responsibly. Therefore, high-level AI teacher training should be established alongside research into the effectiveness of professional development and the subsequent educational processes.

As stressed in Canada, the deficiency of qualified educators is exacerbated by competition with industry. In Israel, it is uncertain whether new AI teachers can be sourced from CS or science fields due to existing shortages. Potential options include recruiting from the mathematics field, which has a close relationship with AI, or other STEM fields. Due to the shortage of highly qualified teachers in STEM education, there is the risk that AI literacy implementations will rely on teachers without STEM background, potentially leading to superficial coverage of important topics.

Another challenge, alongside opportunity, that emerges is the knowledge gaps. UNESCO and the IMF particularly highlight the need for research on AI curricula to evaluate effective pedagogical approaches, measure program effectiveness, and assess learning outcomes. Research is necessary to establish and evaluate pedagogical methods and activities that enhance students' understanding of AI, fostering a comprehensive grasp of both the technical aspects of AI and its social and ethical implications. UNESCO's mapping stresses that research-based evaluation of curricula is crucial, as expert evaluations alone are insufficient to meet the educational needs of young students. Therefore, there is a need for research to follow the implementation of new curricula generally, and specifically for the new AI curriculum in Israel. Second, as already mentioned, due to lack of evidence, organizations like the NSF and UNESCO stress the importance of further research on effective teacher training in this new emerging field.

The UNESCO curricula mapping reveals several key challenges for the successful implementation of AI curricula. One of the primary challenges is the infrastructure required to engage with AI technologies and learning tools. For effective implementation, schools need access to computers, reliable internet connectivity, and other necessary resources. Another takeaway from the mapping is the need for balanced collaboration among multiple stakeholders, including industry, academics, third-sector organizations, teachers, and government officials. Wide-scale implementation

requires strong governmental commitment and a validation mechanism to manage competing interests in curriculum development and delivery.

UNESCO recommendations highlight that collaboration with industry can be highly beneficial, offering expert support and funding opportunities. However, this collaboration must be balanced and validated. It is important that AI education is not limited to specific brands or products. Students need to acquire foundational knowledge, transferable skills, and a value-oriented approach to applying AI across various domains and contexts.

Lastly, the UNESCO mapping emphasizes the importance of diverse competencies as key goals of an AI curriculum. Curriculum activities should be versatile, including both plugged (online) and unplugged (computer-free) activities. The learning outcomes should cover knowledge, skills, and values and attitudes. The knowledge component focuses on AI foundations, while the skills component includes both hard and soft skills related to AI and general functions. Values and attitudes are also essential, but they must complement the knowledge component. The idea is that AI ethics and understanding of social impacts remain superficial without a solid foundation in AI fundamentals. Overall, these three components, knowledge, skills, and values and attitudes, are crucial and should work together.

Research Limitations

First limitation is my reliance on English-language and Hebrew materials, as I was unable to access foreign language sources such as those in Chinese or Korean, which restrained the scope of this review. Another issue is the limited access to curricula due to language barriers, copyright restrictions, lake of evaluation and implementation proofs and overall accessibility restrictions. As highlighted in the curricula overview chapter, I base my work on the UNESCO mapping and their initial analysis of international curricula as I do not have direct access to specific global curricula. The final limitation is the reliance on announcements, policy papers and strategy papers, without the ability to connect them to real-world actions (which was beyond the goals and scope of this review). While the strategies and announcements may differ significantly from real-life implementation, I was unable to track and describe the actions taken to implement these strategies and as a result this analysis is based on official announcements, strategies papers and published research when available.

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Appendix

Figure A1. AI curriculum areas. Adapted from UNESCO (2022).

Category	Topic area	Competency and curriculum considerations
AI foundations	Algorithms and programming	Together with data literacy, algorithms and programming can be viewed as the basis of technical engagement with AI.
	Data literacy	A majority of AI applications run on 'big data'. Managing the data cycle from collection to cleaning, labelling, analysis and reporting forms one of the foundations for technical engagement with using and/or developing AI. An understanding of data and its functions can also help students understand the causes of some of the ethical and logistical challenges with AI and its role in society.
	Contextual problem-solving	AI is often framed as a potential solution to business-related or social challenges. Engaging at this level requires a framework for problem-solving in context, encompassing things like design thinking and project-based learning.
Ethics and social impact	The ethics of AI	Regardless of technical expertise, students in future societies will engage with AI in their personal and professional lives – many do so from a young age already. It will be important for every citizen to understand the ethical challenges of AI; what is meant by 'ethical AI'; concepts such as transparent, auditable, and fair use of AI; and the avenues for redress in case of unethical or illegal use of AI, e.g. that which contains harmful bias or violates privacy rights.
	The social or societal implications of AI	The social impacts of AI range from requiring adjustments to legal frameworks for liability, to inspiring transformations of the workforce. Survey respondents were asked about the extent to which their curricula targeted these issues. Trends such as workforce displacement, changes to legal frameworks, and the creation of new governance mechanisms were given as examples.
	Applications of AI to domains other than ICT	AI has a wide range of applications outside of computer science. The survey asked participants whether and to what extent AI applications in other domains were considered. Art, music, social studies, science and health were given as examples.
Understanding, using and developing AI	Understanding and using AI techniques	This area included (1) the extent to which theoretical understandings of AI processes were developed (e.g. defining or demonstrating patterns, or labelling parts of a machine learning model); and (2) the extent to which students used existing AI algorithms to produce outputs (e.g. training a classifier). Machine learning in general, supervised and unsupervised learning, reinforcement learning, deep learning, and neural networks were given as examples of AI techniques.
	Understanding and using AI technologies	AI technologies are often human-facing applications which may be offered 'as a service'. NLP and computer vision were given as examples. Respondents were asked about the extent to which learners used existing AI technologies to complete tasks or projects, and/or studied the processes of creating these technologies.
	Developing AI technologies	Developing AI technologies deals with the creation of new AI applications that may address a social challenge or provide a new type of service. It is a specialized field requiring knowledge of a range of complex techniques and skills in coding, mathematics (especially statistics), and data science.

Figure A2. Mapping of learning outcomes by AI categories (Knowledge). Adapted from UNESCO (2022).

Domain	Sub-domain	Learning outcomes	Grade levels engaged		
			Primary school	Middle school	High school
AI foundations					
Algorithms	Computational thinking	Understands abstraction	X		
		Understands decomposition	X		
		Explains the roles of decomposition, abstraction, pattern recognition and algorithms in computation		X	
		Discovers commonalities and rules (patterns) in instructions			X
	Algorithm definitions and applications	Understands what algorithms are and do	X	X	X
		Understands that learning algorithms are sets of instructions created by humans to modify an input to create an output		X	
		Identifies examples of types of algorithms (classifiers, generators, regression)		X	
		Recognizes and describes everyday applications of algorithms			X
		Recognizes the importance of algorithms in automated digital processes			X
	Algorithm components and processes	Understands the parts of an algorithm (input, steps to change input, output)		X	X
		Understands the process of training, testing and deploying algorithms		X	
		Compares and contrasts the searching and sorting of algorithms			X
		Analyses the flow of execution of a recursive algorithm			X
		Understands regression algorithms			X
		Compares how advanced data structures are used by algorithms			X
Programming	Programming languages	Develops knowledge of block-based and other programming tools		X	
		Knows different programming languages and production processes		X	X
	Representation and simulations	Understands rule-based reasoning		X	
		Develops an awareness of iterative processes in creating artefacts			X
		Develops knowledge of simulations/models/computational abstractions of real-world physical systems		X	
		Reflects on the limits and possibilities of simulations			X
Contextual problem-solving		Discusses and assesses the power and applicability of various AI approaches to practical problems		X	
Data literacy		Understands data trends	X		
		Understands the principles and processes of data collection and simple analysis	X		
		Understands how to collect, process, analyse, and report using data		X	X
		Understands the types of sources of information		X	X
		Describes the basic structure of a table in a spreadsheet		X	X
		Describes the characteristics of data and information			X
		Assesses the capabilities of big-data management (e.g. warehousing processes)			X
		Discusses the advantages and disadvantages of big-data cloud storage			X
		Compares structured and unstructured data			X
		Explores encoding techniques to represent data efficiently			X
		Develops an awareness of how the transformation and presentation of large datasets through visualization/modelling can be used for decision-making			X

Domain	Sub-domain	Learning outcomes	Grade levels engaged		
			Primary school	Middle school	High school
Understanding, using and developing AI					
AI techniques	AI definitions and components	Understands 'weak' and 'strong' AI	X		
		Describes basic terms related to AI		X	
		Understands what AI is (and what it is not)		X	X
		Understands the parts of AI (dataset, learning algorithm, prediction)		X	X
		Understands and uses basic and general terms related to AI and machine learning			X
		Describes the basic features of AI			X
		Understands that AI has underlying algorithms			X
		Understands convergence in AI			X
	Data use in AI	Explains how data is used to make predictions		X	X
		Describes the flow of data through a deep learning network for classification problems		X	X
	History of AI	Knows the history of AI and its development over time		X	X
		Understands different approaches to developing AI			X
	Understanding how AI works	Explains types of AI techniques and how they work (supervised, unsupervised, reinforcement, ML/DL)		X	X
		Understands how neural networks work and their parts (feed forward, evaluation of a prediction for accuracy, back propagation)		X	X
		Understands the concepts and challenges of artificial general intelligence		X	X
		Knows how GANs work and identifies their parts			X
		Explains heuristic searches and how they work			X
AI technologies	Computer and human perception	Compares computer and human perception	X		
		Understands computer recognition	X		
		Understands methods of measuring with sensors		X	
		Understands the role of sensors in data collection			X
		Understands the difference between AI and human intelligence			X
	Understanding AI technologies	Explores AI technology and tools (e.g. classifier)	X		
		Understands the processes of creating and using NLP		X	X
		Explores the principles of data for NLP processing			X
		Understands autonomous systems			X
		Understands recommender systems and the technology behind them			X
		Understands the process of creating and using computer vision			X
		Develops an understanding of advanced technologies (IoT, cloud computing)			X
		Compares and contrasts an IoT device operating system with a typical desktop OS			X
AI development	Design thinking	Understands design thinking		X	X
	Product development	Understands the product development cycle			X
Ethics and social impact					
Applications of AI to other domains		Identifies/explains AI use cases and applications in everyday life	X	X	X
		Describes how AI drives many software and physical systems			X
		Understands new advances and applications of AI			X
		Knows important areas of application in the AI and information technology professions			X

Domain	Sub-domain	Learning outcomes	Grade levels engaged		
			Primary school	Middle school	High school
Ethics of AI	Ethical terms, definitions and examples	Understands what ethical terms such as 'bias', 'fairness' and 'representation' mean in relation to AI		X	X
		Reflects on human rights and ethical issues in technology/AI use		X	X
		Describes the limitations of AI			X
		Understands the ethical considerations and dilemmas which may arise from AI			X
	Access	Understands issues of access to technology			X
	Bias	Explains how the biases of the programmers influence the fairness of the AI rules			X
		Understands the effects of information quality in decision-making			X
		Understands algorithmic bias and types/sources of bias		X	X
		Understands methods of mitigating/lessening bias in AI algorithms		X	
		Understands different types of bias (representation, selection, etc.)			X
		Analyses cases where AI has been clearly fair or unfair			X
	Intellectual property	Understands intellectual property rights	X		
		Defends a position on ownership of art generated or enhanced by AI		X	
		Understands/respects basic intellectual property laws		X	
	Privacy and security	Develops an awareness of cybersecurity	X		
		Develops deep knowledge of the concept of digital identity			X
		Understands how digital service providers inform users about how personal information is used			X
		Understands how personally identifiable information can be used and shared			X
	Transparency / explainability	Understands the mechanisms of image and data manipulation			X
		Understands the principle of explainable AI and its tenets			X
	Human agency	Understands that humans control AI and machine learning		X	X
		Understands usability, security, and accessibility of computer systems as key features of their design			X
		Understands how to ethically create and/or use AI			X
Social implications of AI	AI's advantages and disadvantages	Understands how AI can benefit humans	X	X	X
		Reflects on the advantages and disadvantages of new technologies	X	X	X
		Outlines the advantages and disadvantages of AI in different social, educational, and professional contexts			X
	AI in everyday life and work	Considers the role, importance and/or impact of new technologies on society (life, work and education)	X	X	X
		Explores emerging technologies that have the potential to disrupt the way people live, learn and work		X	X
		Develops an awareness of digital citizenship	X		
		Understands how AI is changing jobs (even outside STEM)		X	
		Understands the benefits of and demands for STEM jobs		X	
		Recognizes the interactions between nature, technology and society			X
	Environmental impacts	Understands the positive and negative environmental impacts of technology	X	X	X
		Knows the computational and environmental costs of generating AI		X	
		Understands how computational and environmental costs can be reduced (more efficient models, evaluation of costs and benefits)		X	
		Understands how computational and environmental costs lead to inequity in developing AI		X	
	Fakes and misinformation	Reflects on positive/negative aspects and social consequences of deepfakes		X	
		Reflects on the social implications of GAN technology (e.g. fake homework)		X	
		Knows the six key features of misinformation[22]		X	
		Understands how misinformation spreads		X	
	Gender	Develops an awareness of gendered consequences/opportunities in technology			X

Figure A3. Mapping of learning outcomes by AI categories (Skills). Adapted from UNESCO (2022).

Topic area	Description of skills	Grade levels engaged		
		Primary school	Middle school	High school
AI foundations				
Algorithms	Recognizes patterns	X		
	Follows clear instructions for action (algorithms) and carries them out		X	X
	Formulates clear instructions for action (algorithms) verbally and in writing		X	X
	Creates an algorithm and the relevant flow chart iteratively		X	X
	Creates a predictive model			X
	Implements complex data structures and fundamental algorithms (e.g. for sorting and searching)			X
	Evaluates the efficiency of an algorithm in terms of time and space			X
	Optimizes computational procedures (to require fewer steps)			X
Programming	Programmatically controls a robot	X		
	Constructs simple code scripts using block-based programming	X		
	Creates a mobile application with a block-based programming language		X	
	Converts algorithms to code using a text-based programming tool		X	
	Codes in one or more programming languages		X	X
	Masters basic programming structures (e.g. branches, loops, procedures)		X	X
	Assesses user interfaces (usability, intuitiveness) and the technical processes behind them			X
	Uses, creates and reflects on coding (e.g. cipher, QR code)			X
	Creates code to manipulate local data files			X
	Creates software to control a robot or another computing device			X
	Uses modular programming methods in a variety of programming languages			X
	Develops an application using object-oriented programming			X
	Develops secure and user-friendly programs taking into consideration accessibility requirements			X
Contextual problem-solving	Creates simple programs or web applications with suitable tools to solve a specific problem or perform a specific task		X	X
	Designs, develops and employs strategies for solving real-life problems through decomposition and pattern identification			X
	Evaluates possible technological solutions and selects a suitable one, also taking into account proprietary and free software			X
Data literacy	Saves, changes and sorts simple databases	X		
	Creates visualizations of numerical and textual data	X		
	Searches for, selects and collects data from a range of sources using appropriate search strategies	X	X	X
	Organizes collected information (e.g. by using data labels and categorizing)	X	X	X
	Manipulates data, makes calculations, and creates simple charts with a spreadsheet	X	X	X
	Uses ICT tools to manage and maintain a relational database		X	X
	Works with relational databases to produce reports		X	X
	Evaluates the quality, authenticity, and accuracy of data		X	X
	Applies criteria to assess the credibility and reliability of data sources			X
	Implements automated data collection processes and manages data storage on a wide range of physical media and cloud platforms			X
	Parses IoT data streams and creates alerts for anomalous conditions such as extreme winds			X
	Transforms unstructured data into structured data			X
	Uses software tools or platforms to organize, calculate, present, and safeguard data			X
	Creates SQL scripts to manage normalized databases			X
	Uses ICT tools to transform data into information to support accurate decision-making			X
	Uses a range of models and charting methods to analyse, predict and communicate data stories			X

Topic area	Description of skills	Grade levels engaged		
		Primary school	Middle school	High school
Understanding, using and developing AI				
AI techniques	Classifies objects by characteristics	X		
	Constructs a decision tree (paper prototype)		X	
	Designs a workflow to train and test an AI algorithm		X	X
	Cleans and prepares textual data for analysis and ML			X
	Designs and tests supervised learning solutions for classification problems			X
	Uses open-source AI application frameworks to build simple intelligent systems			X
	Interprets the performance of a ML model (e.g. using a confusion matrix)			X
	Identifies whether various media products are GAN or not			X
	Creates GANs in different subject areas (music, art, biology)			X
	Creates a story and illustrations using GANs			X
AI technologies	Builds and tests a classifier using a teachable machine or similar AI tool		X	
	Builds a chatbot with support		X	
	Constructs and controls a simple robot that can use AI		X	
	Programs an autonomous robot		X	
	Sets a new goal for an existing AI algorithm		X	
	Uses existing AI technologies to develop new products			X
	Constructs and prepares a dataset for NLP processing			X
	Creates a chatbot with appropriate human/bot interfaces			X
AI development	Works as part of a team	X		
	Uses design thinking methodology to implement a project as part of a team		X	X
	Creates innovative solutions through AI tools			X
	Manages a technology-development project			X
	Verifies the correctness of the technological solutions applied			X
Ethics and social impact				
AI applications	Uses algorithms to produce art, music, etc.	X	X	X
Ethics of AI	Protects personal data and own/others' privacy	X	X	X
	Identifies instances of bias in AI algorithms		X	
	Identifies the stakeholders/beneficiaries of an AI algorithm		X	
	Builds an ethical matrix for an algorithm (stakeholders and their values)		X	
	Researches exposed private data on the internet		X	X
	Manages digital identities and reputations and demonstrates an understanding of digital footprints			X
	Queries messy data in a table, and find bias			X
	Undertakes self-advocacy and redress (e.g. if rights are violated)			X
	Designs an end-to-end ML process that maximizes transparency and ensures fairness			X
	Writes guidance for AI developers to ensure that AI is made ethically			X
Social implications of AI	Properly disposes of technology	X		
	Identifies deepfakes (independently and with AI)		X	
	Recognizes developments that pose a threat to equal opportunities in the use of IT and identifies options for action		X	X
	Compares, analyses and evaluates information and digital content critically (e.g. to recognize manipulation)		X	X
	Avoids health risks and threats to physical and mental well-being related to IT			X
	Helps shape social development by participating in public discourse			X

Figure A4. Mapping of learning outcomes by AI categories (Values). Adapted from UNESCO (2022).

Value / attitude to be developed	Examples of related knowledge and skills outcomes	Grade levels engaged		
		Primary school	Middle school	High school
Personal				
Interest in ICT	Explores existing AI tools	X	X	X
	Creates innovative solutions through AI tools	X	X	X
Persistence / resilience	Solves problems using programming methodology Tests and redesigns artefacts and products	X	X	X
Personal empowerment	Creates a project using design thinking Researches exposed private data on the internet Identifies avenues of redress if personal rights are violated		X	X
Reflection	Reflects on how 'my personal future work' may be impacted by AI Describes the role and importance of AI and its applications Explores emerging technologies that have the potential to disrupt the way people live, learn and work		X	X
Critical thinking and reflection	Designs, develops and employs strategies for solving real-life problems using computational thinking Explains how the programmers' bias influences the fairness of AI rules Compares, analyses and critically evaluates information and digital content (e.g. to recognize manipulation)			X
Entrepreneurship	Uses design thinking methodology to produce a prototype Develops awareness of entrepreneurship principles/processes to implement innovative ideas			X
Social				
Collaboration / teamwork	Works as part of a team or group Implements a project as part of a team Collaborates online as a member of a team	X	X	X
Communication	Creates a story and illustrations using GANs Writes guidance for AI developers to ensure that AI is made ethically			X
Societal				
Respect for others	Engages respectfully with others Protects personal data and own/others' privacy	X	X	X
Personal responsibility	Disposes of technology properly Understands that humans control AI and ML	X	X	X
Integrity	Understands methods of mitigating/lessening bias in AI algorithms Designs an end-to-end ML process that maximizes transparency and ensures fairness		X	X
Tolerance	Shows tolerance for different ideas/positions		X	X
Human				
Respect for the environment / sustainable mindset	Understands the environmental impact of technology Recognizes the interactions between nature, technology and society Understands how computational and environmental costs can be reduced	X	X	X
Commitment to equity	Reflects on access to AI Understands how computational and environmental costs lead to inequity in developing AI		X	