Undergraduate University AI Education: A Survey

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Abstract

Artificial Intelligence (AI) has become a pivotal technology of the 21st century, prompting the rapid development of undergraduate and postgraduate AI education programs worldwide. This paper presents a comprehensive survey of these programs, spanning the historical evolution of undergraduate AI education and revealing global trends. Undergraduate AI education equips the future workforce with fundamental AI knowledge to harness its potential across diverse sectors. Therefore, many countries paid due attention to University AI education. Overall, Global North countries fare very well in University AI education. China has emerged as a prominent leader in AI education, driven by its strategic national plan. A comparative analysis of renowned Universities showcases the structure of AI curricula, emphasizing the need to balance theory and application. Overall, this paper is a valuable resource for stakeholders interested in the evolving landscape of University AI education.

Keywords: Artificial Intelligence, Education, Taxonomy, University Education

1 Introduction

Humans must understand the world we live in, in order to meaningfully interact with it. To this end, they should analyze huge amounts of data each day at individual, corporate, institutional or societal level. Artificial Intelligence

(AI) is a fundamental science and technology addressing the increased complexity of both our physical environment and the societal processes [1]. As this complexity ever increases, so do the data analysis needs of humanity. Complexity increase is an unstoppable process pertaining all social functions and human constructs, physical or mental ones. Humanity can cope with this trend thanks to AI, data analysis, and, more generally, to Information Technology (IT). Therefore, the demand for AI and IT education will only increase.

Recently, AI emerged as one of the defining technologies of the 21st century, impacting a range of applications from chat-bots and advanced medical diagnosis, to self-driving cars. It is increasingly recognized as a pivotal technology across various industries, leading to a growing demand for AI specialists. Consequently, the role of AI education within undergraduate programs has progressed to the point it becomes a distinct scientific discipline.

In University education, the importance of imparting AI knowledge has been widely acknowledged. Research on various aspects of AI education, including teaching methodologies and curriculum development, has been conducted by scholars and institutions [2], [3], [4], [5]. As can be seen in Figure 1, in 2021, the number of Computer Science (CS) bachelor graduates in North America reached 33,059, which is nearly four times the number recorded in 2012. This substantial rise in the number of CS graduates reflects, among other factors, the increasing interest and enthusiasm for AI-related education at the undergraduate level. Therefore, it can serve as an indirect indicator of a growing interest in AI university education.[6].

Furthermore, the robust job market for AI professionals boosted a substantial demand for CS graduates possessing expertise in AI across a wide array of industries and services. In essence, AI University education evolves and adapts to meet the needs of both AI scientific development students and the job market [7] [8].

Typically, in the past, AI was a specialization of CS and/or Electrical and Computer Engineering (ECE) studies that was delivered at MSc or PhD level. Some AI courses were also delivered at a senior undergraduate level. A new trend has recently emerged, leading to the establishment of AI Departments and/or the delivery of AI Bachelor of Science (BSc) programs that are independent, though sometimes related to CS or ECE study programs and Departments. It seems that this trend greatly intensified in the past five years.

This paper aims at presenting a comprehensive survey of undergraduate AI programs in Universities worldwide, as this is directly related to the emergence of AI Science and Engineering (AISE) as an independent scientific discipline. Its objective is to offer a comprehensive view over the state of undergraduate AI education, documenting how it has evolved over time in response to the dynamic demands of society and economy. The curricular content of AI bachelor programs is also reviewed. Moreover, the challenges confronting institutions as they endeavor to establish AI as a standalone discipline are identified.

In essence, this paper can serve as a comprehensive resource for educators, policy makers, and researchers interested in AI education, delivering insights

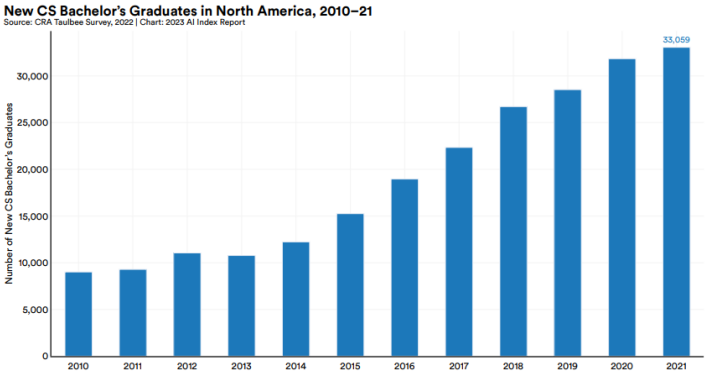

Fig. 1 Total number of new North American CS bachelor's graduates 2010-21 [6]

into the evolving landscape of undergraduate AI programs. By scrutinizing the current state of AI education from a global perspective, the aim is to contribute to the ongoing dialogue concerning the role of AI education in shaping future generations of AI professionals and innovators.

2 Evolution of AI Education

The history of AI education already spans seven decades, marked by pivotal moments that have shaped AI development into the scientific discipline it is today. This section provides a chronological account of highlights of the evolution of undergraduate AI university education.

2.1 Early Developments (1950s-1980s)

The AI foundations were laid in the mid-20th century. In 1956, Dartmouth College hosted the Dartmouth Workshop, a landmark event organized by J. McCarthy, M. Minsky, N. Rochester, and C. Shannon. This event bore historical significance, as it introduced the term *Artificial Intelligence* to the world, marking the formal beginning of AI research and education [9]. This momentum continued with the establishment of the Artificial Intelligence Project at MIT in 1959, under the leadership of J. McCarthy and M. Minsky, ushering in a new era of AI research. In Europe, University of Edinburgh played a pivotal role in the early days of AI education, founding its Department of Artificial Intelligence in 1963. This Department initiated an innovation path by launching the AI2 program during the 1974/75 academic year, which was focused on computational modeling. It also launched AI1 in 1978/79, an introductory program designed to teach the foundational principles and concepts of AI [10]. Of course, during the AI Winter (1960-1980), the slowdown of Machine Learning (ML) research impacted AI education. However, symbolic AI education continued to expand, also been driven by various applications. For example, in 1982, University of Edinburgh introduced the groundbreaking joint degree

program "Linguistics with Artificial Intelligence," bridging Linguistics and AI [11].

2.2 Global AI Expansion (1980s - 2010s)

As the demand for AI expertise continued to grow and Machine Learning re-emerged from its hibernation, Universities worldwide, foremost in USA, responded by expanding their AI education offerings. In Europe, many institutions, like the University of Cambridge and the Swiss Federal Institute of Technology in Zürich (ETH), established AI research groups and integrated several AI courses into their CS programs. Meanwhile, Universities in Asia, notably in China, Japan, and Korea, recognized the importance of AI and began establishing AI research centers and educational programs to meet the burgeoning demand. AI education started gradually shifting from symbolic AI to ML topics, notably Neural Networks (NN).

2.3 AI Revolution (2010s - 2022)

In recent years, AI education has witnessed a remarkable progress. It was fuelled by the AI revolution of the early 2010s, which was based on Deep Neural Network (DNN) research. In 2018, Carnegie Mellon University achieved a groundbreaking milestone, by introducing the first BSc degree program in AI within the United States [12]. This historic step marked a significant recognition of the growing importance of AI and its transformative potential across various domains, ranging from Robotics to Social Media to Genetic Engineering. The demand for AI University education was primarily industry driven, as in the last decade the demand for AI jobs skyrocketed globally.

In the same period, China emerged as a global leader in AI education. In 2018, the Chinese Ministry of Education took a proactive approach by approving 35 Colleges and Universities to offer the initial wave of undergraduate AI studies. This strategic move was well aligned with China's ambitious plans to become a world leader in AI research and development. By 2022, a staggering number of 440 Chinese Universities were offering undergraduate AI programs, demonstrating the nation's dedication to nurture a vast pool of AI talents [13]. Among these institutions, Tsinghua University stood out as the foremost leader in the field, consistently earning recognition on the global stage for its contributions in AI research and education.

Meanwhile, the global enthusiasm for AI studies extended beyond established AI education nodes. For example, in Abu Dhabi (United Arab Emirates), Mohamed Bin Zayed University of Artificial Intelligence (MBZUAI) took a bold step by founding graduate AI education. While, at this stage, MBZUAI focuses on graduate-level AI programs, its emergence coincided with the global quest for AI education and the increasing recognition of its importance [14].

2.4 Generative AI era (2022 onwards)

In the early 2020s, Generative AI (GAI) emerged that boosted synthetic digital content generation (text, images, videos, sound, 3D models) fuelled by AI Foundation Model (FM) and Large Language Model (LLM) research, primarily for generating text and images [1]. The immediate success of GAI fueled AI investments and skyrocketed the demand for GAI skills. This greatly boosted AI University education. Furthermore, it influenced University education in general, as neither science nor arts disciplines were left untouched by GAI. Currently, it is the Arts and Liberal studies that feel the AI pressure strongest.

3 Survey of Undergraduate AI Programs

This survey aims at assessing the current state of global AI University education, primarily at undergraduate level. It was conducted through meticulous manual research, systematically organized at continent level, with a specific focus on identifying Artificial Intelligence or Machine Learning BSc programs. A comprehensive analysis of the collected data revealed that 64 universities across the world (not taking China's vast number of AI programs into account) offer undergraduate-level AI studies, as documented in tables A1, A2, A3, A4 and A5 of Appendix A.

In the pursuit of understanding the landscape of undergraduate AI education, a comprehensive geographical analysis was performed, by delving into its global distribution and trends. The survey data have been used to compile a global undergraduate AI education map, which is illustrated in Figure 2. It is known that most undergraduate AI programs are concentrated in developed countries (Global North). The huge lag of the Global South is really striking. If this trend continues, the Digital Divide between the Global North (advanced economies) and Global South will further increase, hence leading to societal tensions, economic imbalance and political instability. This is also evident from the pie charts shown in Figure 3. The Chinese figures have been entirely omitted from Figure 3, as their inclusion would totally dominate the chart. More regional details on the geographical distribution of undergraduate AI studies follow.

3.1 China

China's remarkable rise in the field of AI can be attributed to the close connection between its rapidly growing AI industry and the exponential expansion of AI education. The core of this remarkable collaboration is the forward-thinking New Generation Artificial Intelligence Development Plan that was initiated by the Chinese State Council [13].

This ambitious plan sets the stage for Chinese AI industry to reach a remarkable 400 billion yuan turnover by 2025. But the real impact becomes clear, when we see how it boosts other related industries and financial sectors,

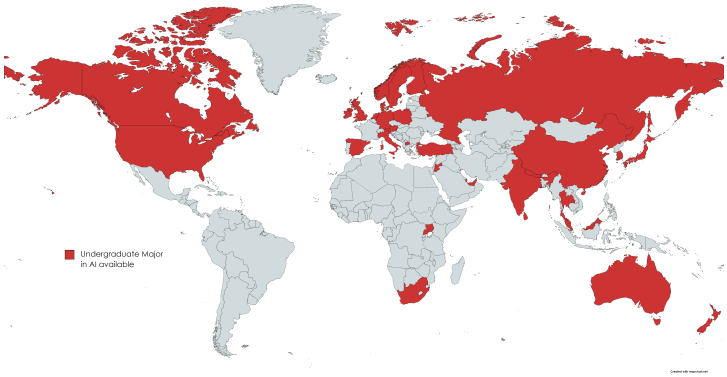

Fig. 2 Map depicting the countries that offer AI as an undergraduate major

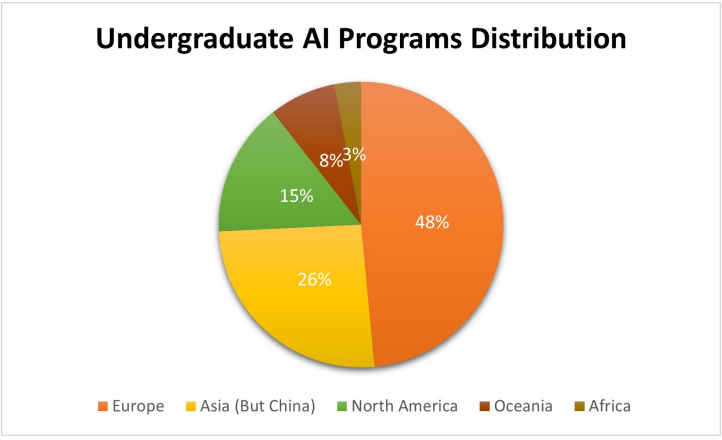

Fig. 3 Global Undergraduate AI Programs Distribution (but China)

pushing them to an astounding 5 trillion yuan. This rapid growth attracts a huge number of young talents like never before [13].

The booming AI Chinese industry is a major reason for China leading the world in awarding bachelor degrees in AI. This strong link between the industry and education creates a positive feedback: the high industrial demand for AI experts motivates more students to study AI on a scale unmatched anywhere else in the world. This in turn, strongly contributes (together with heavy financial investments) to a stronger growth of the Chinese AI industry. However, this industrial and financial drive and extremely fast development also entails the risk that undergraduate AI studies become too market oriented, without properly teaching AI fundamentals and the needed foundational scientific background which are detailed in section 5. However, we do not have data to support that this is indeed the case for China.

3.2 Europe

In the dynamic landscape of undergraduate AI education in Europe, there is a remarkable blend of expected and unexpected contributors making up 48% of the global offerings (but China), as illustrated in Figure 3. Their geographical distribution is illustrated in Figure 4. Countries like the United Kingdom and Netherlands historically stand out as major contenders in the field. Universities in these countries offer comprehensive AI programs, producing a steady stream of AI professionals and researchers. The strong historical UK research initiatives and the Dutch innovation-driven approach to industry helped them solidify their positions in AI education. Several other big European countries, e.g., Germany, Italy, Spain and Poland and smaller ones (e.g., Austria) offer undergraduate AI programs. Furthermore, unexpected contributors, such as North Macedonia and Malta, also make strides in this domain. While these nations may not have historical ties to AI excellence, it seems that they actively embrace AI programs.

It seems that the tradition of cross-country research and education collaboration within the European Union has played an important role in expanding AI education across the continent. However, the benefits are more evident in AI MSc and/or PhD education, as illustrated by the success of the International AI Doctoral Academy (AIDA). It has 60 European University members (plus 18 research and industry members) and coordinates AI education cooperation at advanced, primarily PhD/Postdoc level [15].

3.3 Asia

Asia (but China) accounts for 26% of the offerings in undergraduate AI studies. East Asia, represented by countries such as Japan and South Korea, has a strong focus on AI research and development. Both nations boast robust economies, with Japan being one of the world's largest economies, and South Korea being known for its technological advances in the electronics and automotive industries. Their strong economies allow them to invest heavily in AI education and research, fostering innovation in areas such as Humanoid Robotics and Natural Language Processing.

Southeast Asia is a region with diverse economic profiles. Singapore has a highly developed economy and stands out as a regional hub for AI education and research, attracting global talents. Malaysia, with its middle level economy status, is investing in AI education to enhance its technological capabilities. Thailand, having a similar economy, focuses on AI applications in sectors like Healthcare and Agriculture, driven by its growing economy.

South Asia comprises countries with varying Gross Domestic Product (GDP) levels. In India, Universities offer Bachelor of Technology (B.Tech) degrees on AI. Simultaneously, AI and ML are introduced as specializations within many undergraduate CS programs. Nepal and Sri Lanka, while relatively smaller in economic scale, are gradually introducing AI education

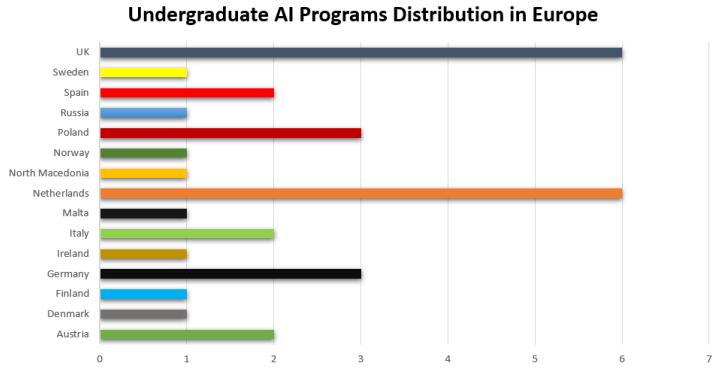

Fig. 4 Undergraduate AI Programs Distribution in Europe

programs to align with emerging economy needs, especially in tourism and agriculture.

The Middle East region comprises diverse economies, ranging from high-income nations, like Qatar and the UAE, to upper-middle-income countries, like Turkey and Jordan. These nations are investing in AI education and research to diversify their economies and promote innovation. Qatar and the UAE, leveraging their substantial oil wealth, have been particularly active in positioning themselves as centers for AI education and research. For geopolitical reasons, countries like Israel and Turkey heavily invest on military AI technology, e.g., on autonomous drones.

3.4 North America

The quality of most North American undergraduate AI programs are undeniable. Furthermore, USA is the world leader in AI research (though this is presently challenged by China). However, this dominance is not well reflected in undergraduate AI education. It seems that several top North American Universities are well satisfied by their current CS and ECE programs and do not venture into specialized undergraduate AI programs. While these programs may not dominate the global AI educational offerings, making up only 15% of the offered undergraduate AI programs, they unquestionably stand out as education and research powerhouses. This US particularity can be explained in various ways. Many leading Universities believe that it is preferable to educate CS or ECE generalists, who then specialize in AI through MSc or PhD studies. Furthermore, when it comes to their economic and technological dominance, US AI companies can always rely on braindrain to cherry-pick the best talents from the entire world.

Carnegie Mellon University, often regarded as a trailblazer in AI research and education, is a prominent example of AI education in USA. Home to a Machine Learning Department, it consistently ranks among the top 12 Best Universities for AI [16]. Likewise, Stanford University, in the heart of Silicon Valley, is another influential player. With a Graduate Certificate program in

AI and a prestigious 12th rank among the Best Universities for AI, it sets the gold standard for AI education [16].

Furthermore, top-tier institutions like MIT and Yale offer Bachelors of Science (BScs) degrees in AI and Decision Making. These programs draw students from around the world. Even Universities with lower global rankings, like Purdue University and New Mexico State University, contribute significantly to accessible AI education.

Canada has been pioneer in AI research in the past decades. Its contribution and fame in AI is much bigger than the country size (at least population-wise). Of course, this prestige is reflected in AI University education. For example, University of Toronto, ranked 48 among the Best Universities for AI [16], offers a highly regarded Certificate Program in AI. Montreal is another AI education hub with several excellent Universities and Institutes, like MILA (Quebec AI Institute). Additionally, Durham College offers an Honours Bachelor in AI.

3.5 Oceania

Australia, despite its geographical remoteness, has emerged as a strong contender in the field of undergraduate AI education, taking up 8% of the global offering, as shown in Figure 3. Currently, four Australian Universities offer BSc programs in AI. Among these institutions, the University of Technology in Sydney stands out, securing the impressive third position in the U.S. News global rankings for the Best Universities for AI [16]. In New Zealand, the Media Design School offers a Bachelor degree in Software Engineering and AI. This program integrates AI concepts within the context of software engineering, preparing students to navigate the intricate interplay between AI and software development.

3.6 Africa

Africa is quietly making its mark on AI education, defying conventional expectations and contributing 3% of the total offerings. While many may not readily associate the African continent with cutting-edge technology and specialized AI programs, it comes as a pleasant surprise that there are AI education offerings.

South Africa, often regarded as a center of technological innovation on the African continent, has been at the forefront of pioneering AI education. Notably, the University of Johannesburg has introduced a specialized BSc Honours program in CS with a strong emphasis on AI. This program stands as a testament to its unwavering commitment to nurturing AI talents.

Even less economically advantaged countries, make efforts in AI education. For example, Uganda, has introduced a dedicated BSc program tailored specifically to AI and Machine Learning. This is highly reflective of the trend toward AI-enabled globalization. It is imperative that Africa and South America (compromising the majority of the Global South countries) expand their

AI education offers, as they are essential for their regional economic and social development.

4 AI Science and Engineering Discipline

Is AI Science and Engineering a separate discipline rather than a CS/ECE specialization? Our opinion is that we live in a revolutionary times, as the ones found at the peak of the first industrial revolution. In the 19th century, Physics was at the forefront of all Engineering disciplines. Nowadays, CS spawns new disciplines, like AI, Network Science or Data Science. Simply put, the IT and AI knowledge is huge to be accommodated in one CS or ECE program of studies. Whether this is done through independent BSc/MSc programs or early specializations within the framework of a CS/ECE program is a matter of debate. Some Universities prefer to produce CS/ECE generalists, that specialize on AI later on. Other Universities are more aggressive, by offering separate undergraduate AI degrees. Both solutions are fine, as long as the depth and integrity of the studies is strictly observed.

Another issue is the maximization of synergy between AI studies and related disciplines, e.g., Computer Science and Mathematics. This can be best served by creating Schools of 'Information Science and Engineering' comprising Departments such as:

- Computer Science or Informatics,
- Mathematics,
- Computer Engineering,
- Artificial Intelligence Science and Engineering, and
- Internet/Web Science.

Such efforts are already being made internationally. Although driven by demand, the fundamental cause for such a development is the recognition of 'information' (and knowledge) as an independent scientific subject, at the same level with matter (studied, e.g., by Physics, Chemistry), (man-made) environment (Engineering Sciences), and life (Health Sciences, Biology). It seems that Computer Science (called Informatics in several countries) is already becoming the mother science of other disciplines, e.g., of Artificial Intelligence Science and Engineering. The same happened in the 19th century: at that time, Physics, Chemistry and Geometry gave birth to all Engineering Sciences we know today.

5 AI Curriculum

In this section, we shall explore the structure and content of a comprehensive AI Curriculum, outlining the core courses that are essential for building a strong foundation in AI. We shall also examine the delicate balance between theoretical AI knowledge and practical applications within the curriculum. Based on the AIDA AI Curriculum for advanced AI studies (MSc,PhD, Postdoc) [15] and expanding upon it, this AI curriculum contains a) AI core courses

and b) AI elective courses. As our current paper focuses on undergraduate AI studies, the proposed AI Curriculum also contains prerequisites coming from Mathematics, CS and Cognitive Science. The proposed AI Curriculum is outlined as below:

AI Prerequisites

1. Calculus and differential equations
2. Linear algebra
3. Probability theory
4. Multivariate statistics
5. Information and coding theory
6. Numerical analysis
7. Convex and non-convex optimization
8. Graph and network theory
9. Signal and systems
10. Mathematical logic
11. Structured programming
12. Object-oriented programming
13. Theory of computation
14. Analysis of algorithms
15. Data structures
16. Functional programming
17. Cognitive psychology fundamentals
18. Neuroscience fundamentals

AI Core courses

1. Foundations of Artificial Intelligence
2. Knowledge Representation and Problem-Solving
3. Reasoning and planning
4. Machine Learning
5. Deep Learning
6. Computer Vision
7. Natural Language Processing and Speech Analysis
8. AI Ethics and Governance

AI Elective courses

1. Reinforcement Learning and Sequential Decision-making
2. Generative Artificial Intelligence
3. Foundations of Trustworthy AI
4. Explainable AI
5. Distributed AI systems
6. Human-Centered Machine Learning

7. AI for Music/Sound Analysis and Synthesis
8. Networked intelligence
9. Human-Centred Media Analysis
10. AI and robotics

This AI curriculum can be complemented with several application-oriented "AI+any discipline" and support courses. The following AI application courses list covers several disciplines, both technical and non-technical, providing a detailed summary of courses on the potential uses of AI on each field, while the AI support courses list covers subjects that are increasingly demanded by a modern workplace.

AI Application courses

1. AI and games
   - Introduction to games and game engines
   - Game AI
   - AI for Procedural Game Content Generation
   - AI for game playing
   - AI for Human Player Modelling
   - Open research platforms and datasets for AI in games
2. AI in Health Sciences
   - Genomic and proteomic sequencing
   - Protein folding and structure prediction
   - AI-powered electronic health records
   - AI for medical imaging and diagnosis
   - AI for drug target identification
   - Privacy protection of medical data
3. AI in Markets and Finance
   - Algorithmic trading
   - Risk management
   - Portfolio management
   - Regulatory compliance
   - Quantitative analysis
   - Credit scoring and underwriting
   - Fraud Detection
4. AI in Humanities
   - Network/graph theory in humanities
   - Computational stylistics
   - Computational history
   - Computational social science
   - AI and literature

- Meta-agoras and meta-societies
- AI and labor
- AI in education
- Computational politics
- Societal and Political Networks
- Social activism
- Virtual Communities
- AI and justice
- Digital crime
- Fake Data
- Mis-/Disinformation
- Digital Identity
- Intellectual Property

5. Deep Arts

- Computational aesthetics
- Generative AI and copyright issues
- AI for narrative and storytelling
- Image/video restyling
- Art curation and AI
- Art conservation and restoration
- Immersive and interactive installations

AI Support courses

1. Data Management
2. Project Management
3. Distributed Programming
4. Parallel Programming
5. Entrepreneurship and innovation

Of course, the AI application and support courses heavily depend on national or institutional priorities.

Particular attention has been paid so that all AI graduates from any level have a sound mathematical and computing background. This will ensure their survival and re-skilling in our times, as technology changes way too fast.

Furthermore, we conducted a comparative analysis of the proposed AI Curriculum and those of selected Universities renowned for their undergraduate AI programs, in terms of reputation and AI education rankings. In this light, we examined the academic offerings of four renowned Universities celebrated for their undergraduate AI programs, namely Nanyang Technological University (Singapore) [17], The University of Edinburgh (UK) [18], Carnegie Mellon University (USA) [19], and the University of Technology Sydney (Australia) [20]. Their comparative course offerings are summarized in Tables B6, B7, B8 and B9 of Appendix B. It is evident that all four Curricula share many common topics with the proposed AI Curriculum (highlighted in bold).

6 Impact of AI on other University disciplines

In this fast-changing world, AI is changing more than just its neighbors, namely the CS and ECE disciplines. It also has important impact on other disciplines, e.g., Liberal Arts and Health Sciences. One way to address this rise is by offering AI as a minor degree, so students following a major in a different discipline can learn about AI. Understanding AI basics helps students in mastering their own discipline and also teaches them how to use AI technology as educational tool.

The use of AI means different things in different disciplines. In Journalism, it helps analyzing news stories, while LLMs can partially automate news editing. AI can also boost news personalization. In Medicine, it changes how doctors diagnose illnesses and manage healthcare. Hence, AI impacts medical education. Even disciplines that did not use math and computers much in the past, can benefit from short courses on AI topics. However, such courses should be in-depth, focusing on deep mathematical and algorithmic understanding of AI, rather than just on memorizing AI buzzwords. Such an approach can help people to combat AI technophobia.

Additionally, it is important that AI studies provide courses that address the ethical and legal side of its use. The extensive adoption of AI requires an ever increasing amount of data, the use of which raises multiple legal issues that students of non related disciplines might be unaware of. The utilization of AI tools that assist on teaching or studying also raises issues, as they often need to collect data from their users in order to become more personalized and effective. Courses that inform students of the legal framework around the use of AI and data would be necessary, as to prepare them for the legal issues they may encounter in their studies, and their work afterwards. They would also inform them of their own rights, on issues such as the collection of their personal data.

Keeping traditional scientific disciplines alive in the age of AI can also be done through special Departments (or study programs). Such Departments, like Language Engineering or Social Engineering ones, can focus on combining AI with subjects like Language or Humanities studies. Superficial AI courses in such disciplines will not work. Instead, it is important that students really understand Mathematics and Computer Science fundamentals, no matter their discipline. Creating special AI related Departments for AI studies, like Mind and Social Science and Engineering (MSSE), and Bio-Science and Engineering(BSE), is really important. If they are embedded in Arts or Medical Schools, respectively, they can help revolutionizing Liberal and Health studies.

Education collaboration on a global scale is essential. Universities are equipping students for a future, where AI and human intelligence should collaborate rather than clash. By teaching AI across various subjects, tackling challenges, and transforming the teaching methods, at a global level, Universities empower students not only to adapt to the future, but also to actively influence it.

7 Conclusions

The landscape of undergraduate AI education is a constantly evolving canvas, reflecting the global recognition of AI as a pivotal force shaping the future of humanity. From China's remarkable rise fueled by ambitious national initiatives to Africa's quiet progress defying expectations, the world is embracing AI education with enthusiasm and purpose. In such a fast moving AI education landscape, it seems that mid-sized countries and mid-rank Universities are more adventurous in providing AI education particularly at the undergraduate level. Obviously, they see a window of opportunity in this domain.

However, establishing a standalone AI major comes with its set of challenges and considerations. The curriculum should strike a delicate balance between: a) mathematical and computing foundations, b) theoretical AI and ML knowledge and c) practical applications, ensuring graduates are well-equipped to become an excellent AI workforce. The foundational and theoretical knowledge is particularly important, as it will ensure lifelong education on capabilities of the AI graduates. AI may be outdated as a discipline in a couple of years (as, e.g., how happened to Cybernetics), but the AI foundation knowledge will be always needed. Challenges include the rapidly evolving nature of the AI discipline, the need for qualified faculty, access to resources, ethical considerations, industry collaboration, and promoting diversity and inclusivity.

Another important issue is how Universities will address the increased mathematization of all sciences. This can be done by greatly strengthening the mathematical and computing basis of all scientific and arts curricula. Another approach is to deliver double (major/minor) degrees having major in one discipline a minor on AI/IT.

In summary, the global adoption of AI education by institutions plays a pivotal role in shaping a future where AI is effectively utilized. By addressing these challenges through a targeted educational approach, AI education is equipping the upcoming cohort of professionals and trailblazers who will be instrumental in shaping this future.

Declarations

Funding

This manuscript was created in the context of project *Horizon Europe - AI4EUROPE - 1010700* from which it received its funding.

Competing interests

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

Ethics approval

Not applicable.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

There were no data created or used in the research conducted in this manuscript, outside of the cited sources.

Code availability

Not applicable.

Authors' contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis, and the first draft of the manuscript were written by Zografia Sotireli. Ioannis Pitas wrote the main body of the manuscript. Christos Papaioannidis contributed on the writing of the manuscript and oversaw the creation of the taxonomy (AI Curriculum). Alexandros Zamioudis created the final version of the manuscript and contributed on data collection and verification. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Appendix A Global Survey of AI Undergraduate Studies

Table A1: List of Asian Institutions Offering Undergraduate-Level AI Studies

Program Title	Institution	Location
BSc in AI	Tsinghua University	China (indicative)
Course in Intelligent Information and Communication Engineering	Niigata Institute of Technology	Japan
BSc in AI	University of Jordan	Jordan

Program Title	**Institution**	**Location**
B.Tech in Computer Science and Artificial Intelligence	Indraprastha Institute of Information Technology	India
B.Tech in Artificial Intelligence	Amity University	India
B.Tech in Artificial Intelligence and Machine Learning	Amity University	India
BBA in Artificial Intelligence	Amity University	India
Bachelor Of Computer Science (AI major)	Technical University of Malaysia, Malacca	Malaysia
Bachelor Of Computer Science (AI major)	University of Malaya	Malaysia
B.Tech in AI	Kathmandu University	Nepal
BASc in Data Science and AI	University of Doha for Science and Technology	Qatar
BSc in Data Science and AI	Nanyang Technological University	Singapore
BSc Honours in Applied AI	Singapore Institute of Technology	Singapore
BSc in AI	Korea University	South Korea
BSc Honours in AI	KAATSU International University	Sri Lanka
BSc in AI	Huachiew Chalermprakiet University	Thailand
BSc in AI and Data Engineering	Technical University of Istanbul	Turkey
BSc Honours Computer Science (Artificial Intelligence)	Heriot-Watt University Dubai	UAE

Table A2: List of European Institutions Offering Undergraduate-Level AI Studies

Program Title	**Institution**	**Location**
BSc in AI	Johannes Kepler University Linz	Austria
BSc in Robotics and AI	University of Klagenfurt	Austria
BSc in AI and Data	Technical University of Denmark	Denmark
B.Eng in AI	Satakunta University of Applied Sciences	Finland
BSc in AI	Deggendorf Institute of Technology	Germany

Program Title	**Institution**	**Location**
BSc Data Science, AI and Digital Business	GISMA University of Applied Science	Germany
BSc in AI and Sustainable Technologies	Tomorrow University of Applied Sciences	Germany
BSc in AI and Machine Learning	University of Limerick	Ireland
BSc in AI	University of Pavia/Milano Statale/Milano-Bicocca	Italy
Bachelor in Applied Computer Science and AI	Sapienza University of Rome	Italy
BSc in Information Technology (Artificial Intelligence)	University of Malta	Malta
Bachelor in AI	Vrije University Amsterdam	Netherlands
BSc in AI	Radboud University Nijmegen	Netherlands
BSc in AI	University of Groningen	Netherlands
BSc in Data Science and AI	Maastricht University	Netherlands
BSc in Data Science and AI	Leiden University	Netherlands
BSc in Cognitive Science and AI	Tilburg University	Netherlands
Bachelor in Machine Intelligence and Robotics	University of Information Science and Technology "St. Paul The Apostle"	North Macedonia
Bachelor in AI	University of Bergen	Norway
Bachelor in Management and AI	Kozminski University	Poland
BSc in AI	Poznań University of Technology	Poland
Bachelor in AI and Data Science	University of Economics and Human Sciences	Poland
Bachelor in AI and Computer Science	Irkutsk National Research Technical University	Russia
Bachelor in AI	The Autonomous University of Barcelona	Spain
Bachelor in AI	Technical University of Catalonia	Spain
Bachelor in Applied AI	University West	Sweden
BSc in AI	The University of Edinburgh	UK

Program Title	**Institution**	**Location**
BSc in AI and Computer Science	University of Birmingham	UK
BSc Honours in Computer Science and AI	Swansea University	UK
BSc in AI	University of Essex	UK
BSc in AI	King's College London	UK
B.Eng Honours in Robotics and AI	University of Hertfordshire	UK

Table A3: List of North American Institutions Offering Undergraduate-Level AI Studies

Program Title	**Institution**	**Location**
Certificate Program in AI	University of Toronto	Canada
Honours Bachelor in AI	Durham College	Canada
BSc in AI	Carnegie Mellon University	USA
Graduate Certificate in AI	Stanford University	USA
BSc in AI and Decision Making	Massachusetts Institute of Technology	USA
BSc in Computer Science with an Artificial Intelligence research focus	Yale University	USA
BSc in AI	Illinois Institute of Technology	USA
BSc in AI	Indiana University–Purdue University Indianapolis	USA
BSc in Computer Science (AI major)	New Mexico State University	USA
BSc in Robotics and AI	Saint Leo University	USA

Table A4: List of Oceanic Institutions Offering Undergraduate-Level AI Studies

Program Title	**Institution**	**Location**
Bachelor of AI	Deakin University	Australia
B.Tech in AI and Autonomous Systems	Murdoch University	Australia
Bachelor in Advanced Computer Science (AI major)	The University of Western Australia	Australia
Bachelor of AI	University of Technology Sydney	Australia

Program Title	Institution	Location
Bachelor of Software Engineering - AI	Media Design School	New Zealand

Table A5: List of African Institutions Offering Undergraduate-Level AI Studies

Program Title	Institution	Location
BSc Honours in Computer Science with AI	University of Johannesburg	South Africa
BSc in AI and Machine Learning	International Business, Science and Technology University	Uganda

Appendix B Undergraduate Course Comparison Between 4 Universities

Table B6: First Year Course Comparison Among Universities

Nanyang Technological University	The University of Edinburgh	Carnegie Mellon University	University of Technology Sydney
Introduction to Computational Thinking & Programming	**Introduction to Computation**	Principles of Imperative Computation	**Mathematics 1**
Calculus	**Introduction to Object-Oriented Programming**	Integration and Approximation	Web Systems
Discrete Mathematics	**Introduction to Linear Algebra**	**Math Foundation of CS**	**Discrete Mathematics**
Inquiry and Communication in an Interdisciplinary World	**Calculus and its Applications**	Interpretation and Argument	**Programming Fundamentals**
Navigating the Digital World		**Computing**	**Programming 1**
Data Structures & Algorithms		Great Theoretical Ideas in Computer Science	Communication for IT Professionals
Object-Oriented Design and Programming		**Matrices and Linear Transformations**	**Database Fundamentals**

Nanyang Technological University	**The University of Edinburgh**	**Carnegie Mellon University**	**University of Technology Sydney**
Introduction to Data Science & AI		**Calculus in Three Dimensions**	**Introduction to Data Analytics**
Ethics & Moral Reasoning in a Multi-Cultural World		Principles of Functional Programming	Introduction to Information Systems
Healthy Living & Mental Well-being in an Aging Society		**Concepts in AI**	

Table B7: Second Year Course Comparison Among Universities

Nanyang Technological University	**The University of Edinburgh**	**Carnegie Mellon University**	**University of Technology Sydney**
Algorithm Design and Analysis	Introduction to Computer Systems	**AI: Representation and Problem Solving**	**Mathematics 2**
Software Engineering	**Discrete Mathematics and Probability**	**Parallel and Sequential Data Structures and Algorithms**	**Network Fundamentals**
Probability and Introduction to Statistics	**Foundations of Data Science**	**Probability Theory for Computer Science**	**Programming 2**
Sustainability: Society, Economy & Environment	Software Engineering and Professional Practice	**Probability and Computing**	Business Requirements Modelling
Career and Entrepreneurial Development for the Future World		**Intro to Machine Learning**	**Machine Learning**
Introduction to Database Systems		**Intro to Computer Systems**	**Introduction to Artificial Intelligence**
Artificial Intelligence			**The Ethics of Data and AI**
Statistics			

Nanyang Technological University	**The University of Edinburgh**	**Carnegie Mellon University**	**University of Technology Sydney**
Data Analysis with Computer Communication Across the Sciences Science & Technology for Humanity			

Table B8: Third Year Course Comparison Among Universities

Nanyang Technological University	**The University of Edinburgh**	**Carnegie Mellon University**	**University of Technology Sydney**
Machine Learning	Informatics Large Practical	**Computer Vision**	AI/Analytics Capstone Project
Data Analytics and Mining	Professional Issues	**Natural Language Processing**	Project Management and the Professional
Calculus III	Computer Security	Modern Regression	**Natural Language Processing**
Professional Internship	System Design Project		**Deep Learning and Convolutional Neural Network**
			Advanced Artificial Intelligence
			Emerging Topics in Artificial Intelligence
			Introduction to Computational Intelligence
			Image Processing and Pattern Recognition
			Data Visualization and Visual Analytics
			Theory of Computing Science
			Reinforcement Learning

Nanyang Technological University	**The University of Edinburgh**	**Carnegie Mellon University**	**University of Technology Sydney**
			Internet of Things

Table B9: Fourth Year Course Comparison Among Universities

Nanyang Technological University	**The University of Edinburgh**	**Carnegie Mellon University**	**University of Technology Sydney**
Final Year Project	Final Year Project	Electives	One additional full-time year of study in the Bachelor of Information Technology

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