AI Curriculum for Junior Secondary Education

Preface

With rapid advancements in computing, communication, sensory technologies, as well as the ever-increasing availability of big data, Artificial Intelligence (AI) is infusing into our everyday lives and fundamentally transforming the ways we live and work. Around the globe, governments are realizing the disruptive power and potential of AI. Countries are incorporating AI curricula in educating the young generation to ensure that they will be future-ready. The Chinese University of Hong Kong (CUHK) recognizes the need for introducing AI into Hong Kong's pre-university education to cultivate the competitiveness of our young generation.

Funded by The Hong Kong Jockey Club Charities Trust, the **CUHK Jockey Club AI for the Future Project** ("The Project") brings together the strong expertise of CUHK's Faculty of Engineering and Faculty of Education. The Project aims to create a new AI curriculum, a sustainable AI education model, and relevant supporting infrastructure to establish a conducive ecosystem for AI education in Hong Kong, starting with the junior secondary forms. The Project also incorporates in the process the teaching experiences of front-line teachers, as well as empirical assessments and iterative refinements of the course content in achieving our educational objectives.

The AI curriculum presented in this package is the outcome of the Project's work in the first year, comprising a set of novel AI teaching materials designed for junior secondary school students. The curriculum covers a total of 12 chapters and 55 modules. Topics include *"See", "Hear", "Speak", "Read", "AI Reasoning", "Simulate", "Think and Create", "Social Good, Social Impacts and Challenges of AI", "AI and Ethics"* and *"AI and Future of Work."* The modules are organized into three levels (Beginner, Intermediate and Advanced) to allow for flexible teaching by secondary schools.

The Project devotes particular attention towards AI Ethics to instill in students the ethical principles related to the use of AI, covering *Transparency, Justice and Fairness, Beneficence, Responsibility and Privacy*. We hope the curriculum will suit junior secondary students well, and equip them with sufficient AI knowledge, skills and ethical concerns that will help them overcome societal challenges of the future.

CUHK Jockey Club AI for the Future Project

Key Project Members

The Project is divided into five main components: AI Curriculum Development, Assessment and Evaluation, Teacher Development and School Engagement, E-platform, and Public Education and Dissemination.

Principal Investigator

Professor Yeung Yam

Professor Yeung Yam received his B.Sc. degree in Physics from CUHK, and his M.S. and Sc.D. degrees in Aeronautics and Astronautics from MIT. He is the Director of the CUHK Shenzhen Research Institute and a Research Professor at the Department of Mechanical and Automation Engineering. He is also the Associate Master of the Lee Woo Sing College of CUHK. Professor Yam served as the Chairman of the Department of Mechanical and Automation Engineering from 2004 to 2011, and the Interim Dean of the Faculty of Engineering of CUHK in 2018. He is currently serving as the Founding Director of the Intelligent Control Systems Laboratory. His research interests include intelligent systems, human skill acquisition for dexterous manipulations, endoscopic-based surgical robots, computational method for controller design, bio-system modelling and analysis, and technology development for industrial applications. He is a Fellow of the IMechE and a Fellow of HKIE. He has published over 200 technical papers in his fields of interest.

Key Project Members

Co-Principal Investigator
Curriculum Development Team Head
Assessment and Evaluation Team Co-Head

Professor Helen Meng

Professor Meng is Patrick Huen Wing Ming Professor of the Department of Systems Engineering & Engineering Management at CUHK. She received the S.B., S.M. and Ph.D. degrees in Electrical Engineering from Massachusetts Institute of Technology. She is a recognized scholar in the field of multilingual speech and language processing, multimodal human-computer interaction and Big Data analytics. She leads the interdisciplinary research team that received the first RGC Theme-based Research Scheme Project in Artificial Intelligence in 2019. She is also an invited member of the AI4SDGs AI for Children Working Group. Her recent awards include the 2019 IEEE Signal Processing Society Meritorious Service Award, 2018 CogInfoComm Best Paper Award, 2017 Outstanding Women Professional Award (one of the twenty since 1999), 2016 Microsoft Research Outstanding Collaborator Award (one of 32 academics worldwide), 2016 IBM Faculty Award, 2016 IEEE ICME Best Paper Award, 2015 ISCA Distinguished Lecturer, 2015 HKCS inaugural Outstanding ICT Women Professional Award and 2012 Asia-Pacific Signal and Information Processing Association (APSIPA) inaugural Distinguished Lecturer. She is a Fellow of IEEE, ISCA, HKIE and HKCS.

Key Project Members

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Professor Ching Sing Chai

Professor Chai is Associate Dean (Postgraduate Studies) of the Faculty of Education, as well as a Professor in the Department of Curriculum and Instruction. He received B.A. from National Taiwan University. He then received P.G.D.E. and M.A. in Instructional Design and Technology from Nanyang Technological University and later Ed. D. in Teaching and Learning from University of Leicester. His research interest includes Teacher Education, Technological Pedagogical Content Knowledge, Teacher beliefs and ICT in Education.

Key Project Members

Teacher Development and School Engagement Team Head

Professor Thomas Chiu

Professor Chiu is an Assistant Professor in the Department of Curriculum and Instruction. He has a strong academic background in Mathematics, Technology and Teacher Education – B.Sc. (HKUST), P.G.D.E, Ph.D. (HKU), M.Sc. (PolyU), Oracle Super Trainer and Microsoft System Trainer, with extensive teaching and leadership experience in schools. His expertise is in quantitative and design-based research methodologies. His specializations include educational technology (multimedia learning, IT in education policy, online pedagogy), and motivation and learning (self-determination theory). His research domains focus on mathematics and technology. He is an international scholar of the Center for Self-determination Theory. He has recently proposed a model of student engagement for online learning and a sustainable curriculum planning approach for Artificial Intelligence education for schools.

Key Project Members

E-Platform Team Head

Professor Irwin King

Professor King is Chairman and Professor of the Department of Computer Science and Engineering. He has launched an eLearning platform KEEP (Knowledge & Education Exchange Platform), developed and initiated by CUHK with all partner institutions, as a project investigator. He received his B.Sc. degree in Engineering and Applied Science from the California Institute of Technology, and his M.Sc. and Ph.D. degrees in Computer Science from the University of Southern California, Los Angeles. He was elected IEEE Fellow in 2019. He also owns six international patents, including the VeriGuide System which is plagiarism detection software to detect similar sentences and perform readability analysis of text-based documents in both English and Chinese to promote academic integrity and honesty. His research interests cover machine learning, social computing, web intelligence, data mining, and multimedia information processing.

Key Project Members

Curriculum Development Team Co-Head
Teacher Development and School Engagement Team Co-Head

Professor Savio Wong

Professor Wong is Associate Professor of the Department of Educational Psychology. He received his Bachelor's degree in Cognitive Science and PhD in Psychology from The University of Hong Kong. He also received Fulbright-RGC HK Senior Research Scholar Award and was appointed as Visiting Associate Professor at the Massachusetts Institute of Technology in 2018. His research interests are in neural mechanism of impulsivity and decision-making in adolescents, psychophysiological markers of emotion, application of wearable sensors in special education (e.g. assisting the learning of students with autism or ADHD).

Curriculum Development Team

This AI Curriculum is the productive outcome of a co-design process involving CUHK's Faculty of Engineering, Faculty of Education and six Pioneering Secondary Schools in Hong Kong.

Faculty of Engineering

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Pioneering Secondary Schools

 Diocesan Girls' School

 Munsang College

 HKSKH Bishop Hall Secondary School

 The Chinese Foundation Secondary School

 Man Kwan Pak Kau College

 Ying Wa College

Curriculum Structure

Gaining awareness of the background, capabilities, and future implications of AI technologies

Awareness

Knowledge

Understanding how AI technologies work

Interactions

Empowerment

Ethics and Impact

Experiencing AI technologies with different applications

Exercising creativity in design, development and integration of AI technologies and systems

Considering ethical issues and social impact brought about by AI

Courseware

Slides
Guided Discussions
Worksheets
Hands-on Exercises
Supplementary Information

* The above content is authored in English. A translated Chinese version is also included. The courseware is to be supported by an E-Platform currently under development. Some modules are further supported by associating AI toolkits and software for hands-on learning.

Curriculum Matrix

| Chapters	Modules				
	Awareness	Ethics and Impact	Knowledge	Interactions	Empowerment
1. Introduction to AI	✓	✓	✓	-	-
2. Fundamentals of AI	✓	✓	✓	✓	-
3. See	✓	✓	✓	✓	✓
4. Hear	✓	✓	✓	✓	✓
5. Speak	✓	✓	✓	✓	✓
6. Read	✓	✓	✓	✓	✓
7. AI Reasoning	✓	✓	✓	✓	✓
8. Simulate	✓	✓	✓	✓	✓
9. Think and Create	✓	✓	✓	✓	✓
10. Social Good, Social Impacts and Challenges of AI	✓	✓	✓	✓	✓
11. AI and Ethics	✓	✓	✓	-	✓
12. AI and Future of Work	✓	✓	✓	-	✓

✓ Beginner Level ✓ Intermediate Level ✓ Advanced Level

12 Chapters with 55 Modules divided into three levels to allow for flexible teaching by secondary schools

Content Overview

This infographic captures an overview of the course content. We begin at the core, with the introduction of AI and the key drivers of its recent, rapid advancements, namely, Big Data, Machine Learning and Cloud Computing. Another core emphasis is on ethical considerations in the use of AI applications and their societal impacts. The middle circle in pink illustrates our coverage of various branches in AI, including perceptual machine intelligence such as "see" and "hear", human language technologies such as "speak", "read and write", machine reasoning, use of simulation for problem-solving, and how machines can generate content "creatively". The outer circle in green shows various possible applications that are supported by AI, many of which carry important societal implications, especially on the future of work.
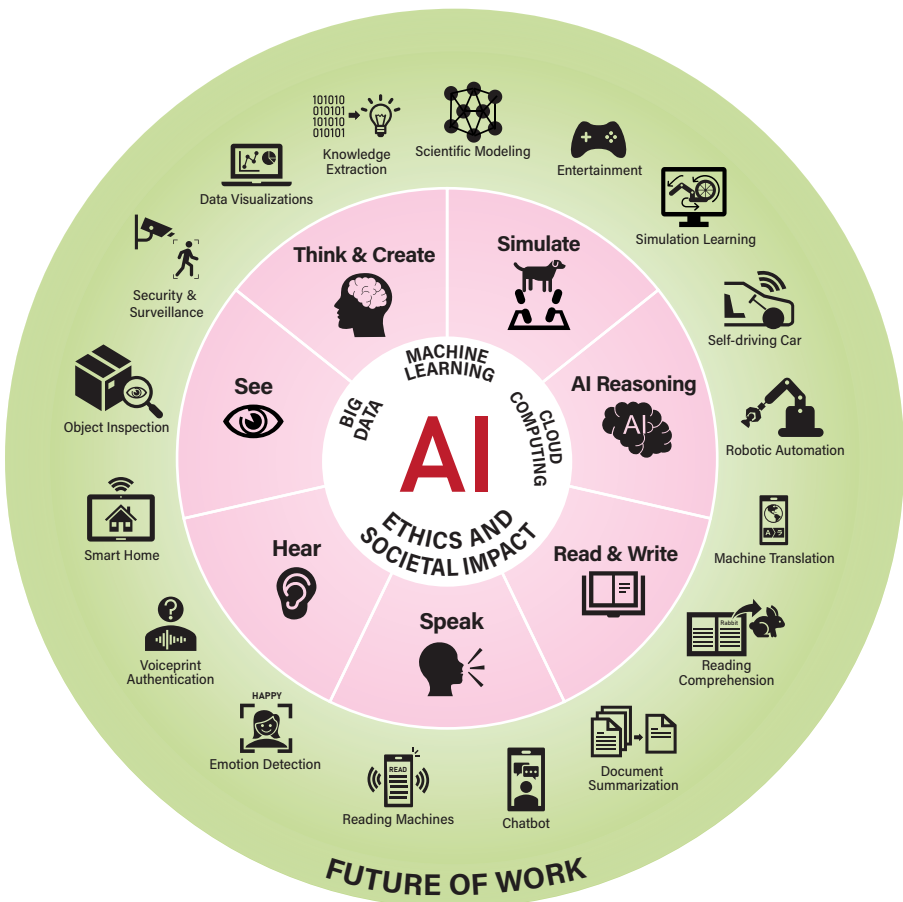
Overview of Chapters

Chapter 1 – Introduction to AI

This chapter presents an introduction to AI which provides students with an awareness of AI in daily life, and what AI is. Students will learn the types of AI, the inputs/outputs of AI, and AI testing. They will be given real-life examples to understand the limitations of AI. Built on the basic awareness and knowledge, this module will enhance students' understanding in AI and awareness of ethical issues in AI.

Learning Objectives:

1. To develop an awareness of AI, what it can do and what it cannot do;
2. To identify the use of AI in daily life;
3. To obtain knowledge of the history of AI;
4. To obtain knowledge of different types and subtypes of AI, possible inputs/outputs and the concept of machine learning; and
5. To recognize the importance of ethical principles in AI.

Chapter 2 – Fundamentals of AI

This chapter introduces the fundamentals of AI. Students will learn about typical AI systems via the IPO (input, process, and output) framework. They will also be presented with examples to help them understand the basics of machine learning, which enables AI models to "learn" from training data in order to make "intelligent" decisions or predictions. Built upon the basic awareness and knowledge, this chapter will also introduce students to ethical considerations in AI applications.

Learning Objectives:

1. To gain an awareness of the fundamentals of AI via an IPO framework, big data, machine learning and AI model training and testing;
2. To understand concepts related to data, including the 5Vs of big data, and aspects of data quality;
3. To understand the basic mechanisms in machine learning, AI model training and testing; and
4. To understand the importance of training data quality in relation to the performance of AI models and systems, as well as related ethical considerations.

Overview of Chapters

Chapter 3 – See

This chapter provides an elementary introduction to computer vision, the techniques that enable computers to see the world. In this chapter, students will be exposed to various applications in everyday life that can benefit from computer vision techniques. Driven by the curiosity to learn how these techniques are developed, students can then proceed to learn the basic knowledge of image processing and computer vision. At the end, this chapter will guide students to build a simple application using what they have learned from the course, and to discuss possible ethical issues related to computer vision techniques.

Learning Objectives:
1. To develop the awareness of computer vision techniques and their use in everyday life;
2. To understand the basic concepts of digital images;
3. To understand the basic pipelines of image recognition - features and classifiers;
4. To acquire basic skills to build a simple visual recognition system; and
5. To be aware of ethical issues that may arise from the use of computer vision techniques.

Chapter 4 – Hear

This chapter provides an introduction to the knowledge of human speech, and how AI can "hear" human speech by using Automatic Speech Recognition (ASR). Students will be aware of ASR applications that are used in our everyday lives. Basic concepts about spoken language, including acoustics, phonetics and linguistics, will be presented. The pipeline of ASR will be discussed. This chapter will introduce some ethical aspects related to applications of ASR technologies.

Learning Objectives:
1. To gain awareness of how machines can "perceive" speech through ASR technologies;
2. To appreciate the challenges in developing ASR technologies;
3. To learn about the key processes in ASR;
4. To raise awareness of ethical considerations in applications of ASR; and
5. To gain hands-on experience with ASR systems and understand the capabilities and limitations of ASR technologies.

Overview of Chapters

Chapter 5 – Speak

AI aims to support spoken language communication, which requires not only the recognition of input spoken language (covered in Chapter 4), but also the synthesis of output spoken language. This chapter introduces the technology of text-to-speech synthesis (TTS), which enables machines to "speak". Students will gain an awareness of using TTS in real-life applications, knowledge in the science of speech production, and the incorporation of such knowledge in TTS. Ethical considerations related to TTS will also be discussed.

Learning Objectives:
1. To gain awareness of how humans produce speech and the rich information encoded in speech signal;
2. To appreciate the challenges in developing TTS technologies;
3. To learn about the approach to achieve speech synthesis and the key processes involved;
4. To gain awareness of ethical considerations in applications of TTS; and
5. To gain hands-on experience with TTS and ways to manipulate the technology to obtain different speech outputs.

Chapter 6 – Read

This chapter introduces the field of natural language processing (NLP) under AI. Students will learn about how machines can process and "understand" text, such as in information extraction, topic classification, machine translation, summarization and question answering. They will also be guided to explore how machines process natural language. This chapter will also discuss some ethical issues related to NLP.

Learning Objectives:
1. To develop an awareness of how machines process text, or natural language;
2. To appreciate the ambiguity in human language and the challenges in developing NLP technologies;
3. To learn about NLP processes through the textual sentiment analysis as an example;
4. To gain awareness of ethical considerations in NLP applications; and
5. To gain hands-on experience in development of a simple sentiment analysis system.

Overview of Chapters

Chapter 7 – AI reasoning

Humans interact with the world through the three steps: "sense", "reasoning" and "act". In this chapter, we introduce students to the process of how humans arrive at a specific action to take based on the information available, and show how machine can be made to emulate such a reasoning process. Specifically, we categorize human reasoning roughly into the three levels: skill-based, rule-based and knowledge-based. Generally, AI machines are classified as the ones capable of performing some extents of knowledge-based reasoning. In this chapter, students will learn the basic principles of the three levels of reasoning and their ensuing performances through the example of a moving car stopping at a traffic light. They will also be learning via interactive simulations and/or experimentation with a hardware toolkit. Most importantly, they will have a chance to explore and discuss the potential ethical issues arisen from AI reasoning.

Learning Objectives:

1. To understand the basic principles and components of human reasoning;
2. To understand that AI is the technology of injecting human reasoning process into machines;
3. To be mindful of the ethical issues and trade-offs in AI reasoning; and
4. To experience the training and execution of an AI Driver via an interactive simulator and/or hardware toolkit.

Chapter 8 – Simulation

This chapter introduces AI techniques that read continuous data from daily life and play with these natural processes to simulate. In this chapter, students will be aware of the emerging technologies in simulation and discuss why it could help people better explore unseen or unusual cases in many activities. Discussion on some general concepts in simulation will also be introduced. To raise awareness in the related ethical issues, discussions in several domains, including privacy, copyright and other issues will be presented. In the further sections, students will learn the data structure and representation for continuous data and how AI models recognize them. For advanced studies, students will learn to recurrently make decisions and creation along the time, and will have hands-on experiments on AI-assisted game simulation applications.

Learning Objectives:

1. To gain awareness to applications that use simulation techniques and discuss how simulation is different from human thoughts and why simulation will be a hot topic in AI;
2. To be mindful of the ethical issues and trade-offs arisen from simulation technologies;
3. To review how AI senses and analysis, and discuss the occasions when the input is not static but with dynamic changes;
4. To understand the basic principles of Recurrent Neural Network, which recurrently reads data and predicts outputs with respect to input changes;
5. To understand the basic idea of Q-learning, which is a modern framework to simulate many scenarios without known rewards;
6. To get hands-on experience with experiments on Recurrent Neural Networks; and
7. To design/conduct extended studies on deep reinforcement learning and understand the deeper insights of reinforcement learning and Deep Q Network (DQN).

Overview of Chapters

Chapter 9 – Think and Create

This chapter introduces AI techniques that understand real-life information and create novel content, which is usually known as generative synthesis. In this chapter, students will be aware of the recent applications based on generative synthesis and explore the differences in content creation between human and AI-based systems. As generated content is usually considered not real in human point of view, students will discuss the potential ethical issues of generative techniques, including security, identity, copyright and many other issues. Students will first have a short review on previous chapters on feature extraction and analysis, which composes the "think" part. Then, they will learn the basic principles of generative image network and adversarial learning, which supports the "create" part. They will also have chances to discuss and build experiments on generative synthesis and get a deeper understanding on the related topics.

Learning Objectives:
1. To gain awareness of generative synthesis and emerging applications with related techniques;
2. To be mindful of the ethical issues and trade-offs arisen from generative techniques;
3. To review the idea of "features", which is the basic of generative synthesis;
4. To understand the basic principles of generative image network which reassembles features and rescales them to create novel contents;
5. To understand the idea of Adversarial Learning, which helps to further increase the fidelity and realness of the created contents;
6. To get hands-on experience by experiments on generative synthesis; and
7. To design/conduct extended studies on given experiment testbed and play with some potential new ideas.

Chapter 10 – Social Good, Social Impacts and Challenges of AI

This chapter presents the potential benefits and negative impacts that AI could bring to the society. It provides students with an awareness on how AI could be employed to improve care services in everyday living, and how AI could be used for disruptive purposes. Students will go through self-selected examples to understand how AI affordances can be harness for beneficial purposes. They will apply what they have learned in previous chapters to design possible uses of AI to promote common good.

Learning Objectives:
1. To understand what is social good;
2. To be able to articulate aspects of social impacts and challenges of AI;
3. To learn how AI contributes to social good via different examples;
4. To learn how a misuse of AI could harm society via different examples; and
5. To grasp the idea on how AI could be employed for an identified social problem.

Overview of Chapters

Chapter 11 – AI and Ethics

This chapter introduces students to AI Ethics – bringing their attention to the ethical considerations concerned with the development of AI technologies. The chapter introduces the fundamental concepts on AI Ethics, and discusses the principles of ethical development and application of AI technologies. Through a series of case studies, this chapter guides students to develop a critical sense in assessing AI ethics from different perspectives. This chapter also highlights the importance of balanced data and discusses the impact (and problems) arising from data bias in AI systems.

Learning Objectives:
1. To gain awareness that AI can do good and AI can do harm;
2. To learn about the ethical principles of AI;
3. To understand how bias develops in data and how it impacts AI applications; and
4. To acquire the skills in applying ethical principles to analyze and assess AI applications.

Chapter 12 – AI and Future of Work

This chapter presents an overview of the future workspace with the advancement of AI. Students will have the opportunities to evaluate the strength and weaknesses of human beings and AI in various jobs. Through the process, students are expected to develop a positive attitude toward the potential changes in the job nature brought by AI and understand how to prepare themselves to meet with the challenges of the future society.

Learning Objectives:
1. To gain awareness of how technology advancement has revolutionized human society and improving livings throughout history;
2. To learn about how AI have changed the nature of existing jobs, and envision the direction of advancement by AI in the future;
3. To understand the ethical concerns of using AI in the workspace; and
4. To analyze the role of AI on the jobs that students are interested in and generalize the possible effects of AI on future jobs.

Credits

The CUHK Jockey Club AI for the Future Project ("The Project") wishes to acknowledge the use of illustrations/ pictures/ videos/ case studies for educational purposes from the following companies/ organizations:

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