Introducing Artificial Intelligence in High School Curriculum

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Abstract

In May 2019, the United Nations Educational, Scientific and Cultural Organization (UNESCO), convened the first conference on Artificial Intelligence (AI) and Education to reflect on the impact of this emerging technology on teaching and learning. In the history of education, disruptive technologies including electronic calculators, computers, the Internet, and the World-Wide Web have set new milestones and entirely redefined the landscape of education. The design and implementation of AI conversational models, including ChatGPT by the American company Open AI, strongly suggest that accessing and using knowledge will be a lot easier in the near future. It also means that having knowledge at one's fingertips is becoming a reality. That is to say, there is a need to prepare learners and teachers for the coming technological and social changes induced by AI. Following this trend, we suggest in this paper that younger generations should be trained in the design and implementation of the building blocks of this new technology. Therefore, our paper lays down the foundations of AI curriculum design and development for high schools. It also helps prepare young students for the coming technological and social changes, and the Fourth Industrial Revolution (4IR). To achieve this goal, we propose an initiative that focuses on three directions: 1) Creating accessible course contents adapted to young audiences; 2) Training teachers to master the new technology in order to deliver appropriate content; and 3) Harnessing the necessary resources to create an environment that supports learners and teachers and help them thrive.

Keywords: Curriculum Design and Development, Artificial Intelligence, Secondary Education, Learning, Teaching

Introduction

In the last few decades, artificial intelligence (AI) has been attracting a lot of attention from the public, industries and society. Through collaborations, information and communications, AI applications spread quickly from the confines of academic and industrial research laboratories to the public. Today, virtually all segments of modern society including the entertainment industry, the financial system, the media, the medical and health sciences are using AI tools and techniques to solve complex problems or improve their processes. It is only recently that a number of governments and international organizations including the United Nations through the UNESCO initiated policies and strategies for leveraging AI in order to achieve their sustainable development goals (SDG) (UNESCO, 2022; Human-centered AI, 2021).

In this perspective, UNESCO organized the first international conference on AI and education ("Planning education in the AI era: Lead the leap") in Beijing, China in May 2019. This event served as a platform for governments, international organizations, society and related industry to reflect on the impact of this emerging technology on teaching and learning. The main outcome of this conference is the Beijing Consensus on AI and Education which suggests participants should take actions towards the systematic integration of AI to innovate teaching and learning through the delivery of flexible education systems (UNESCO Digital Library, May 2019, p. 16-18).

Traditionally, the research and teaching of AI are done in science and engineering departments of universities worldwide (Winston, P. H., 1992). The contents, tools and techniques of AI education at the academic level are out of reach of the public. In addition, younger students in secondary schools have no clue of the inner workings of this new technology beyond its mundane applications they enjoy. AI-based apps are embedded in virtually every social media platform or tools they use daily. For example, current search engines integrate voice input in addition to text (Text-to-Speech technology from NLP in AI), to make online search accessible to everyone. Yet, formal AI learning remains elusive in secondary-level education. Therefore, there is a need to downsize and adapt existing higher-level AI curricula to young learners. In the meantime, it is possible to bring into interested schools open-source curricula as volunteer-based programs the way computer science and programming were introduced through the CodeEd program to girls in New York (CodeEd, 2023).

The new AI curricula will help them become familiar early on with the fundamental concepts and methods of the field. High-school students exhibit enough level of maturity and critical thinking for understanding the technological and cognitive foundations and methods of AI. This paper starts a fruitful discussion on the wide-scale implementation of AI in high-school science education (Nisheva-Pavlova M. M., 2021). After this introduction, Section 2 lists a number of notable corporate and governmental projects that are pushing AI into the standard secondary-level education. Then, in Section 3, I propose the structure and content of a curriculum that would progressively implement AI into any current high-school science curriculum. Last Section 4 concludes this contribution.

Related Initiatives

Recently, several inspiring initiatives on AI education targeting young audiences, has emerged around the world. These projects focused mainly on AI education at the K-12 level

(Nisheva-Pavlova M. M., 2021; UNESCO, 2022). They devoted much attention to crafting balanced contents of theory, practice and also philosophical, legal and ethical issues. The expected challenge here is to find the right level of adaptation of university content to high-school audiences. For example, key topics in a traditional academic AI curriculum like problem-solving by search or planning, knowledge representation, automated reasoning, and natural language processing are either left out for convenience or ridiculously simplified. These issues are not actually new and quite common when a known and successful field is "transferred" from academia to high-school. The history of Biology in secondary-level education provides an excellent illustration. In spite of these challenges, the following successful initiatives from around the world are paving the way to a smooth integration and acceptance of AI education.

AI4ALL Open Learning in USA

AI4ALL Open Learning is an American non-profit organization founded in 2019 originally at Stanford University. Its mission is to created a diverse and inclusive environment in AI education, research and development. The main goal of the Open Learning platform is to provide free, accessible AI curriculum and resources for high school teachers of all disciplines to use in classrooms of all subject areas. Within the AI4ALL, there is the specific AI for K-12 initiative (AI4K12) which develops guidelines for integration of AI in K-12 (UNESCO, 2022). According to its founders, it is a "curated resource directory to facilitate AI instruction" and "a community of practitioners, researchers, resource and tool developers focused on the AI for K-12 audience" (Touretzky, D. et al., 2019).

China's New Generation AI Development Plan for 2030

In 2018, AI was first introduced to Chinese high-school curriculum to attract young people towards this field. The same year, a related nine-chapter textbook named "Fundamentals of Artificial Intelligence" was published (see Figure 1), (China Daily staff writer, 2018).
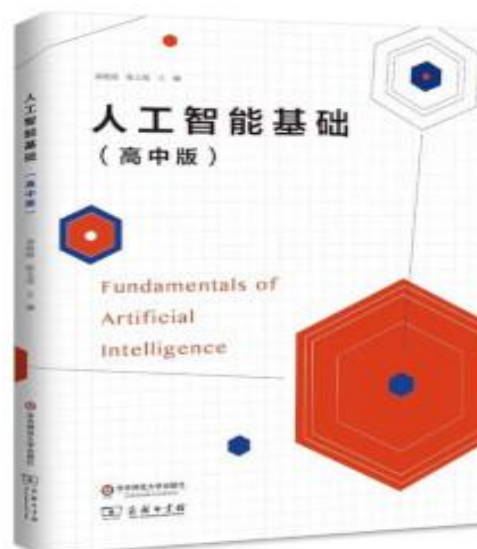

Figure 1: First high-school AI textbook in China: "Fundamentals of Artificial Intelligence". (Source: SHINE - https://www.shine.cn/news/metro/1804293918/)

It includes the history of AI and its applications in daily life such as facial recognition, auto driving and public security. The Chinese government selected 40 pilot high-schools to

implement its AI agenda made of basic recognition techniques of image, sound and text and also deep learning. Then, in 2019, China, the State Council for the People's Republic of China launched the national AI strategy including R&D, capacity building, education, and ethical norms for national security. As China is mandating AI education in high school, it is also urging corporations involved in AI development to partner with schools and universities in training students.

AI Education Initiatives in India

Under the leadership of an organization called AI School of India, a team of experts created a special AI curriculum specifically for K-12 students in the innovative AI LAB environment (Staff writer, 2021). These experts include ISTE, Intel and IBM-certified educators and engineers supported by academics from Oxford University in U.K. and Graz University of Technology in Austria who designed contents. The AI LAB is equipped with hands-on, interactive and virtual AI courses with young learners having control over timing and resource allocation. The main objective of the AI LAB is to make young students AI -literate, discover the world of AI and immerse them into a unique learning experience. However, there are still questions about the readiness of this audience to tackle real-world problems using AI tools and techniques. In addition, the Indian Central Board of Secondary Education (CBSE) partnered with IBM to launch the "AI for high school program".

AI in Secondary-Level Education in Korea

Around the end of 2019, the ministry of education of the Republic of Korea (South Korea) announced a bold new "National AI Strategy" that will put the country on the world AI map. Then in 2021, it embarked on an ambitious program to introduce AI in Korean high-schools (Yonhap, November 2020). The ministry also intends to expand this program in terms of technological infrastructure and material to kindergartens, elementary and middle schools by 2025. These secondary-level curricula elective AI subjects include "Introductory AI" and "Mathematics of AI". In addition, the elementary and middle school curricula will cover basic programming skills, foundations of AI, practical use of AI and its ethics. In this plan, Korean graduate schools and universities will train and supply teachers who will teach students (Kim, S. et al., 2021).

Saudi Authority for Data and Artificial Intelligence

In July 2020, the Saudi Data & AI Authority (SDAIA) was created to spearhead the national agenda for Data & AI and position the kingdom in the data-driven economies. One of the three core elements of the SDAIA is the National Center for Artificial Intelligence (NCAI). The objective of this center is to support AI research and development, serve as an AI advisory board to government, and promote AI education and awareness. In September 2019, Riyadh's Misk Schools of the Misk Foundation became the first Saudi school to introduce AI into the classroom. Misk Schools uses Century, an AI-based teaching and learning platform that adapts learning to individual student's strengths (Al-Kinani, M., April 2019).

Proposal of an AI Curriculum for High-School

The Learner's Perspective

There are certainly many successful methods for teaching AI to young audiences. The selected projects mentioned in the "Related initiatives" section above, provide an interesting array of strategies and examples. Here, we put an emphasis on the practical side of AI. Getting hands on experience with AI methods and techniques is the best way to initiate and attract young people to a new technology. The following tables suggest a layout of the most important elements of a course syllabus in the typical high-school education. Here, I assume that the standard number of years for completing high-school is three years. The contents of the following tables provide information on each year's content via modules. A course syllabus is an informal contract between the teacher and the learner (Parkes, J., & Harris, M. B., 2002). Each table introduces a module, its intended learning outcome, a related planned experience when possible, and the module synopsis.

AI Syllabus for Year One

In the first year, students have a smooth and gentle introduction to AI, knowledge representation and the world of computer programming. The main purpose of this content in year one is to attract students and make sure that their overall perception and feeling about AI is very positive from the beginning. It would serve as an incentive to continue further their exploration and discovery of AI.

First Year High-School - Artificial Intelligence			
Module	**Intended Learning Outcome**	**Planned Learning Experience**	**Module Synopsis**
A Gentle Introduction to Artificial Intelligence	- Understand the nature, history and foundations of Artificial Intelligence. - Discover applications of AI in real life.	Watch videos of successful AI applications in society and industry (ex. apps, software, robots) Corrode videos series (https://code.org/educate/resources/videos#how-ai-works)	Artificial intelligence is a field that explores intelligent human behavior. It then tries to duplicate and implement this intelligence in a computer system.
Knowledge Representation (KR) in Artificial Intelligence	- Get familiar with the form of Knowledge Representations in AI. - Learn logic and reasoning. Use logical reasoning to make simple inferences	Use tools and platform to draw and implement visually KR in a lab. environment	This module introduces the concept of knowledge and its many representations. It also presents elementary logic, propositional logic and first order logic.
A gentle introduction to algorithms and languages for Artificial Intelligence	Develop abilities in the most used programming languages for AI: Python, Java, R	Learn by example the basics of computer programming. Coding short programs in IDE (ex. AI Lab from Code.org)	This module introduces computer programming in Python, Java, and R. It also shows how these languages are important for AI systems.

Table 1: AI curriculum for high-school, first year

The first step is to learn how to program in high-level languages. Nowadays, it is quite common to use an AI-powered environment in secondary education to teach how to write computer programs in high-level languages. For example, PyCharm and Visual Studio are

integrated development environment (IDE) that are used together with useful code completion extension like GitHub Copilot and IntelliCode from Microsoft. The next logical step in this exploration is Knowledge Representation and Reasoning (KRR) in AI for high school as explained in (Guerreiro-Santalla, S., 2021) which deals with how humans represent knowledge and reason logically when solving a problem. This representation is done in a format that computing systems equipped with inference engines or theorem provers can use to solve complex problems. To this end, students learn about some of the most popular formalism including semantic nets, frames, rules and ontologies. To help students feel grounded with these concepts, the Planned Learning Experience (see Table 1) could introduce the Knowledge Machine (KM), a free knowledge representation and reasoning tool made of a language and a reasoning engine. A student can use KM in a laboratory setting, to easily create a knowledge base (KB) as a collection of facts, objects, rules, and relationships. In addition, he/she would also design rules that connect facts and allow us to reason about those facts. Then, during the experimenters can run simulations and ask questions (queries) to the KB, and make inferences based on facts and rules in the KB.

AI Syllabus for Year Two

In year two, the objective is to introduce students to core AI techniques and methods and teach them how to solve real-world problems using these techniques as proposed in Table 2. That is to say, students discover Machine Learning, its algorithms, search and planning techniques. Machine learning is a branch of AI and data science that creates and train algorithms (ex. Neural networks, Linear regression, Clustering) for the purpose of classifications, predictions, and mining of insights from large datasets (IBM, 2023) With this technology, students learn how to build simple models from collected data in order to solve complex real-world problems. That is to say, the learner identifies, defines and analyzes a problem. Then, given the model he/she built previously, an optimal solution (least costly path) is chosen and implemented.

Second Year High-School - Artificial Intelligence			
Module	**Intended Learning Outcome**	**Planned Learning Experience**	**Module Synopsis**
Machine Learning (ML) part I: Basics	- Understand simple learning algorithms - Building models from collected data	* AI lab projects that showcase ML applications in virtual sandboxes. * Introduction to Machine Learning: Image Classification uising the *MIT App Inventor* tool.	The content of ML, Part 1 includes the study of learning algorithms and how to use them in building models. It explains predictive and descriptive methods.
Problem-solving using AI techniques	- Learn about **AI search** methods. - Learn about **AI planning** - Acquire problem-solving skills	Hands-on lab experiments with AI planners	The objective of this module is problem-solving using critical thinking, logical reasoning, and creativity.
Capstone project	- Identify and solve an AI-friendly real problem - Master AI techniques for solving an actual problem	AI lab projects that showcase simple real-world problems. example: Microsoft AI Lab - Innovation Sandbox	The student conducts a research project on a special topic

Table 2: AI curriculum for high-school, second year

To make sure the expected learning outcomes are fulfilled, students must engage in a group Capstone project that gives them a unique opportunity to carry out independent work of interest and craft innovative solutions to real-world problems. The ultimate purpose of the Capstone project is to encourage young students to think critically and learn how to tackle and solve challenging problems. It is a good way of checking students' knowledge acquisition and skills. Additionally, its creative nature also helps improve their oral communications and independent research skills.

AI Syllabus for Year Three

The third year of AI covers Deep Learning, a special topic in Machine Learning; Natural Language Processing, a central theme in AI; Robotics and Vision; and the social and ethical impact of AI as displayed in Table 3. The Robotics module introduces students to actual robots and how to program them to perform simple actions. For young people, these robots are perceived as toys and interacting with them takes the form of playing games. Learning about Robotics in schools may assist students in turning their knowledge into creativity and innovation. For example, in he U.S., some K–12 students are exploring science with an online tool called BrainPOP that offers movies, quizzes and play games on math, science, social studies, English, technology, and art. At the same time, the platform tracks students' learning progress and provide teachers with lesson plans, tutorials, scheduling tools, and guidelines. A study conducted by the Games for Learning Institute (G4LI) at the NYU's Steinhardt School of Culture showed that the game-based learning approach can get students interested in and motivated to learn difficult subjects (Biles, M., 2018).

In spite of the glitters and promises of a better environment, AI should not be trusted to be fair and neutral and may present a potential peril for mankind. With little government

oversight, AI technology is being used by private corporations to make important decisions on patients' health, human resources, credit applications in fintech, and decisions in a court of justice. AI systems trained by human experts are able to capture their expertise over time, perform tasks better, more efficiently and with fewer errors. It is essential that young learners be aware at an early age of some of the unintended consequences of the use of AI and ethical concern for society including privacy and surveillance, bias and discrimination, and human judgment (Pazzanese, C., October 2020).

Third Year High-School - Artificial Intelligence			
Module	Intended Learning Outcome	Planned Learning Experience	Module Synopsis
Machine Learning part II: Deep Learning	- Understand Learning models and learning algorithms. - Learn about neural networks and their applications.	* AI lab projects that showcase ML applications in virtual sandboxes. * Building ML and deep-learning models to solve real-world problems.	The content of Part II includes the study of predictive and descrip-tive methods, learning algorithms and Neural networks.
Natural Language Processing (NLP)	- Understand the syntax, semantics and morphology of natural languages. - Build computational models of discourse.	Experiments with Text to Speech (TTS), automatic summa-rization, AI machine translation software	This module introduces comp-utational modeling of natural (human) languages. Topics: language morphology, modeling, and discourse analysis.
Robotics and Computer Vision	- Learn the basic building blocks of a robot - Develop robot cons-truction skills - Learn to program robots	* Lab. experiments with robots using Spark-funRedBot, EngageK12. Visit robot-enabled factory.	This module is a hands-on series of sessions to introduce the basic concepts of robotics and computer vision.
Social and ethical impacts of AI	* Be aware of the ethical implications and moral questions that arise from the implementation of AI technologies. * Appreciate issues of bias, fairness, transparency, and privacy in AI.	* Study of examples of AI ethical chal-lenges and recom-mendations (see UNESCO docs) * Fake Voices: The Ethics of Deepfakes with the *MIT App Inventor*.	The use of AI entails risks and challenges, or inequalities and divides. This module focuses on the ethics of AI, a human-centred AI that can benefit the entire humanity

Table 3: AI curriculum for high-school, third year

Sandel, a political philosopher and Professor of Government at Harvard University Law School said: "Debates about privacy safeguards and about how to overcome bias in algorithmic decision-making in sentencing, parole, and employment practices are by now familiar." (Pazzanese, C., October 2020, A veneer of objectivity section) Therefore, it is a good idea that at this early age in high-school, students learn about responsible implementation of AI systems and where the consequences of the misuse of AI could lead us (Russell S., June 1996).

The Teacher's Perspective

Teaching AI in higher education is now a well-established activity in terms of structure, content and methods. Given the sensitive context of high-school, simply downsizing university AI programs cannot work. The success of AI education in high-schools rests on competent teachers that have been trained or reeducated in teaching AI-related content. That

is to say, except for teachers who already specialize in AI-related fields, there is a need to design a course tailored to prospective AI educators. Such initiative should be done by AI researchers at the university level in cooperation with local governments through an on-the-job training program for high-school teachers in service.

Teaching Resources and Environment

In order to teach this new discipline, it is important that teachers create an open network to support one another in terms of resources, best-practices, tips and advice. For example, the network would propose the idea of a moderated AI Education platform that collects contributions from experienced teachers and curriculum designers, and AI experts (Manaris, B.; Russell I., 1996). Then, the platform will make freely available AI course materials, tools, best practices, related policies, and frameworks. The following presents several useful AI-powered tools and platforms that effectively assist teachers in designing and delivering contents.

* Lesson planning tools assist teachers in assembling pedagogical documents, teaching strategies and supporting material and organizing field trip when necessary. For example, Content Technologies, Inc. (CTI), a US-based company, uses Deep Learning to create textbooks tailored to specific course contents and students' needs. A syllabus is uploaded into the CTI engine that creates personalized textbooks and contents. Another AI-powered tool is Netex Learning which helps anyone design responsive curricula.

* Teachers and education administrators use data and learning analytics to understand their students' progress and behaviour. Then, students can improve their performance through guided experience. OnTask is a popular tool that follows user-defined data points teachers identify as important, to help them track students' progress, and give more frequent, better, personalized feedback.

* AI can help identify students with learning issues, diagnose the areas of difficulties and suggest a plan to assist these students.

* There are several self-paced tools based on AI technology that provide professional development to educators.

Conclusion

The main purpose of this paper is to start a conversation about the idea of including AI in high school. It also suggests a standard AI curriculum for high schools that relies on the general guidelines introduced by the UNESCO and draws from traditional courses taught in universities around the world for decades. However, this paper attracts the attention and focuses on the experimental aspects of introducing this field that is entirely new to secondary-level education. This contribution is also suggesting that it is possible for African high-schools to step into the arena and build their own AI curricula and prepare the new generations for the challenges of the coming 21st century industrial revolution.

Acknowledgments

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