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POLICY INSIGHTS

Evaluating international AI skills policy: A systematic review of AI skills policy in seven countries

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Abstract

As artificial intelligence (AI) is having an increasingly disruptive impact across industries, companies continue to report having difficulty when recruiting for AI roles, while new graduates find it difficult to find employment, indicating a skills gap or skills misalignment. International approaches to AI skills programmes can offer a guide to future policy development of a skilled workforce, best placed to harness the economic opportunities that AI may support. The authors performed a systematic literature review on AI skills in government policies and documents from seven countries: Australia, Canada, China, Singapore, Sweden, the United Kingom and the United States. We found a divide between countries which emphasised a broader, nationwide approach to upskill and educate all citizens at different levels, namely the United States and Singapore and those countries which emphasised a narrower focus on educating a smaller group of experts with advanced AI knowledge and skills, namely China, Sweden and Canada. We found that the former, broader approaches tended to correlate with higher AI readiness and index scores than the narrower, expert-driven approach. Our findings indicate that, to match world-leading AI readiness, future AI skills policy should follow these broad, nationwide approaches to upskill and educate all citizens at different levels of AI expertise.

1 | NAVIGATING THE UNCERTAINTY OF FUTURE AI SKILLS POLICY

With artificial intelligence (AI) having an increasingly disruptive impact on professional roles across a number of industries, from healthcare and transportation to journalism and the media, future economic growth and stability depends on the capacity to maintain a leading position in AI-enabled industries (Office for Artificial Intelligence [OAI], 2021). In response to a growing number of AI-specific job roles, governments from across the globe have invested in a number of initiatives, including supporting AI conversion courses, offering scholarships for underrepresented groups, and primary and secondary research on skills frameworks. Despite these efforts, AI roles continue to be hard to recruit for and new graduates often lack the skills required by employers to fulfil AI-specific job roles (Fenlon & Fitzgerald, 2019; Ras et al., 2017; Shmatko & Volkova, 2020). Beyond AI-specific job roles, projections about the future of work present a striking image of numerous roles and professions across sectors becoming impacted by AI (Royal Society, 2018), such that effective AI skills policy will also need to address users, managers and regulators of AI to balance the creation and uptake of AI. Navigating a shifting landscape, there is uncertainty regarding the strategic direction for AI skills policy and where concentrated efforts should be directed.

In response to these uncertainties, we performed a systematic literature review on AI skills government policies and reports from seven countries: Australia, Canada, China, Singapore, Sweden, the United Kingdom (UK) and the United States (US). We found that overall, there was an international emphasis

on tertiary education and academic research over school-level education and professional accreditation. Most countries saw professionals as the main stakeholder for AI skills uptake, closely followed by academia and industry leaders. All countries promote inclusivity programmes for AI skills based on gender, ethnicity and/or regional and rural communities. Though, we found a significant divide between countries which emphasised broader, national approaches to upskill and educate all citizens at different levels, namely the United States and Singapore, and those countries which emphasis a narrower focus on expertise or advanced AI knowledge, skills and world leadership, namely China, Sweden and Canada. We found that the former approaches tended to correlate with higher AI readiness and index scores than narrower, expert-driven approaches.

Our findings have significant implications for the future of AI skills policy. AI skills policymakers have an opportunity to learn from those countries which have successfully implemented skills policies leading to greater AI readiness among citizenry. In particular, our findings support the development of a broad, nationwide approach to AI skills education for all citizens, at different levels of AI and science, technology, engineering and mathematics (STEM) expertise.

2 | BACKGROUND

Though AI is expected to bring major societal and economic benefits, its development and deployment also raise major concerns about the concentration of power, inequality and discrimination (Ulnicane et al., 2021). In particular, there are concerns relating to the redesign and replacement of professional roles, unequal job distribution and economic disruption, as well as how these changes are expected to alter the relationships between citizens, governments and markets (Feijóo et al., 2020; Santana & Díaz-Fernández, 2022). One of the challenges of ongoing AI skills research is to try to understand how disruptive technologies will change particular professional roles and contribute to growing AI skills gaps (Ras et al., 2017).

Policymakers can play an effective role to facilitate uptake of AI across key economic sectors while mitigating harmful impacts of disruptive technologies, thus promoting benefits to society at large. In doing so, they should involve diverse stakeholders and create purposeful, cost-effective, evidence-based policies with iterative feedback, evaluation and renewal (Swanson & Bhadwal, 2009). Government reports provide evidence for policy evaluation, detailing objectives, expenditures and partnerships. This paper uses these reports as benchmarks, laying groundwork for future success research. However, commitment to a policy and fulfilment of that policy are two distinct processes. As such, we are laying the foundation for retrospective research into the success of AI skills policies in the future.

One key dimension along which AI policy is designed is the contrast between policy which is broad and inclusive and that which is narrow and exclusive. Ulnicane et al. (2021) note a paradigm shift from a traditionally narrow focus on economic competitiveness, growth, employment and national prestige towards a broader consideration of a range of actors in innovation process from civil society to industry leaders, academia and government; to 'focus on demand-side of technology in addition to supply-side' (p. 161). This seems pertinent given the potential wide-ranging impacts of AI on professions, industrial sectors, not to mention impacts on the environment and other social issues, such as mental health, that policymakers must balance.

Narrow approaches to AI policy include both state- and non-state-driven approaches. In an 'oligopoly', industry leaders are free to develop codes of conduct which are not binding but overseen, and are legally accountable only to themselves (Feijóo et al., 2020; Dignam, 2020; Ulnicane et al., 2021 p. 166). Narrow approaches to AI policy may also include pursuing the development of a small number of experts, from across industry, academia and other sectors. Here, universities are the 'engines to produce human capital' both in producing scientific and technological talent and in conducting cutting-edge research (Feijóo et al., 2020, p. 4).

Alternatively, broad approaches to AI policy emphasise the need to bring together developer and user-driven standards and share common visions (Ulnicane et al., 2021, p. 169). In particular, broad approaches open up and include voices to define the values and needs in solving AI problems, including the future of work and skills (Ulnicane et al., 2021 p. 170). The United Kingdom and the United States, for example, have both been noted as emphasising a need to increase diversity in AI (Ulnicane et al., 2021 p. 169).

Policymakers must decide who counts as relevant stakeholders to include in policy development. Government bodies alone are limited in their attempt to 'steer' a nation, since social systems are determined by all kinds of institutional, cultural, technological and other factors (Ulnicane et al., 2021 p. 160). To effectively engage society in shaping AI development and deployment, some policy documents suggest multi-stakeholder approaches (Ulnicane et al., 2021 p. 168). This blurring of boundaries and mutual dependency between state and non-state actors, or the public and private sectors, are key characteristics of 'hybrid governance' (Radu, 2021; Ulnicane et al., 2021, p. 160).

Policy analysis and evaluation are key instruments in implementing rationalised and simplified regulation (Adelle & Weiland, 2012). However, a gap remains in the analysis and evaluation of AI skills policy following its implementation. This gap exists, in part, due

to the modern nature of the policy problem, without the benefit of hindsight or decades of policy to analyse. Policy is also historically under-evaluated due to a number of constraints on research methodologies, resources and difficulties integrating academic research into governmental frames. Before any evaluation takes place, it can be difficult to define clear and relevant metrics by which policy ought to be compared and quantified. As a result, policy assessments are often highly focused on the economic, ignoring broader social and environmental aspects (Turnpenny et al., 2008). However, this gap also exists due to a lack of will, interest or buy-in from government actors to commit to the evaluation of policies after their implementation. Policy evaluation is expensive, and ministers and policymakers are often under pressure to expend resources on taking action to address issues rather than evaluating existing approaches (Winzar et al., 2023).

Academia can play a role in filling the gap left by a lack of policy evaluation, to perform a comparative analysis between policy frameworks by different competing national governments. The role of this paper is to, in part, fulfil this role. This paper takes a critical stance by comparing and contrasting the AI skills policies of a variety of governments, to better understand the effectiveness of national approaches. Comparing and contrasting approaches has the advantages of seeing diverse policy approaches in action, in different regions, cultures and contexts. Our analysis is the first to map out the AI skills policy landscape to understand where governments are placing emphasis and resources.

3 | METHODOLOGY

The authors conducted a systematic literature review of government reports, policies and frameworks. The literature encompassed official reports, policies and frameworks by national governments, affiliated institutions, such as government ministries or agencies, and affiliated authors, such as government-funded research groups. As discussed in the literature review and given the focus, the authors considered only government reports as primary sources since such documents can be used as benchmarks for government action. At the same time, including government affiliated institutions and authors widened the range from government strategy documents alone to include perspectives from industry and academia, ensuring a range of perspectives, expertise and detail were included. The sources were in either English or English translation.

Time and resource constraints limited the number of countries we could analyse in sufficient depth. After discussions with research funders, we settled on selecting seven countries for in-depth review. Given these constraints, we prioritised including a range of countries for analysis representing a diversity of regions, investment capacity and AI readiness.

We selected countries from the top 17 of the Government AI Readiness Index (GAIRI) (2022), as compared with rankings in the Global AI Index (GAI) (2022). Table 1 compiles the countries from the top 17 of the GAIRI (2022) along with respective GAI (2022) scores. This process allowed for the inclusion of countries with high AI investment and innovation, which nevertheless had low per capita talent; for example, China is ranked second in the GAI but 17th in the GAIRI. There was likewise a need to compare a variety of countries to differentiate government policy approaches and objectives in different regions and thereby uncover different strategic approaches to AI skills policy. Thus, we avoided including multiple countries similar in size and region, for example, Finland, Sweden and Norway. We also avoided selecting multiple countries of similar levels of investment capacity, such as France and the United Kingdom. To further differentiate strategic approaches at different levels of investment capacity, mid-level countries like Australia and Canada were included alongside top performers, like the United States and Singapore.

After reviewing the countries in Table 1 in accordance with our criteria, the seven countries we selected for analysis are: Australia, Canada, China, Singapore, Sweden, the United Kingdom and the United States.

3.1 | Search strategy

The authors included sources which referred to “AI”, “STEM”, “Computer Science”, “Data Science” or thematically equivalent. We looked for AI-specific government reports pertaining to “Competence”, “Skills”, “Skills Gap”, “Education” or thematically equivalent, or ‘National AI Strategy’ or thematically equivalent. Searches were conducted using a combination of OECD.AI (the policy observatory, which monitors national government policy by country, and therefore offers a rich repository of resources) and web search (pages 1–3, or further as needed) as sources for data retrieval. The inclusion of OECD.AI resources allowed for a comparative compilation of sources, specifically focused on policy at a national level. Based on our search criteria, 25 sources were identified and included in data synthesis. Our search strategy is compiled in Table 2, and a complete list of sources in Appendix.

3.2 | Data extraction

Data extraction and subsequent content analysis was achieved through manual coding. One researcher attributed a word or short phrase to assign a summative

TABLE 1 AI Index scores by country.

Country	Government AI Readiness Index (2022)	Global AI Index (2022) Overall	Global AI Index (2022) Detailed
US	1st	1st	1st in Talent, Research, Development, and Commercialisation
Singapore	2nd	6th	4th in Research and 5th in Commercialisation
UK	3rd	3rd	3rd in Talent
Finland	4th	13th	8th in Government Strategy
Canada	5th	4th	1st in Government Strategy
Republic of Korea	6th	7th	3rd in Development
France	7th	10th	5th in Government Strategy
Australia	8th	11th	4th in Development
Japan	9th	16th	5th in Development, 7th in Infrastructure
Netherlands	10th	8th	6th in Talent, 8th in Development
Denmark	11th	14th	13th in Talent and Research
Norway	12th	25th	16th in Infrastructure
Sweden	13th	19th	10th in Talent
Taiwan	14th	24th	12th in Infrastructure, 14th in Research
Germany	15th	9th	6th in Research
Austria	16th	22nd	18th in Research, 19th in Government Strategy
China	17th	2nd	1st in Infrastructure and 2nd in Research, Development, Government Strategy and Commercialisation

TABLE 2 Search strategy.

Sources considered	Type:	Official government reports; policies; frameworks
	Language:	English or English translation
	Issuer:	Governments, or affiliated institutions (e.g., ministries, agencies), or affiliated authors (e.g., government funded university faculty staff)
	Country:	Australia, China, Sweden, Singapore, U.S.A, UK, Canada,
Sources included	Which refer to:	"AI", "STEM", "Computer Science", "Data Science", or thematically equivalent; AND
	Which refer to:	"Competence", "Skills", "Skills Gap", "Education", or thematically equivalent; OR
	Which refer to:	"National AI Strategy", or thematically equivalent
Retrieval		OECD.AI by country; AND
		Web search (pages 1–3, or further as needed)

attribute for a portion of the raw text pertaining to some element of AI skills (Saldaña, 2013). Raw coded data were cleaned on Open Refine. A total of 3083 codes were attributed across the 22 sources, with 473 unique codes. Formal coding was reviewed at each stage by the entire research team in an effort to reduce subjective bias.

Because manual data extraction of textual data can be tedious and difficult at scale, some turn to natural language processing (NLP) to automate parts of the coding process and support analysis of textual data. Successful applications of NLP tools enable researchers to explore massive datasets at a greater depth (Crowston et al., 2011). However, there are several drawbacks to NLP including the additional time-consuming steps of data preparation and rule development, and the loss of reliability in sparse data (Crowston et al., 2011). In cases where the dataset is very large and would take an unrealistic time for manual coding, NLP's benefits can outweigh these costs. Whereas in the case of our study, in which documentation of AI skills policy is minimal, we found manual coding to not only suffice but also be particularly useful in uncovering cases of ambiguity, conflict and lack of engagement, which contributed significantly to our key research findings.

3.3 | Content analysis

After the data were manually coded, we analysed this data in search of common themes, correlations and trends within the international AI skills policy landscape. Our analysis is informed by how common a theme is across the AI landscape, based on the number of appearances across our sources. However, we took

into account that themes identified numerically may not necessarily indicate actual weight or significance equally across countries. For instance, if a singular program has more investment than multiple smaller programs, our analysis may bias the smaller programs by weighting their appearance in reports as more frequent. 'Mentions', in this manner, are not necessarily an indicator of significance, but do indicate a form of prioritisation. We therefore examined commonalities across countries by taking these considerations into account to arrive at the six AI skills themes presented below: AI Skills Landscape; Skills; Stakeholders; Talent Pipelines; Evaluation; and Intervention Methods.

The main author then qualitatively analysed the sources across major themes identified in our coding analysis in the second pass (Saldaña, 2013). Coding was then reviewed by the entire research team, in an effort to reduce subjective bias. The coding also only forms part of our analysis, with qualitative insights and the literature review driving evaluation of our quantitative analysis and providing further insights.

Our analysis was limited to English or English translations, which has some impact on countries where English is not the national language (Sweden, China). However, at least in the case of Sweden, the national governments routinely publish their reports in English. In terms of China, our analysis may be hampered by translation limitations and/or the limited amounts of material available. We have relied on OECD reporting and a few translated reports that do align with our other sources. However, due to resource constraints, the inclusion of non-English reports is outside of the scope of this paper and requires further investigation in future research.

4 | FINDINGS

4.1 | AI skills landscape

Every country we scrutinised recognised the presence of a skills gap and the transformative impact of AI technologies on an evolving job market. However, the majority of these deliberations remain at a high level, lacking comprehensive scrutiny into the intricate dynamics of each nation's shifting job landscape and skill requirements. Our analysis also uncovered disparities between countries which strategically position these changes as opportunities to leverage distinctive advantages in global leadership, and others which place comparatively less emphasis on this.

Of the international coding instances referencing the current AI skills landscape, 48% (221/457) describe gaps or challenges, of which 44% (97/221) reference skills gaps specifically, and 44% (203/457) reference changing job markets. Countries often articulate the disruptive influence of AI across diverse industries, emphasising the requisite competencies essential for harnessing its potential. For instance, Australia suggests, 'The new AI workforce is needed to meet the operational requirements of industry. Already supply is failing to meet demand' (Hajkowicz et al., 2019, p. 47). While China is 'mindful of the systemic and long-term transformation of the labour market… due to AI adoption' (UNESCO and Ministry of Education of the People's Republic of China [MoE], 2019, p. 6).

This discourse around skills gaps tend to represent high-level concepts that communicate the need for strategic planning, but are not often accompanied by detailed explanations of specific gaps or changes. This could be attributed to certain countries relying on pre-existing, externally sourced and globally derived evidence of the AI skills gap, rather than conducting exhaustive reviews specific to individual nations. For instance, Technation's report draws upon insights gleaned from surveys conducted by Deloitte and McKinsey & Company across various countries. This usage enables the report to introduce overarching concepts like 'AI skill gaps', 'AI adoption' and 'AI power users', while bypassing extensive analysis (Ticoll, 2020, pp. 8–9). Whereas Singapore offers extensive documents dedicated to providing 'evidence-based, systematic' and detailed considerations of AI-driven transformations of job families. These include *A Guide to Job Redesign in the Age of AI* (Infocomm Media Development Authority Singapore [IMDAS], 2020) and *Skills Demand for the Future Economy* (Skills Future Singapore [SFS], 2022).

We also noted a difference between countries which consider the AI skills gap as a challenge to overcome, and others which see an opportunity for global leadership. Twenty-five per cent (9/36) of China's and 20% (20/100) of Sweden's current AI skills landscape coding instances specifically reference global leadership or advantage. Internationally, this discussion makes up only 7% (32/457). Some countries explicitly recognise their disadvantages compared to other nations in terms of AI readiness. For example, 'Canada lags global leaders in AI adoption' (Ticoll, 2020, p.7). Whereas China pursues 'world-class universities and world-class curricula' (MoE, 2019, p. 7), 'world-leading AI technology innovation and personnel training centres' and 'world-leading' AI industry (The State Council for the People's Republic of China [SCPRC], 2017, pp, 6–7). Across academic, industry and education domains, China aims to 'lead the world in new trends in the development of AI' (SCPRC, 2017, p. 4). While Sweden aims to develop 'innovative strength and international attractiveness for leading AI competence and corporate AI development' (Vinnova, 2018, p. 12). The *Nordic AI and Data Ecosystem 2022* states, 'Our vision is for the Nordics to become a leading region in digitisation, ethical AI and responsible use of data by 2030', emphasising 'leaders[hip] in ethics and equality' (Nordic Innovation, 2022 pp. 4, 162). Sweden, in particular, is

described as a leader among the Nordic countries in terms of the number of start-ups and start-up unicorns (privately held start-ups worth $1 billion), talent and investments (Nordic Innovation, 2022).

Overall, all of the countries we reviewed acknowledge the existence of a skills gap and a changing job market. Both concepts seem to be used to communicate to broad audiences the need for strategic planning, with relatively little details on specifics. Focusing solely on high-level concepts may limit governments from identifying root causes and implementing effective AI skills policies. We also found that emphasising leadership is another way that some governments are communicating the need for strategic planning, though governments differ in which aspect of the AI skills landscape they expect to dominate.

4.2 | Skills

We found a lack of consensus within AI skills policy regarding the specific skills that should be prioritised for nurturing a dominant role in AI-powered industries. Countries often focus on different skills and terminology, some prioritising advanced or expert level AI skills while others concentrate on developing a more broadly STEM educated citizenry with transferable professional skills and flexibility beyond AI-specific applications.

International discussion of the future of skills focuses mostly on developing AI skills, as opposed to broader STEM skills or general professional skills and expertise. AI-specific skills comprise 46% (157/345) of the international skills coding instance, considered separate to broader STEM skills which make up 31% (106/345), and professional skills and experience which make up 23% (81/345). Internationally, emphasis is most often on educating and developing advanced AI skills rather than basic AI skills or a broadly AI-skilled population. Advanced AI skills make up 22% (35/157) of AI-specific skills coding instances, whereas basic AI skills make up only 3% (5/157). International discussions also tend to refer to AI skills broadly, as opposed to referencing any particular skills. 'AI literacy', 'job-relevant AI skills', 'AI-ready', 'AI knowledge' and 'AI competency' are some examples of broad language we found across our sources (Ministry of Enterprise and Innovation [MEI], 2018; Smart Nation Singapore [SNS], 2019; Ticoll, 2020; UNESCO and MoE, 2019).

Some specific AI skills noted by Singapore and Canada include developing algorithms, machine learning and predictive modelling (Hamoni et al., 2021; SFS, 2022; Ticoll, 2020). Where STEM skills are discussed, technical skills tend to be the subject of focus, particularly data skills (Nordic Innovation, 2022; SNS, 2019; Ticoll, 2020). Technical skills make up 46% (49/106) of international STEM skills coding instances, 55% (27/49) of which are data skills.

In contrast to international trends, the United States prioritises a more broadly STEM literate public, with STEM skills making up 69% (46/67) of the US skills coding instances. A broadly STEM-skilled public is described as essential to ensure the United States keeps up with technological changes. 'A STEM-literate public will be better equipped to handle rapid technological change and will be better prepared to participate in civil society' (Committee on STEM Education of the National Science and Technology Council [CENSTC], 2018, p. v). A broadly STEM-skilled population is also seen as essential to ensuring a 'diverse workforce', which is 'needed for the United States to lead and prosper in an increasingly competitive world driven by advanced technology' (CENSTC, 2018, p. 1). Of particular focus is general STEM literacy (33% or 15/46 of the STEM skills coding instances), computational thinking (28% or 13/46) and digital literacy (17% or 8/46). There is minimal discussion of AI-specific skills, at only 6% (4/67) of the US skills coding instances.

Also in contrast to the international trends, Singapore discusses skills more broadly than AI-specific applications, emphasising flexibility, professional skills and experience. Singapore recognises that 'there is an increasing demand for soft skills to support enterprise transformation' (SFS, 2022, p. 97). 'Critical core skills' are defined as those professional skills which are essential for supporting business transformation, while 'priority skills' are those which are highly transferable across multiple job roles (SFS, 2022). Forty-three per cent (24/56) of Singapore's skills coding instances reference these professional skills and experience, whereas AI-specific skills make up only 35% (19/54) and STEM skills 23% (13/56).

Overall, international discussion of the future of skills tends to be vague and exhibits little agreement in terms of which skills ought to be prioritised and developed. Discussion mostly focuses on developing AI skills, as opposed to STEM skills or professional skills and experience. AI skills are discussed mostly in broad terms, such as the need to develop AI-literacy or AI-competency among the population, as opposed to clear and specific guidance on which skills are in demand and which need to be developed. That being said, advanced AI skills are emphasised over broad or basic AI knowledge across the population. Whereas some countries, particularly the United States and Singapore, prioritise transferable professional skills and a broadly STEM literate public over AI-specific applications.

4.3 | Stakeholders

Another area of conflict we found across international AI skills policy is determining 'who counts' as key stakeholders and setting of future AI skills development. Though all countries tend to focus on

professional stakeholders, some focus on leaders and experts while others focus on the broader workforce. Internationally, countries also tend to focus on academic settings as key areas of AI skills development. However, there is again conflict between those which focus on elementary education, such as PreK–12 settings, and others which focus on universities and research institutions.

There is a strong focus internationally on professional stakeholders. The stakeholder of greatest focus is the workforce, making up 19% (67/344) of international stakeholder coding instances and vastly outweighing other stakeholder groups. Canada in particular prioritises experts (21% or 21/101 of the Canadian stakeholder coding instances)—particularly domain experts (57% or 12/21 of the expert coding instances) and industry experts (33% or 7/21)—and various organisational or political leaders (23% or 13/101). Canada describes the ideal AI team as consisting of domain experts with PhDs, business experts with MBAs and AI experts with undergraduate or master's degrees (Hamoni et al., 2021, p. 25). In these teams, 'each expert plays a specific role in product development throughout the product development cycle' (Hamoni et al., 2021, p. 26). Whereas Singapore is mostly concerned with upskilling its broader workforce which make up 40% (19/47) of the Singaporean stakeholder coding instances. SFS (2019, p. 29) states that 'organisations need to reimagine how they work, reinvent their business models, and reskill their workforce to remain relevant'.

In contrast, the United States emphasises an inclusive approach to general STEM skills and AI literacy. For the United States, the stakeholders of greatest concern are general populations and local communities which are divided into various demographic categories: including, 'geography, race, gender, ethnicity, socioeconomic status, veteran status, parental education attainment, disability status, learning challenges, and other social identities' (CENSTC, 2018, p. 6). Communities account for a relatively high proportion (17% or 12/70) of the US stakeholder coding instances, compared to international trends (4% or 15/344 of international stakeholder coding instances). CENSTC's report 'represents an urgent call to action for a nationwide collaboration with learners, families, educators, communities, and employers' (2018, p. v). In that context, it is expected that 'STEM ecosystems engage educators and individuals within and outside a formal educational setting' (CENSTC, 2018, p. 10).

Beyond stakeholders, international AI skills policy tends to focus mostly on academic settings—particularly tertiary education and research settings. Academic settings make up 66% (129/195) of international setting coding instances, whereas professional settings comprise only 28% (54/195). Canada (FSC, 2020; Ticoll, 2020) and the United States (CENSTC, 2018) focus on elementary education settings such as schools. In the United States, 75% (18/24) of the setting coding instances reference academic settings, of which 50% specify schools. Canada also focuses on academic settings, at 59% (or 10/17) of the Canadian setting coding instances, again of which 50% specify schools.

Whereas China is heavily focused on tertiary education and high-level research (MoE, 2019). Universities and colleges comprise 37% (32/86) and 28% (24/86) of the China setting coding instances, respectively, whereas only 5% (4/86) reference pre-kindergarten to Year 12. China also focuses mostly on academic stakeholders over the broader workforce, in contrast to international trends (MoE, 2019; UNESCO and MoE, 2019). While 35% (11/32) of the China stakeholder coding instances reference academics, only 6% (2/32) reference the workforce. China's *AI Innovation Plan* states that 'By 2030, colleges and universities will become the main force behind building the world's main AI innovation centres and will lead the development of a new generation AI talent pool' (MoE, 2019, p. 4).

Overall, there are two main trends in terms of which stakeholders and settings are prioritised in international AI skills policy. Whereas Canada and China are particularly interested in developing teams of experts, the United States seeks to include a broader network of communities, families and other citizens into the development of an AI ecosystem, and Singapore focuses on the broader workforce. Moreover, some countries, in particular China, see universities as the centre for development of high-end AI talent and innovation. Whereas the United States and Canada focus mostly on elementary education.

4.4 | Talent pipelines

Internationally, we found two main approaches to developing and maintaining adequate AI talent pipelines to fulfil job requirements and maintain a leading position in future AI-driven economies. Most countries tend to focus on attracting international talent and fostering international exchanges and profiles, which together comprise 38% (14/37) of international talent pipelines coding instances. Whereas other countries, most prominently the United States, focus on nurturing and retaining local talent to fulfil future skills requirements.

China and the United Kingdom, in particular, see international top talent and expertise as key to closing the AI skills gap. China, for instance, aims to 'increase efforts to promote academic exchange and collaboration at the international level', including by 'bring[ing] in famous international scholars more often to participate in academic discipline development and scientific research' (MoE, 2019, p. 6). One of the key tasks of China's *National New Generation AI Plan* is to 'make the construction of a high-end talent team of

the utmost importance in the development of AI" and 'especially accelerate the introduction of the world's top talent and young talent, forming China's AI top talent base' (SCPRC, 2017, p. 14). Clearly, then, China places great 'focus on the introduction of international top scientists and high-level innovation teams' (SCPRC, 2017, p. 14). The United Kingdom similarly emphasises the need to 'attract the brightest and best people at developing AI' as well as to 'attract, recruit, and retain a substantial cohort of leading researchers and innovators' (OAI, 2021, pp. 24–5). By contrast, the United States has substantial discussion of local recruitment and prioritising its own citizens in its AI talent pipelines (CENSTC, 2018, p. 16). In particular, the United States reinforces an 'American workforce', and will 'give preference to American citizens, to the extent permitted by law' (US Government, 2019, p. 3971).

4.5 | Intervention methods

With the inconsistencies among the sources we have examined and the lack of thorough investigation of skills gaps, we observed a wide array of potential policy measures to address these gaps. These range from detailed, task-oriented job redesign to expansive collaborations spanning multiple sectors, again, oftentimes discussed in overarching terms.

Internationally, there is a focus on practical skills and on work-based methods for closing the skills gap and adapting to the changing job market. Practical methods of focus include skilling (11% or 137/1204 of the total intervention methods coding instances)—specifically upskilling (67% or 92/137)—training (11% or 134/1204), job redesign (6% or 71/1204) and practical experience (4% or 52/1204). Given its focus on the broader work force and changing job market, it is unsurprising that Singapore, in particular, champions task-based job redesign and upskilling the workforce (IMDAS, 2020, p. 5). This job redesign should be centred around the employees who will be most affected and guided by their needs: 'employees can provide insight into how well a proposed AI solution fits the tasks they perform' (IMDAS, 2020, p. 24). Singapore expects a willingness to upskill across sectors, as 'an open mindset to accept new skilling, upskilling and cross-skilling, helps organisations to brace for their digital transformation endeavours' (Skills Future Singapore (SFS), 2022, p. 29). The UK government also proposes several methods for upskilling and reskilling professionals across career stages (Office for Artificial Intelligence (OAI), 2021; HM Treasury, 2021). These include new apprenticeships, technical based qualifications (T-levels) and work experience placements (HM Treasury, 2021). While professionals will be able to access business-focused modular training with fast-tracked interviews to improve job prospects, as well as free basic digital skills training free (DBEIS, 2017; Department for Education [DfE], 2022; HM Treasury, 2021; OAI, 2021).

Most countries prioritise such training and shorter courses over formal education. Training—in particular, workplace training and short training programmes—makes up 11% (134/1204 of intervention methods coding instances), while formal education makes up only 3% (or 38/1204). In contrast to international trends, both the United Kingdom and China emphasise formal education as a key intervention method. The UK Government aims to develop world-leading computing education for every child (National Centre for Computing Education [NCCE], nd; OAI, 2021). Beyond school-aged children, the United Kingdom focuses on tertiary education due to its 'significant role' in bringing benefits for the UK economy (DBEIS, 2017, p. 100). While China promotes the development of an AI-specific discipline and the digitalisation of education in order to close the AI skills gap (MoE, 2019, p. 7–8; SCPRC, 2017, p. 14). China sees education as key to strengthening their AI talent pipelines and thereby providing pools of world-class talent: 'Improve the AI education system, strengthen the construction of a talent pool and echelons, especially accelerate the introduction of the world's top talent and young talent, forming China's AI top talent base' (SCPRC, 2017, p. 14).

Other methods discussed to close the AI skills gap include providing resources, funding and fostering cross-sector partnerships. Sweden, in particular, discusses fostering partnerships in depth as a key method to close the skills gap (Heintz et al., 2021; Vinnova, 2018). 23% (71/308) of Sweden's intervention methods coding instances reference partnership, whereas internationally, partnerships make up only 14% (169/1204) of this discussion. One of the five recommendations from the *Nordic AI and Data Ecosystem Report* is that 'the Nordic countries should share best practices, use-cases, and knowledge with each other' (Nordic Innovation, 2022, p. 7). This also includes partnerships within Sweden, as 'collaboration among companies, public operations, research institutes, universities and university colleges will be crucial in realising Sweden's AI potential' (Vinnova, 2018, p. 11).

Australia, Canada, China and Sweden also discuss the need to develop and supply resources as methods to close the AI skills gap. This discussion tends to be broad and at a high level. Australia (Hajkowicz et al., 2019) and Sweden (Nordic Innovation, 2022; Vinnova, 2018) focus on online or digital resources, particularly datasets which may be needed to support training and practice with AI model development. While Canada focuses on providing labour market information (FSC, 2020).

Overall, there were some commonalities around a focus on practical skills and on work-based methods for closing the skills gap. Although this is not universal,

as the United Kingdom and China emphasise formal education as key to developing talent pipelines. Other suggested intervention methods include partnerships, developing and distributing resources, and providing funding, though these methods tend to be discussed at high levels and in broad terms. Given the disparity across the sources we have reviewed, and the lack of specifics and detailed interrogation, it is unsurprising to see such a broad range of possible policy interventions to close the skills gap. Not to mention the complexities surrounding how countries will need to engage at different levels and across different areas of focus, there is clearly a requirement to empirically investigate intervention methods further.

4.6 | Evaluation

Evaluation was a common theme from our content analysis, but the discussion and elaboration of evaluation topics was limited within the policy reports. Discussions of evaluations mostly centred on the need to develop appropriate metrics for future evaluations. Metrics make up 45% (54/120) of international evaluation coding instances.

Metrics that were mentioned most include human-centric (26% or 14/54 of international metrics coding instances), employee-centric (35% or 19/54), participation rates (15% or 8/54) and trust (9% or 5/54), with a lesser emphasis on AI readiness (4% or 2/54). China in particular champions human-centric metrics for evaluation (SCPRC, 2017; UNESCO and MoE, 2019), while Singapore advocates for employee-centric metrics (IMDAS, 2020). In particular, 'an uncompromising priority is the building of trust with employees through understanding and anticipating their concerns about AI's impact on their work and helping them evolve', and thus 'employers should strive to ensure that employees would benefit from the new job role' (IMDAS, 2020, p. 4, 27). In contrast, Australia mostly discusses evaluation in terms of AI readiness and enablement (Hajkowicz et al., 2019, pp. 19–20), and the United States is mostly concerned with the participation rates of various demographic groups (CENSTC, 2018, p. 30–33). While Canada mostly focuses on using evidence from evaluations to replicate 'best practice' and draws lessons learned from others (FSC, 2020, pp. 11, 14, 21, 34).

Overall, the discussion and elaboration of evaluation topics was limited within the policy reports. This is perhaps because AI skills policy is still in the process of development, with countries evidently still in conflict over which metrics are most appropriate by which to measure the success of policy approaches. It seems clear that, based on the broad and vague concepts used, and the lack of evidence developed across the themes we have discussed, many countries have not yet described their skills gaps or policy programmes in adequate detail so as to understand what needs to be evaluated, by whom and how.

5 | DISCUSSION

It is clear from our analysis that many key concepts relating to the growing AI skills gap and disrupted job market remain the object of debate and ambiguity in AI policy. One such division is between countries which prioritise world-leading AI expertise and cutting-edge academia, and those which consider broader populations and transferable skills.

In our review, we found that China prioritises advanced AI skills, tertiary education and advanced research, with significant discussion of global leadership. Similarly, Canada prioritises experts and leaders and advanced AI skills over a broader STEM-educated or basic AI-skilled public. As with China, Sweden includes substantial discussion of world leadership. Whereas the United States strongly promotes an inclusive, diverse, nationwide STEM education ecosystem, made up of local talent and a range of community-based stakeholders. The United States is also broad in focus considering the whole talent pipeline, from pre-K to professionals. We found that Singapore also takes a broad view in prioritising skill and task-based, employee-centric methods for the entire workforce.

This found division accords with Ulnicane et al.'s (2021) distinction between traditional narrow focuses on economic competitiveness, growth, employment and national prestige versus broader consideration of a range of actors in the innovation process. Where universities are seen as 'engines to produce human capital', both by training new talent and by conducting cutting-edge research, such governments are less interested in producing the largest number of individuals with postgraduate education, rather focusing on improving the quality of student education and training as key arenas for AI competition (Feijóo et al., 2020). China, in particular, is noted as showing a strong focus on solving specialised, cutting-edge problems through research as opposed to concerns about the societal implications of AI (Feijóo et al., 2020). However, where leading private-sector AI developers give control to a small group of insiders with tight connections and similar backgrounds and interests, governance in these leading AI companies is unusually autocratic and lacking in accountability (Dignam, 2020). In such a case, a small and unrepresentative group of individuals wield disproportionate power over the shape and future of technology, and thereby broader governance (Dignam, 2020). The potential consequences of unequal job distribution and economic disruption would in turn reshape the relationships between citizens, governments and markets with far-reaching implications for countries

(Feijóo et al., 2020). In particular, within the case of the AI skills gap, there is a risk of economic or other wars breaking out due to the fierce and increasing competition of skilled workers (Feijóo et al., 2020).

The limitations of those countries which prioritise the advanced skills and expertise of a small number in terms of AI readiness perhaps foreshadow some of the far-reaching implications noted in policy analysis, wherein the broader population is excluded from the shape and governance of future technology, to a nation's own detriment. In particular, we find there to be a correlation between higher AI readiness/index scores and broader, nationwide approaches to upskill and educate all citizens at different levels, as opposed to a narrower focus on expertise or advanced AI knowledge and skills, and world leadership, which correlate with lower AI readiness scores.

Given the focus on universities, research and world-leading education, it is unsurprising to note that China scores second in Research and Development in the GAI 2022. However, China also scores 17th in AI readiness. Sweden, which placed a similar emphasis on world leadership as China, also placed lower, at 13th and 19th in the 2022 GAIRI and GAI, respectively. Canada, which focuses on expertise in AI teams, placed fifth and fourth in the 2022 GAIRI and GAI, respectively. China, Sweden and Canada, which emphasises world leadership, cutting-edge research and expertise, scored lower of the countries we reviewed in this work. Whereas the United States tops both GAIRI and GAI of 2022, and Singapore places second in our table, scoring second in GAIRI and sixth in GAI of 2022.

This analysis of our findings should not be interpreted as carving out clear distinctions between nations' AI skill successes, as many key concepts in AI skills policy remain the subject of dispute. Nevertheless, one interpretation of these results is that broader, nationwide approaches to upskill and educate all citizens at different levels tends to correlate with higher AI readiness/index scores than a narrower focus on expertise or advanced AI knowledge and skills, and world leadership. Those countries with lower AI readiness scores take a narrow approach, wherein a small number of highly educated elites are able to harness and define the future of AI technologies, to the exclusion of the broader populations. Broader engagement and inclusion are prescribed in some policy documents to avoid narrow concentrations of power, increases in inequality, lack of diversity and biases (Ulnicane et al., 2021 p. 170). In the case of AI skills, including a broader range of stakeholders, such as schools, the workforce and local communities, into policy considerations could ensure that a nation is agile and equipped to keep up with continually changing job markets and skill requirements.

Our findings uncovered the limited discussion and elaboration of broad and vague concepts, and the lack of evidence developed across the themes we have discussed. With this, it is clear that many countries have not yet examined the current AI skills landscape in adequate detail so as to understand the requirements, best policy approaches and evaluation metrics to ensure AI technology is harnessed responsibly and sustainably. Future development of AI skills policy requires critical reflective approaches to AI education, considering in sufficient depth the broader skills sets currently being envisioned by governments, who discuss AI skills and literacy broadly, as opposed to examining in sufficient depth the changing job markets and specific skills required.

6 | CONCLUSION

Evidence suggests that AI skills talent pipelines have not kept up with the rapid increase in implementation of disruptive technology across industries, and employers are struggling to find adequately AI-skilled workers to fill new job demands. This study aimed to understand how governments from across the world are discussing the AI skills landscape and mitigating this growing AI skills gap.

We performed a systematic literature review of seven countries, examining discussions and approaches to mitigate the AI skills gap. We uncovered a range of themes and approaches which affirm a distinction between narrow and broad policy approaches. We observed that countries like the United States and Singapore adopt broader, nationwide approaches that prioritise inclusive, diverse and comprehensive STEM education ecosystems involving various stakeholders. Whereas other countries including China, Canada and Sweden tend to focus on narrower expertise and advanced AI skills, often with a strong emphasis on world leadership and research. Our analysis suggests that broader, inclusive approaches correlate with higher AI readiness scores. Countries like the United States and Singapore, prioritising diversity and engagement, rank higher in AI readiness compared to those focusing mainly on expertise and world leadership.

Further exploration of these trends within policy discussions and approaches to close the AI skills gap would benefit from sourcing both primary and secondary sources from a greater variety of countries. A broader corpus, targeted on more recent 2023 and 2024 publications, could also test if public and government interest in AI education and concern for a growing AI skills gap has accelerated with the media hype.

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CONFLICT OF INTEREST STATEMENT

We have no conflicts of interest to disclose.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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APPENDIX

Title	Issuer	Country	Type	Issuer Type	Retrieval	Date (Year)
Executive Order on Maintaining American Leadership in AI: National AI Strategy	United States Government	United States	Executive Order	Government	OECD.AI	2019
Charting a Course for Success: America's Strategy for STEM Education	Committee on STEM Education of the National Science and Technology Council	United States	Strategy	Government Committee	OECD.AI	2018
Artificial Intelligence Training for the Acquisition Workforce Act	U.S Government; Office of Management and Budget; General Services Administration	United States	Policy	Government	OECD.AI	2022
National Approach to Artificial Intelligence	Ministry of Enterprise and Innovation, Government Offices of Sweden	Sweden	Framework	Government Ministry	OECD.AI	2018
AI Competence for Sweden – A National Life-Long Learning Initiative	F. Heintz et al. (2021)	Sweden	Report	Government-funded university staff	OECD.AI	2021
The Nordic AI and data ecosystem 2022	Nordic Innovation	Sweden (includes Denmark; Finland; Iceland; Norway)	Report	Intergovernmental forum	Web Search	2022
Artificial intelligence in Swedish business and society: Analysis of development and potential	Vinnova	Sweden	Report	Government Agency	Web Search	2018
National AI Strategy	Smart Nation Singapore and Digital Government Office; National AI Office	Singapore	Strategy	Government offices	OECD.AI	2019
Skills Demand for the Future Economy	Skills Future Singapore (SFS)	Singapore	Framework	Government Agency	Web Search	2022
A Guide to Job Redesign in the Age of AI	Infocomm Media Development Authority	Singapore	Framework	Government Authority and Commission	OECD.AI	2020
Australia's AI Action Plan	Department of Industry, Science, Energy and Resources	Australia	Report	Government Department	Web Search	2021
Artificial Intelligence and Emerging Technologies in Schools	Department of Education	Australia	Report	Government Department	Web Search	2019
State of Australia's Skills 2021: now and into the future	National Skills Commission	Australia	Report	Government Agency	Web Search	2021
The Impact of AI on the Future of Worker and Workers	Australian Institute of Machine Learning	Australia	Report	University	Web Search	2021
Artificial Intelligence: Solving problems, growing the economy and improving our quality of life	CSIRO	Australia	Report	Government Agency	Web Search	2019

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APPENDIX (Continued)

Title	Issuer	Country	Type	Issuer Type	Retrieval	Date (Year)
National New Generation AI Plan	The State Council for the People's Republic of China	China	Strategy	Government	OECD.AI	2017
Artificial Intelligence Innovation Action Plan for Institutes of Higher Education	Ministry of Education	China	Strategy	Government Ministry	OECD.AI	2019
Beijing Consensus on AI and Education	UNESCO; Ministry of Education of the People's Republic of China	China	Strategy	Government Ministry and Intragovernmental Body	OECD.AI	2019
Building Canada's Future AI Workforce	The Information and Communications Technology Council	Canada	Report	Government Council	Web Search	2021
Skilling Canadians for Leadership in the AI Economy	Technation	Canada	Report	Industry-Government Partnership	Web Search	2020
Canada – A Learning Nation: A skilled, agile workforce ready to shape the future	Future Skills Council; Employment and Social Development Canada	Canada	Report	Government Council	Web Search	2020
National AI Strategy	Office for Artificial Intelligence (OAI)	UK	Strategy	Government Office	OECD.AI	2021
Industrial Strategy	Department for Business, Energy & Industrial Strategy (DBEIS)	UK	White Paper	Government	OECD.AI	2017
Build Back Better: our plan for growth	HM Treasury	UK	Strategy	Government	Web Search	2021