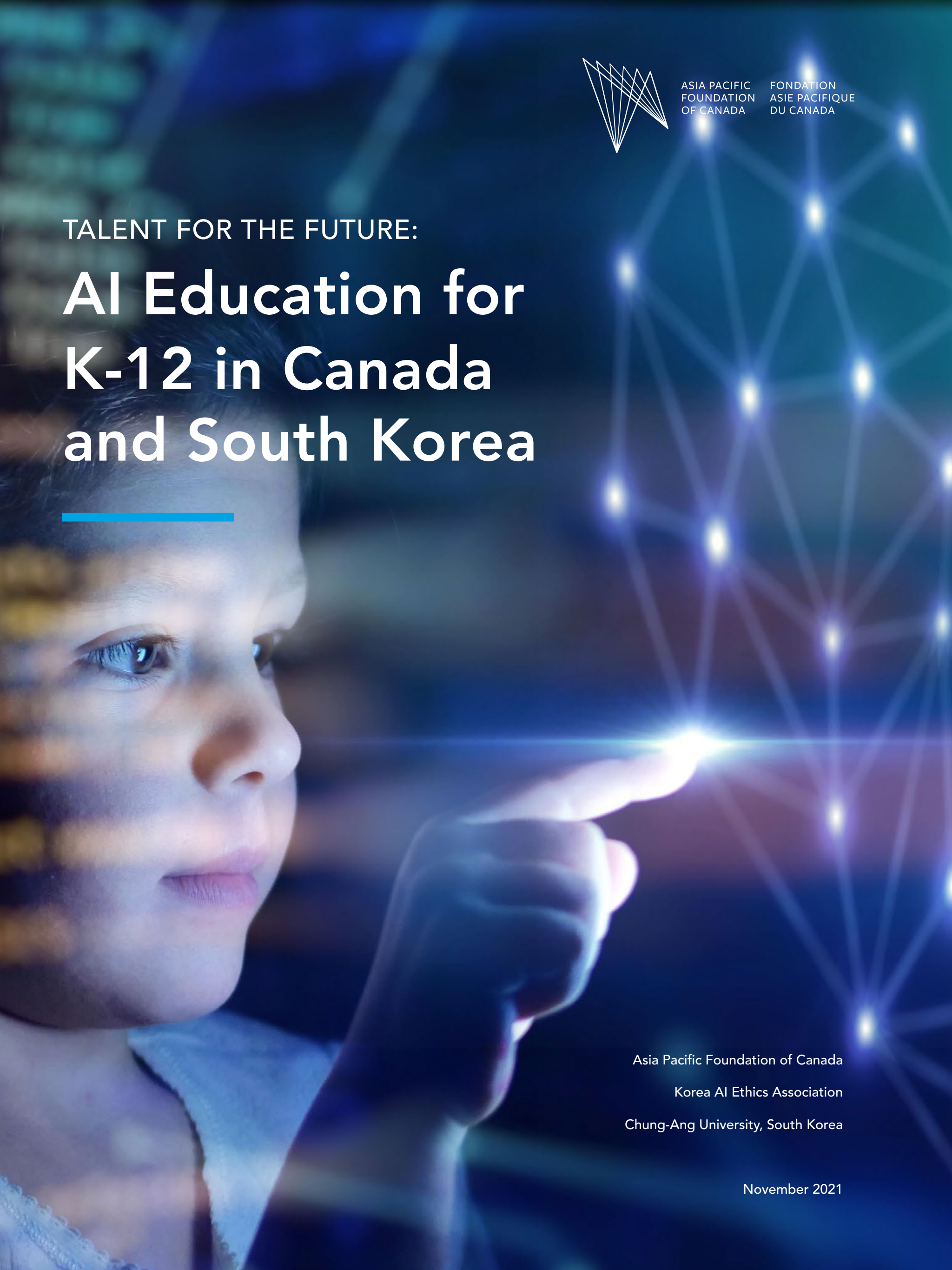

ASIA PACIFIC FOUNDATION OF CANADA
FONDATION ASIE PACIFIQUE DU CANADA

TALENT FOR THE FUTURE:

AI Education for K-12 in Canada and South Korea

Asia Pacific Foundation of Canada

Korea AI Ethics Association

Chung-Ang University, South Korea

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CONTENTS

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EXECUTIVE SUMMARY

The adoption of artificial intelligence (AI) has accelerated during the COVID-19 pandemic, around the world and across different sectors. Now, AI is poised to impact the lives of citizens in all aspects of their lives. The pressing need for educating the next generation of workers and citizens has resulted in countries around the world emphasizing national AI strategies and education planning documents. However, there is a general shortage of information about the implementation of the K-12 education curriculum.

In this context, the Asia Pacific Foundation of Canada, the Korea AI Ethics Association, and Chung-Ang University have collaborated on this report that provides a brief overview of AI education for K-12 students in Canada and South Korea.

The report demonstrates that AI education is still in the nascent stages for both Canada and South Korea. However, South Korea has national-level plans to introduce AI education in a systematic manner, while Canada generally relies on local and civil society initiatives. Such a divergence reflects differences in education and governance systems in the two countries.

More than anything, the two cases demonstrate the importance of creating opportunities for international discussions about K-12 AI education, sharing good practices, and identifying solutions to common challenges. The authors of the report hope to initiate a discussion within Canadian and South Korean stakeholders on the issue through this publication.

The report also highlights the need to provide a forum for international discussions about K-12 AI education between practitioners and policy-makers. Lastly, based on the research and analysis conducted, the report also provides the following takeaways for governments, the private sector, and civil society stakeholders in Canada and South Korea to consider:

1. **Governments must make tangible investments in AI education for K-12 to provide equal opportunities for all students to acquire essential knowledge and skills;**
2. **Private sector and civil society participation should be encouraged, but the government should ensure the quality and consistency of AI education; and**
3. **AI ethics must be front and centre of the curriculum.**

INTRODUCTION

During the last decade, the world has seen remarkable advances in the field of artificial intelligence (AI) and its application throughout society. The adoption of AI has accelerated in the private sector, especially during the COVID-19 pandemic, and the AI global market is projected to reach US$312.4B by 2027.[1] Governments around the world have made AI a priority, launching national strategies to encourage research and development, facilitate regulatory reforms, and increase talent pools. The talent shortage has been consistently highlighted as a key issue in AI policy. Key decision makers in government, academia, and the private sector have responded by launching and increasing support for AI education and research, mostly at the post-secondary level, as they view AI primarily as an investment for economic competitiveness.

At the international level, UNESCO has created an international advisory board to support its member countries in developing: (1) an AI skills framework for schools; (2) an online repository of AI education resources; and (3) workshops to support the integration of AI training into local curriculums.[2] Furthermore, UNESCO facilitated the adoption of the "Beijing Consensus on Artificial Intelligence and Education" in 2019, which emphasizes a human-centred approach to AI in education and provides key policy recommendations.[3]

Beijing Consensus on Artificial Intelligence and Education

Five Areas of Policy Recommendation	Recommendations on Four Crosscutting Issues
AI for education management and delivery;	Promoting equitable and inclusive use of AI in education;
AI to empower teaching and teachers;	Gender-equitable AI and AI for gender equality;
AI for learning and learning assessment;	Ensuring ethical, transparent, and auditable use of education data and algorithms; and
Development of values and skills for life and work in the AI era; and	Monitoring, evaluation, and research.
AI for offering lifelong learning opportunities for all.	

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 UNESCO, "Artificial Intelligence in Education," UNESCO, August 2, 2019, https://en.unesco.org/artificial-intelligence/education.

3 UNESCO, "Beijing Consensus on Artificial Intelligence and Education," unesco.org, May 18, 2019, https://unesdoc.unesco.org/ark:/48223/pf0000368303.

The discussions on AI in basic education broadly diverge into two strands: one on children ***using*** AI and the other on ***teaching*** AI to children. For the purposes of this report, the first strand will not be discussed in depth, but key points in the discourse will be briefly discussed here.

Broadly speaking, there is an understanding that the use of AI for educational purposes has the potential to enhance the learning experience. However, at the same time, there are concerns of potential misuses and ensuing violations of children's rights. There are several initiatives on the topic of children and the use of AI. The Canadian Institute for Advanced Research has sponsored a workshop on AI and the development of children, with a focus on the use of algorithms in online content for children.[4] UNICEF released its *Policy Guidance on AI for Children* in September 2020, with nine key requirements for "child-centred AI."[5] This is a closely watched space but is not covered in depth in this report.

The second strand, ***teaching*** AI, is the main area of focus in this report. In recent years, AI has become increasingly ubiquitous, and key decision makers across the private and public sectors have started to emphasize the importance of skills related to AI. In tandem, experts have started to raise the importance of integrating AI education in the elementary and secondary curriculum. They emphasize not only the importance of developing basic computational thinking and coding skills to further scaffold toward more complex computing skills, but also of instilling basic AI literacy skills for the broader public.

There are several key initiatives in the United States that have drawn attention in the field of AI and education. The Association for the Advancement of Artificial Intelligence (AAAI), one of the top AI academic organizations, and the Computer Science Teachers Association created the AI for K-12 Working Group in 2018 and launched the AI4K12 initiative, which has developed guidelines for new AI curriculums and developed a database of resources for students and educators.[6]

4 Krista Davidson, "AI & Society Workshop Explores the Risks of AI on Children," CIFAR, April 30, 2019, https://cifar.ca/cifarnews/2019/04/30/ai-society-workshop-explores-the-risks-of-ai-on-children/.

5 UNICEF and Ministry of Foreign Affairs, Finland, "Policy Guidance on AI for Children," September 2020, https://www.unicef.org/globalinsight/media/1171/file/UNICEF-Global-Insight-policy-guidance-AI-children-draft-1.0-2020.pdf.

6 David Touretzky et al., "Envisioning AI for K-12: What Should Every Child Know about AI?," Proceedings of the AAAI Conference on Artificial Intelligence 33, no. 01 (July 17, 2019): 9795–99, https://doi.org/10.1609/aaai.v33i01.33019795.

Furthermore, existing programs and organizations that focus on computing science education, such as AP Computer Science or code.org, have integrated AI content into their curriculums.[7]

AAAI's Five Big Ideas in AI
1. Computers perceive the world using sensors;
2. Agents maintain models/representations of the world and use them for reasoning;
3. Computers can learn from data;
4. Making agents interact comfortably with humans is a substantial challenge for AI developers; and
5. AI applications can impact society in both positive and negative ways.

Overall, broadly speaking, AI education for elementary and secondary students is still in its nascent stage, and it is very much decentralized. There are broad guidelines and a plethora of resources, but there is no dominating school of thought for curriculums. In this context, this collaborative research report presents a cross-national comparison of AI education for elementary and secondary students in Canada and South Korea. It depicts different attempts to integrate AI into the basic education curriculums in two very different settings and draws both universal and local lessons for relevant stakeholders. The research report operates with the understanding that AI education is a rapidly evolving field, and it aims to serve as a tentative facilitator of international discussions and collaboration on the matter, as opposed to a definitive, evergreen resource.

Canada and South Korea are deemed to be leaders in the field of AI, and each country presents differing contexts for AI education for elementary and secondary students that enable useful lessons to be drawn. Canada is home to world-class post-secondary AI research institutes and thought leaders, and there are very active civil society organization efforts on coding and AI education. However, there are no federal standards or guidelines on AI education as the education portfolio falls under the responsibilities of the provinces and territories. On the other hand, South Korea has drawn global attention for its ambitious investments in education and R&D, which have placed it on top of the Bloomberg Innovation Index in the past few years. South Korea has announced plans to rapidly integrate AI education into its basic education curriculums to match its lofty goal of becoming a competitive "AI nation."

In each case study, the overview of the key public and private efforts to teach AI in the elementary and secondary curriculums are provided, followed by a brief SWOT analysis for a current snapshot of the state of AI education in Canada and South Korea. This analytical framework also provides insight into education-related policies or initiatives that should be supported long-term, as well as areas that require more support from government. Then, the conclusion section will bring together the analyses from the two case studies and provide policy recommendations for relevant stakeholders. The methodology of this research report consists of desk research and expert interviews.

7 College Board, "AP Computer Science a Course," AP Central, July 10, 2021, https://apcentral.collegeboard.org/courses/ap-computer-science-a/course.

CANADA

Canada has a highly regarded public education system that has generally performed competitively in comparison to its international peers, making it a relatively strong foundation for digital education. In the Programme for International Student Assessment rankings, Canadian students have performed well, higher than the OECD average in the 2018 assessment.[8] A study indicated that 94% of the 15-year-old students had access to a computer at home, and the digital literacy skills of Canadian youth was reported to be generally higher than those of their OECD peers.[9]

Unlike South Korea, Canada does not have a national ministry of education that sets national education policies or curriculums. Instead, education falls under the jurisdiction of Canada's 13 provinces and territories. Provinces and territories have their own ministries of education that establish policies and curriculums that reflect local needs. In addition, locally elected school boards serve as a link between the community and the provincial or territorial governments.[10] In this context, education policy is decentralized across Canada, and efforts to create national standards are mostly conducted by the Council of Ministers of Education, Canada, an intergovernmental body that mostly provides a forum for education policy-makers across Canada and civil society organizations that target specific issues in education policy.[11]

8 Council of Ministers of Education, Canada, "PISA 2018 Canadian Report," CMEC, 2019, https://www.cmec.ca/581/PISA_2018.html.

9 Statistics Canada, "The Daily — Digital Literacy Skills of Canadian Youth Compare Favourably with the OECD Average," www150.statcan.gc.ca, December 14, 2020, https://www150.statcan.gc.ca/n1/daily-quotidien/201214/dq201214a-eng.htm.

10 Canadian School Boards Association (CSBA), "Public Education in Canada," cdnsba.org, 2020, https://www.cdnsba.org/all-about.

11 CMEC, "About Us," cmec.ca, 2021, https://www.cmec.ca/11/About_Us.html.

Public School Initiatives

Since 2017, the federal government has invested a total of C$110M in a program called CanCode, which funds 27 projects by civil society organizations that provide digital skills learning opportunities for students in K-12 and training programs for teachers.[12] However, official curriculum development and delivery falls under the jurisdiction of the provinces and territories. They have developed various curriculums for relevant courses that highlight technical training, as well as creating local frameworks on digital literacy, as the Government of British Columbia has done.[13]

AI has been integrated into courses such as computing science, robotics, and automation throughout Canada, but in a manner that is not standardized. Saskatchewan's 2019 curriculum for Robotics and Automation includes discussions on AI applications in its mandatory Ethics and Laws module, as well as optional AI-specific modules, in which the concept and social implications of AI applications are discussed.[14] Alberta's introductory computer science courses include modules on AI concepts, applications, and ethics, as well as a program specialization in robotics and AI.[15] Modules on AI are also included in advanced university preparatory programs available throughout Canada, such as Advanced Placement or International Baccalaureate.[16] However, these courses are often very specialized and computing science education is not mandatory at the high school level.

Across Canada, public school systems have mandatory career management or civic studies that emphasize the importance of digital literacy, in which AI education could be included at the discretion of instructors. However, at the time this research paper was drafted (March 2021), there were no official government mandates or guidelines to include modules on AI.

Civil Society

Several civil society organizations and private sector actors have been active in filling in the gap in AI education across Canada. The CanCode funding program has been instrumental in this context. One of the key players in this space is Canada Learning Code (CLC), a not-for-profit organization whose goal is to "[bring] accessible computer science to communities across Canada so everyone can create with technology."[17] CLC offers free lesson plans and

12 Innovation, Science and Economic Development, Canada, "MP Hehr Announced New CanCode Investment," canada.ca, July 19, 2019, https://www.canada.ca/en/innovation-science-economic-development/news/2019/07/mp-hehr-announced-new-cancode-investment.html.

13 Ministry of Education, "Digital Literacy – Province of British Columbia," www2.gov.bc.ca, 2015, https://www2.gov.bc.ca/gov/content/education-training/k-12/teach/resources-for-teachers/digital-literacy.

14 Ministry of Education, Saskatchewan, "2019 Saskatchewan Curriculum: Robotics and Automation 10, 20, 30," September 5, 2019, https://bit.ly/3HdxdSz.

15 Government of Alberta, "Program of Study: Computer Science," www.learnalberta.ca, 2021, https://www.learnalberta.ca/ProgramOfStudy.aspx?lang=en&ProgramId=74838#427524.

16 International Baccalaureate Organization, "Find an IB World School," International Baccalaureate®, 2021, https://www.ibo.org/programmes/find-an-ib-school/?SearchFields.Region=iba&SearchFields.Country=CA&SearchFields.State=AB%7CCA&SearchFields.Keywords=computer&SearchFields.Language=&SearchFields.BoardingFacilities=&SearchFields.SchoolGender=.; College Board, "AP Course Audit," apcourseaudit.inflexion.org, 2021, https://apcourseaudit.inflexion.org/ledger/search.php.

17 Canada Learning Code, "Learning for the Digital World: A Pan-Canadian K-12 Computer Science Education Framework," July 31, 2020, https://k12csframework.ca/wp-content/uploads/Learning-for-the-Digital-Future_Framework_Final.pdf.

resources that educators in diverse subject areas – from computing science to social sciences – can integrate into their existing curriculum.

CLC, noting the "inequitable access to high-quality and comprehensive foundational Computer Science education for all students across Canada," published *Learning for the Digital World: A Pan-Canadian K-12 Computer Science Education Framework* in August 2020 in consultation with its advisory group and workshops across the country that engaged over 650 stakeholders.[18]

The framework aims to set a national standard on quality computing science curriculum for K-12 students in Canada, and identifies five focus areas of competency (programming, computing and networks, data, technology and society, and design). Under its data section, the framework highlights "Applications of AI & Machine Learning," which provides specific competencies for each learning stage.[19] Here, the emphasis is not so much on learning the technical elements of AI and machine learning, but rather on identifying AI and assessing ethical issues related to its application.

18 Ibid.

19 Ibid.

Actua's Artificial Intelligence (AI) Education Framework

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 with 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 aective 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, effciency 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 effcient 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

Source: Actua, "Actua's Artificial Intelligence (AI) Education Handbook," actua.ca, January 2020, https://www.actua.ca/wp-content/uploads/2020/01/Actua-AI_Handbook.pdf.

AI Module from the Canada Learning Code K-12 Computer Science Education Framework

Applications of AI & Machine Learning

Start here	Identify commonly used digital tools that incorporate AI (artificial intelligence) and machine learning and acknowledge how such tools help people accomplish tasks that only humans could previously do.
Emerging learner	Define AI and give real-world examples of how it has been used to extract information from data.
Developing learner	Describe basic algorithms of AI systems and how data and machine learning interact.
Provident learner	Assess how human biases are embedded within technical systems and artificial intelligence.
Going further	Explain how machines learn. Discuss specific ethical challenges with machine learning and AI.
Connections to other areas	**Focus Areas:** Technology and Society (Ethics, Safety and the Law); Programming (Algorithms) **Capacities and Dispositions:** Critical Thinking, Citizenship

Source: Canada Learning Code, "Learning for the Digital World: A Pan-Canadian K-12 Computer Science Education Framework," July 31, 2020, https://k12csframework.ca/wp-content/uploads/Learning-for-the-Digital-Future_Framework_Final.pdf.

Actua is another not-for-profit organization that has contributed to Canada's AI education efforts. It is a charitable organization that delivers science, engineering, and technology educational programs to youth in Canada.[20] Actua developed an AI Education Framework, with data, perception, representation & reasoning, learning, natural interaction, and societal impacts as its six main themes.[21] Like Canada Learning Code's K-12 Computer Science Education Framework, Actua's AI Education Framework focuses on the understanding of the main concepts in AI and its social implications.

20 Actua, "About," actua.ca, 2021, https://www.actua.ca/en/about/.

21 Actua, "Actua's Artificial Intelligence (AI) Education Handbook," actua.ca, January 2020, https://www.actua.ca/wp-content/uploads/2020/01/Actua-AI_Handbook.pdf.

Kids Code Jeunesse (KCJ) is another key player in this space. KCJ is a charitable organization that provides bilingual computing science education to K-12 students across Canada, and it has reached over 10,000 educators and 375,000 youth through its programs thus far.[22] KCJ's new initiative, *#kids2030: Educating Kids on Code, AI & the Global Goals* seeks to educate over 1 million kids and 50,000 educators on AI and ethics, and on the use of technology for achieving the UN's sustainable development goals. Its 10-year road map aims to create education materials on AI ethics and digital citizenship in collaboration with other organizations.[23]

These civil society organizations, supported by government and private sector funding, aim to provide high-quality computing science programs to Canadian youth who may not have access to them in their public-school systems. In addition to workshops and training programs, they provide turnkey resources that educators can easily integrate into their curriculums. It should be noted that in addition to the funding from CanCode or other federal government entities, these organizations collaborate closely with private sector actors such as Amazon (CLC), Google (Actua), and Microsoft (KCJ), which provide not only funding, but also technical expertise.

SWOT Analysis

STRENGTH

- Canada is home to world-class research AI institutes and technology companies, which provide direct and indirect resources for students in the form of educator training, mentorship, and youth programs;
- Civil society organizations, such as those mentioned above, provide affordable resources and opportunities for students and educators, and the generous support of the federal government suggests the expansion of such programs moving forward; and
- The flexibility of school curriculums and general support for development of digital skills and literacy allow educators to easily integrate AI education into their teaching portfolio.

WEAKNESSES

- There is no standardization of computing science or AI curriculum across Canada due to its decentralized educational system. The quality and availability of AI-related programs are not evenly distributed;
- While Canadian students in general have good access to digital infrastructure and educational programming, the digital divide remains a challenge, especially for students in rural and northern areas;
- Education ministries, which make the decisions on curriculums and program deliveries, have been slow to adopt AI into official curriculums and to provide the

22 KCJ, "About," kidscodejeunesse.org, 2021, https://kidscodejeunesse.org/about.

23 KCJ, "#kids2030," kidscodejeunesse.org, 2021, https://kidscodejeunesse.org/kids2030.

resources to make AI education accessible to all, not just to gifted or advanced students specializing in computing science; and

- Educators do not necessarily have the skill set to teach AI, and recruitment of good computing science educators can be challenging due to the competition with the industry.

OPPORTUNITIES

- Highly localized curriculum and the existence of resources such as CLC, Actua, and KCJ mean that entrepreneurial parents, educators, or institutions have access to good resources to provide quality AI education to children;
- Educators across Canada are aware of the importance of AI education, especially after the pandemic, and ministries of education have been upgrading their curriculums to reflect more up-to-date needs; and
- The federal government has been supportive of AI education and training, as evidenced by – among others – the investment of C$110M in the CanCode program and C$750M in the Broadband Fund program, which creates a supportive policy and educational environment.

THREATS

- AI education remains in its infancy, and it will likely remain decentralized across the country and reliant on civil society organization programs, continuing to limit access to quality computing science programs depending on the geographic location;
- Without official mandates to include AI education in the curriculum and resources to support its inclusion from the provincial and territorial governments, educators may remain slow, if not unwilling, to incorporate it into their curriculums; and
- Major technology companies and government agencies are racing to recruit computing science graduates with competitive benefits, and this could exacerbate the shortage of knowledgeable computing science educators in the public school system.

SOUTH KOREA

South Korea has an active and committed government currently acting on plans and promising significant funding to update and roll out a K-12 public school curriculum with AI education coursework. In the 2020 basic plan for AI education, the Ministry of Education (MOE) expressed the intent to transform South Korea into a country that best employs AI. For this purpose, the MOE released the Education Policy Direction and Core Tasks for the Artificial Intelligence Era in November 2020. The document lays out plans to gradually introduce AI subjects in K-12 schools over the next four years. More specifically, the new curriculum includes programming, basic principles of AI, AI utilization, and AI ethics.

In March 2021, no public schools – from elementary through high school – in Korea were teaching AI as an independent subject. However, starting in the 2021 fall semester, two courses, AI basics and AI mathematics, were included as elective subjects in career-pathway programs in high schools nationwide. As for elementary and middle schools, the MOE and local-level education offices (at metropolitan and provincial levels) plan to implement a combined education program, integrating the AI curriculum into the pre-existing software coursework. In addition, the MOE is developing AI-related course materials for distribution and use in K-12 schools. By 2025, the MOE expects that the updated curriculum will be implemented throughout the country, and AI education will be fully adopted in all K-12 schools.[24]

Public School Initiatives

AI EDUCATION IN ELEMENTARY SCHOOLS

The goal of AI education in elementary schools is to instil basic AI literacy by adopting AI convergence education programs and by implementing AI education. According to the plans of the Ministry of Education and each education office, the elementary school curriculum basically focuses on familiarizing students with AI.

In addition, the Ministry of Education announced a plan to have trained 5,000 AI teachers by 2024 by training students majoring in AI in graduate schools of education. Simultaneously, the MOE promised to develop an accredited AI textbook for elementary school.[25]

As examples of specific education methods, teachers can engage learners by using AI chatbots (for answering quizzes after learning the content, such as English or math, with the help of a chatbot) and teach classes using various AI devices such as AI speakers. In addition, students themselves can use AI education platforms for creating and solving problems in class.

24 남윤철, "인공지능시대 교육정책의 방향과 핵심과제," 교육부, 행복한 교육, January 2021, https://happyedu.moe.go.kr/happy/bbs/selectHappyArticleImg.do?bbsId=BBSMSTR_000000000191&nttId=10119.

25 Cho Ki-sung, "AI education, is it being done properly?" Korea Education Daily, 2020, https://www.hangyo.com/news/article.html?no=90531

The next software education curriculum model (draft)[26]

Primary Category	Secondary Category	Grades 1-2	Grades 3-4	Grades 5-6
AI and convergence	Data science			Understanding of big data Conceptual understanding of AI Implementation of AI II (e.g., machine learning)
	Artificial intelligence		Implementation of AI I (e.g., voice recognition)	

Report of AI education curriculum structure in primary and secondary schools[26]

Category	Grades 1-2	Grades 3-4	Grades 5-6
Understanding of AI	**AI story (smart robot)**	**Strong AI Weak AI**	**AI vs. human Moravec's paradox Turing test**
AI and data	**Various types of data (video, image, sound, text)**	**Number guessing with hints**	**Make aware in a new situation based on the previous data/Make a new situation based on the data**
AI algorithm	**Classifying things Finding commonalities**	**Make certain reactions made by context and conditions**	**Classify things according to the previous data**
Implementation of AI	**Making AI robot (using recycled materials)**	**Machine learning hands-on experience (classification of images and videos)**	**Making AI-driven artifacts (block coding)**
AI and its impact on society in everyday life	**Changes made by AI**	**Commonalities and differences between human and AI**	**The Fourth Industrial Revolution AI ethics**

As an example of a curriculum developed by the Ministry of Education, an AI-based math learning program called "Knock! Knock! Math Explorers" was distributed to students in first and second grade in elementary schools across the country on September 14, 2020. This AI program analyzes the results of a math quiz that students take after learning the topic from math textbooks and the math curriculum, and then recommends learning content suitable for the student. This pilot program is operated at five schools (Seoul, Daegu, Gyeonggi, Chungnam, and Gyeongbuk) and will be gradually distributed to a total of 34 Korean schools in 16 countries around the world.[26]

26 김수현, "초등학교 1∞2학년, AI로 맞춤형 수학학습…고교엔 AI 과목 신설," 연합뉴스, September 13, 2020, https://www.yna.co.kr/view/AKR20200911147700530?input=1195m.

AI Education in Middle Schools

AI education in middle schools focuses on instilling basic AI literacy. According to the Ministry of Education, the goal is to help middle school students to understand the principles of AI and apply them in real life. Currently, 34 class hours are provided through software education, but this number is set to increase. [27]

In the mid-to-long-term development plan for AI-based convergence education (2021-2025), the Seoul Education Office announced that it will bolster AI-based project classes by taking advantage of optional activities, creative activities, and electives approved by the school principal.[28]

Seoul Education Office, AI education development plan for middle schools

Objective

Nurturing innovative talents with future core competencies through AI-based convergence education

Main Targets		Strategies	Specific Plans
Reforming Public Education through AI-based Convergence	1-1	Curriculum centered on future core competencies	• Education for AI-based convergence competencies • Reinforcement of core subjects and work education
	1-2	Support growth of education community	• Self-driven learning environment • Support teacher training and parents' participation
AI-based Targeted Education and Bridging the Education Gap	2-1	AI-based convergence education	• AI-based individuated education • AI ethics and digital literacy education
	2-2	Enhanced educational welfare of the vulnerable	• Literacy education of AI-based system • Tutoring the vulnerable with AI technology
Enlarging Educational Infra-structure through AI Technology	3-1	Constructing AI-based education environment	• AI data implantation into education environment • Construction of AI data-based support platform
	3-2	School safety and innovative work relief	• Accident prevention and diagnosis through AI • AI-based work automation and work relief
	3-3	Expansion of AI-based cooperation and education culture	• AI data implantation into public, government and research governance • Nurturing glocal culture through AI education

Source: 서울특별시 교육청, "AI 기반 융합 혁신미래교육 중장기 발전 계획 발표," 서울교육소식, *February 9, 2021, https://enews.sen.go.kr/news/view.do?bbsSn=170640&step1=3&step2=1.*

In short, AI education in middle schools will focus on fostering two major skills: (1) problem-solving, by understanding the concept of AI and by applying it to software; and (2) the ability to apply completed AI programs to solve practical problems in real life.

27 Kim S., Kim H.Y. (2018) A Computational Thinking Curriculum and Teacher Professional Development in South Korea. In: Khine M. (eds) Computational Thinking in the STEM Disciplines. Springer, Cham. https://doi.org/10.1007/978-3-319-93566-9_9

28 서울특별시 교육청, "AI 기반 융합 혁신미래교육 중장기 발전 계획 발표," 서울교육소식, February 9, 2021, https://enews.sen.go.kr/news/view.do?bbsSn=170640&step1=3&step2=1.

AI Education in High Schools

For AI education in high schools, the MOE proposed providing the opportunity for deep learning by helping students acquire AI principles and integrate them with other subjects. As a first step, the MOE planned to establish the criteria for AI education suitable for each grade level by the second half of 2020. Until 2025, the MOE will continue to bring to light best practices for AI-related subjects and offer them at the discretion of the local education office or school principals.[29] The MOE also decided to expand the operation of two pilot projects: "AI education in exemplary schools" and "regular high schools as a centre for AI convergence education." These schools convert about 15% of all classes into AI-based subjects for three years and provide students with opportunities to receive basic AI education, including in AI, programming, and big data analysis.[30]

The Ministry of Education's plan for operating exemplary high schools for intensive AI education[33]

Regular High Schools as a Centre for AI Convergence Education	AI Education Exemplary Schools
An information technology course is a mandatory subject for the first year of high school; Second- and third-year students in high school can choose from various AI-related subjects (over 26 credits in the span of three years); and Operation of collaborative courses within the community (over four credits per year).	An information technology course is a mandatory subject in middle and high schools; Clubs related to AI are allowed in elementary, middle, and high schools; and Efforts are made to raise awareness of AI education in the community.

2020	2021	2022	2023~	2020	2021	2022
34 schools	51 schools	68 schools	Further increase	247 schools	500 schools	Further increase

Furthermore, when revising the curriculum in 2022, the MOE plans to consider the education content, including programming, AI basic principles, AI use, and AI ethics, to ensure that AI education programs are implemented in schools by 2025. Before the curriculum is revised, the MOE plans to prioritize the development of supplementary teaching materials and use career education and after-school programs to help students build diverse AI-related experience. Starting in the second semester of 2021, AI basics and AI mathematics will be taught as electives for high school students' career education. In addition, the existing 12 career programs related to AI will be expanded to 15.[31]

Meanwhile, support for AI education in vocational high schools will also increase. Through funding, the MOE is encouraging vocational high schools to revise their curriculums to incorporate content related to new industries, such as AI, information protection, and smart factories. By 2024, the Seoul Education Office plans to transform 10 vocational high schools in Seoul to specialized high schools that intensively teach either AI or big data. In 2020, the

29 교육부, "인공지능시대 교육정책방향과 핵심과제," Korea.kr, 대한민국 정책브리핑, December 4, 2020, https://www.korea.kr/archive/expDocView.do?docId=39237.

30 Ibid.

31 교육부, "인공지능시대 교육정책방향과 핵심과제," Korea.kr, 대한민국 정책브리핑, December 4, 2020, https://www.korea.kr/archive/expDocView.do?docId=39237.

Seoul Education Office selected four specialized high schools in Seoul for AI and big data. In addition, AI literacy classes will be taught to all first-year students in specialized high schools in Seoul starting in 2021.[32]

Nonetheless, what Korea needs the most to expand its AI education as planned is to train teachers who can provide AI education. In addition to training 5,000 AI specialist by 2025, the requirements for teacher licences will be revised to include the completion of AI courses at the National University of Education. In addition, the Colleges of Education also plan to offer software and AI majors as teaching subjects and major-related mandatory subjects, to train 800 to 1,000 specialized teachers over five years, and to dispatch one in each elementary school and middle school. The new teacher training process will also adopt practical training involving AI-related content; in the meantime, teaching subjects and prerequisite courses will also include AI and information technology education.[33]

Civil Society

Among many AI education programs available for the general public, K-MOOC (Korean massive open online courses) is jointly operated by the Ministry of Education and the National Lifelong Education Promotion Agency. Initially, university lectures were created as online content and offered for free, but along with growing demand for AI education, K-MOOC now offers 55 courses related to AI.[34]

32 서울특별시 교육청, "AI 기반 융합 혁신미래교육 중장기 발전 계획 발표," 서울교육소식, February 9, 2021, https://enews.sen.go.kr/news/view.do?bbsSn=170640&step1=3&step2=1.

33 이하은, "인공지능 인재 양성 청사진 발표, 신규사업 신설 등 '교육계 전방위 변화,'" 한국대학신문, November 20, 2020, http://news.unn.net/news/articleView.html?idxno=500031.

34 Korean Massive Open Online Courses, National Institute for Lifelong Education, South Korea, "K-MOOC Courses" www.kmooc.kr, 2020, http://www.kmooc.kr/courses.

Bundled big data and AI courses in K-MOOC by the Korean Ministry of Education

Basics of AI Technology
Artificial Intelligence is a branch of computer science that studies information processing models that can mimic human intelligence and cognitive functions. As a fundamental problem of artificial intelligence, the course deals with theories and fundamental computational problems related to empirical search, reasoning, learning, and knowledge expression methods.

Data Mining
Data mining is a theory and technique for finding useful patterns in large amounts of data, and has been applied in various fields such as web search and recommendation systems. In this course, students learn basic concepts and related theories of data mining.

Basics of AI Technology
Machine learning is a discipline that extracts information from data or learns patterns, and is the most core field for artificial intelligence technology. First, the course deals with general optimization and online problems based on basic linear algebra concepts.

Big Data and Machine Learning Software
Big data and machine learning software are software that analyzes various data and creates predictive models. In this course, you will learn various big data analysis methods (batch processing, stream processing, interactive query, graph processing, etc.) and how to perform real data analysis using the concepts you have learned.

Source: Korean Massive Open Online Courses, National Institute for Lifelong Education, South Korea, "Courses," www.kmooc.kr, 2020, http://www.kmooc.kr/courses.

As for local governments, the Seoul Metropolitan Government recruited students for the first semester of a software specialists' training program, Seoul Software Academy Cluster (SSAC), in November 2020. SSAC consists of seven courses in five fields: web, app, AI, big data, and internet of things/robot. It provides free education to 120 citizens of Seoul for three or six months, depending on the curriculum. The three-month course is a small-scale course that allows people to directly learn from a developer in the field and to focus on solving real-world problems. The six-month course enables students to become actual developers and find a job in a related field. [35]

AI education for the general public in Korea focuses on vocational training to create jobs and find employment in jobs that use AI technology. For this reason, most AI education projects funded by the Ministry of Education or the Ministry of Science and ICT also offer employment-related programs.

Compared to public school education, the programs offered to the general public often differ in the teaching content, depending on the main entity or the institution that is in charge, because continuing education for the general public is not a part of the regular curriculum.

35 Seoul Industry Promotion Agency, "2021년도 싹(SSAC) SW교육 파트너 모집 공고 (2021.08.23까지) 〉 SBA-서울산업진흥원," www.sba.seoul.kr, July 30, 2021, https://www.sba.seoul.kr/kr/sbcu01s1?bseq=5037846.

SWOT Analysis

STRENGTHS

- The country has the most advanced IT infrastructure and distribution rate in the world. South Korea's internet penetration rate per household has been number one in the world for many years. Korea was also the first country to commercialize 5G. According to a survey done by the Pew Research Center, Korea has the highest smartphone ownership in the world, at 94%; and
- Koreans also have IT utilization skills in daily life and a deep appreciation of education. South Korea is thus expected to quickly catch up with the AI education levels of other advanced AI countries when AI education is fully implemented.

WEAKNESSES

- Korea had a late start compared to other countries in regard to its AI agenda, which can be seen as the biggest weakness of AI education in Korea. Although AI technology is rapidly being adopted in all industries in Korea and the demand for experts such as AI developers is soaring, the supply is not keeping up with the demand;
- There is a labour shortage, for example of teachers who specialize in AI; and
- AI teaching materials, such as textbooks, are still needed to distribute in schools.

OPPORTUNITIES

- The Korean government has a strong interest in promoting and investing in the AI industry. In line with the policy direction of the government, the demand for AI specialists is expected to continue to rise;
- Investment in AI education is actively being made and Korean companies, aware of the government policies, are concentrating on R&D and commercializing the AI industry; and
- Government, industry and civil society have emphasized the need and importance of AI education. Recent domestic experiences with AI ethics issues have increased the public's awareness of AI technology and the technology's social and ethical impacts.

THREATS

- The current AI education in Korea focuses on teaching AI technology. Teaching AI ethics related to dysfunction and impact of AI is vital for proper AI development and safe use. Therefore, it is necessary to expand the AI ethics education courses and curriculum, which are currently only partially covered; and
- It is necessary to establish more systemic, comprehensive, mid- to long-term plans reflecting the national goals for AI education, unlike the current AI education policy being implemented by each education office.

CONCLUSION

The review of Canada's and South Korea's AI programs and curriculums demonstrates a divergence in the introduction of AI education for K-12 students in both countries, which reflects the different education systems and governance structures. Canada's education system is decentralized, and there is no national AI curriculum. Instead, enterprising schools and civil society organizations have filled that niche – such as the work done by Canada Learning Code or Kids Code Jeunesse. On the other hand, South Korea has a national ministry of education, and it has rolled out a concrete, multi-year plan to introduce a national curriculum. It is also supporting AI education by training additional teachers and creating teaching materials.

Since both approaches are in the early stages, it is premature to make an assessment of the two. However, a point researchers wish to highlight is the need for policy-makers, educators, experts, and other stakeholders to engage in consistent dialogue at the domestic and international level on the topic of AI education. This is not only to keep track of developments in AI curriculums at the K-12 level, but to also exchange best practices, successful programs, and potential pitfalls.

At the moment, both Canada and South Korea have world-class and robust talent pipelines in AI. In the last two years, Canada has scored in the top 10 in two global AI talent surveys conducted by the OECD and private companies.[36] Meanwhile, South Korea experienced a significant increase (133 percent) in AI researchers between 2019 and 2020 alone.[37] Canada and Korea have succeeded in their AI talent efforts in part due to heavy investment in higher education initiatives to foster and attract AI expertise. However, developing AI education for K-12 students has the potential of further sustaining and increasing domestic AI talent pools, complementing existing strengths in higher education.

36 Simon Hudson and Yoan Mantha, "Global AI Talent Report 2020," jfgagne.ai, 2020, https://jfgagne.ai/global-ai-talent-report-2020/#anchor-6; Government of Canada and CIFAR, "Canada's Leadership in AI – Talent, Ecosystems, and Responsible AI," oecd.ai, May 4, 2021, https://oecd.ai/en/wonk/canada-national-ai-strategy-2021.

37 Simon Hudson and Yoan Mantha, "Global AI Talent Report 2020," jfgagne.ai, 2020, https://jfgagne.ai/global-ai-talent-report-2020/#anchor-6.

As AI research and development continues and more AI applications become widespread around the globe, policy-makers in Ottawa and Seoul need to make concerted efforts to support the K-12 AI education resources currently available and aid in the development of new ones to future-proof domestic workforces for generations to come.

In addition to highlighting novel K-12 education in Canada and South Korea and kickstarting much-needed conversations and exchanges among international policy-makers, experts, and stakeholders, there are additional salient points that emerge from the overview of the two report's studies.

First, governments must make tangible investments in AI education for K-12 to provide equal opportunities for all students to acquire essential knowledge and skills. In both Canada and South Korea, the lack of resources and teachers capable of teaching AI has been highlighted as a major barrier. South Korea has rolled out a national plan to train the trainer, but there will be discrepancies in opportunities depending on the region. In Canada, the lack of a national strategy and the decentralized nature of the education system do not guarantee the delivery of high-quality AI education across the country. In this context, it is important for governments at the territorial and provincial level to make tangible investments – and a good place to begin would be teacher training and resources for AI education. However, at the federal level, the government still has an important role to play, mainly in supporting provincial and territorial AI education initiatives. It can also provide national-level guidelines as a starting point for subnational jurisdictions to strive for.

Second, private sector and civil society participation should be encouraged, but the government should ensure the quality and consistency of AI education. In Canada, the private sector and civil society have filled in for the government, providing much-needed support for AI education. On the other hand, the South Korean government and its local boards of education have been the drivers on this front with limited private sector or civil society input. The two models could balance each other better. The private sector provides more opportunities for experiential learning that is directly applicable for future employment, and civil society brings in valuable normative perspectives. Greater collaboration with the private sector to provide hands-on opportunities for students and curriculum development will be beneficial in South Korea. On the other hand, government-led initiatives on AI education, like those in South Korea, create greater ripple effects and stronger co-ordination between different stakeholders, which ultimately provides greater quality and consistency across the country. The main takeaway here is that anything on AI should be a multi-stakeholder effort, and education should reflect this as well.

Finally, AI ethics must be front and centre of the curriculum. It is important for AI curriculums to not focus solely on technical or skill-building aspects; this limits the target audience for AI education initiatives to students specializing in computing science. In the curriculums of both countries, AI ethics should be integrated into different fields in addition to math and computing science (English, social studies, etc.) to ensure that learning about technology occurs in a wider array of contexts and that students develop sufficient digital literacy to engage with AI-driven technology as they transition into adulthood.

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ABOUT

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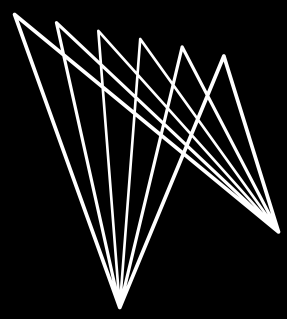
KOREA ARTIFICIAL INTELLIGENCE ETHICS ASSOCIATION (KAIEA)

The KAIEA has been established as a non-profit organization that supports and implements AI to be used safely and ethically for the world and humanity.

KAIEA is the only AI ethics-oriented organization in Korea and is actively engaged in research, development, education, and dissemination of AI ethics with co-operation of the government, corporations, universities, and citizens.

CHUNG-ANG UNIVERSITY'S HUMANITIES RESEARCH INSTITUTE

Chung-Ang University's Humanities Research Institute has been conducting the HK+ project since November 2017 to develop scholarship on "artificial intelligence humanities" with support from the National Research Foundation of Korea. The HK+ artificial intelligence humanities project aims to produce future-oriented, academic, and interdisciplinary research outcomes on the foundation of humanities-based reflections on rapidly changing artificial intelligence technology and industries.



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