Six Key Principles in Designing Artificial Intelligence (AI) Curriculum for Middle Schools

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Abstract

Recently, AI education in K-12 schools has begun in full swing; however, educators and experts found designing AI-related curricula challenging. We seriously lack of the relevant studies to inform practitioners to design and implement AI-related curricula. Curriculum design approaches could inform researchers and curriculum designers how to planning a quality and sustainable curriculum. Teacher perspectives are very essential to make sense of the emerging AI technology for curriculum designing. According. This paper used four curriculum design approaches – content, produce, process and praxis as the framework and thematic analysis to analyze data collected from 12 K-12 schools including individual interviews, teaching documents, meeting minutes, school-based curriculum documents of 24 teachers. Hence, we posited 6 key principles - definition, relationale, impact (content), flexibility, learning, communication (process) - in designing AI curriculum.

Keywords: Artificial Intelligence Education, Curriculum Design, K-12 schools, design principles

Introduction

The explosive growth of Artificial Intelligence (AI) is fundamentally transforming the way we live, learn and work. The emerging ubiquity of innovative AI applications has significant implications to our society and our future generations. AI has grown way beyond a branch of professional and academic research. It is necessary to move AI education from professionals to the mainstream (Chiu and Chai, 2020). Topics in AI, which have conventionally been covered in post-secondary education, are making their way into K-12 classrooms as a global strategic initiative (Pedró et al., 2019). This initiative aims to educate the future generation. AI education in K-12 not only helps children understand what the emerging technologies are and how they work, but also inspires future AI users, ethical designers, software developers and researchers (Pedró et al., 2019). However, curriculum design for K-12 schools is more complex compared to post-secondary education. It involves considerations of how the new initiative translates into practice and considerable variation in delivery can be expected from school to school. Hence, designing AI or AI-related curricula is challenging (Chiu & Chai, 2020; Touretzky et al., 2019).
To address the global initiative, we lack of relevant studies that informing how to design a quality AI curriculum for K-12. Curriculum designing theory could inform researchers how to design the curriculum (Chiu & Chai, 2020). As such, this study used four basic curriculum theory approaches - curriculum as content, product, process and praxis – as a framework to suggest six principles in designing AI curriculum for K-12 schools.

**Literature Review**

**Four curriculum design approaches**

Curriculum refers to the totality of student experiences in the educational process that are planned and guided by the teachers, and learned by the students in any environments (e.g. group, individual, classrooms, after schools, online) (Kelly, 2009; Marsh and Willis, 2003). Current literature points out four major design approaches to understand curriculum. They are curriculum as content, product, process and praxis (Kelly, 2009; Grundy, 1987; Glatthorn et al., 2018), and theorize curricula design. They are useful for researchers to study curriculum innovation and for practitioners to create or revise curriculum.

The curriculum as content approach sees education as transmission of knowledge. This approach is thus a body of subject content, i.e. a syllabus, and the identification of effective teaching methods (Blenkin et al., 1992; Glatthorn et al., 2018; Kelly, 2009). Teachers will follow suggestions stated in the curriculum - an order of contents, a knowledge structure, and teaching methods to teach. They tend to limit their lesson planning to a consideration of the body of knowledge that they want to deliver. The justification for the curriculum lies in its content, but not its effects. This view of curriculum is very popular amongst primary school teachers (Kelly, 2009).

The curriculum as product see teaching as instrumental to enhancing student competencies. It takes the performance and competence of students as the core components (Bonnett et al., 1999; Swanson & Pashby, 2016) and the assessment of student learning outcomes as main goal (Glatthorn et al., 2018; Kelly, 2009). The curriculum development is viewed as a technical exercise. This curriculum approach aims to prepare students adequately for specific tasks; therefore, its development requires detailed attention to what the students need to learn and know. This approach is often found in many technical, skill-based, training programmes where specific tasks or jobs have been identified. It often prepares lists of competencies, inform students what they must learn and how they will do it; therefore, the students have little or no voice to their learning. By having pre-defined outcomes, this approach tends to direct attention to teaching. These two approaches create set of documents for implementation. However, contemporary education advocates student-centered approaches - curriculum as process and praxis by shifting the focus of curriculum from teaching to learning (Kelly, 2009).

The curriculum as process sees teaching as development and emphasizes how teachers, students and content interact and evolve, rather than pre-defined content and outcomes. The learning goals have will change as the triadic relationships evolve (Kelly, 2009). The curriculum is not a standard package of materials for all the teachers to cover and deliver in their classrooms, but a guideline about teaching practice (Glatthorn et al., 2018). It could tell us what teachers and students do to prepare and evaluate the lessons, i.e. what actually happens in the classroom (Chiu & Chai, 2020). For example, choices of content depend on what fit student needs and interests; learning outcomes are developed from the collaboration of teachers and students, but not applied...
to all the students. In this curriculum, students are not treated as objects but as subjects who have voices (Chiu & Hew, 2017; Chiu & Lim; 2020).

The process approach emphasizes meeting student needs, and does not make clear statements about the interests it serves. Bringing this issue to the center of the process, the curriculum as praxis sees teaching as committed action, and focuses on making sense of the knowledge in the learning process by connecting it to real world applications (Glatthorn et al., 2018; Grundy, 1987). Guided by teachers, students will learn with peers to solve real-world problems by working out an action plan for acquiring the content knowledge and achieving the outcomes. The learning process and outcomes are continually evaluated.

Adopting a particular curriculum design approach has a major influence on teaching and learning strategies (Priestley & Biesta, 2013). For example, the content approach encourages teacher-centered approaches to teaching; the heavy emphasis on product encourages drilling and practice; the process approach leads to the design of student-centered learning activities; the practice approach tends to adopt problem-based learning. However, these four approaches to curriculum designing are not mutually exclusive (Glatthorn et al., 2018; Kelly, 2009). For example, followers of the process approach would not argue that content and assessment are unnecessary and negligible, but the selection of content is a secondary consideration. The first two approaches adopt behavioral stance and structured teaching, and set objectives and attainment targets that must be taught to students. The last two approaches are “the curriculum is not simply a set of plans to be implemented, but rather is constituted through an active process in which planning, acting and evaluating are all reciprocally related and integrated into the process” Grundy (1987). They draw on student-centered learning theory, and educational and developmental psychology. They identify and nurture the strengths of students, with every student taking an active role in her or his learning, and with both students and teachers developing the curriculum.

AI education for K-12 research

Most studies on AI education for K-12 focused on what techniques and skills should be included and what AI tools should be adopted in teacher teaching (Burgsteiner et al., 2016; Papert and Solomon, 1971; Sensetime, 2018; Williams et al., 2019). For example, the first formal study of teaching children AI was to explore AI concept through LOGO programming and Turtle robot (Papert and Solomon, 1971), which was a pilot teaching, rather than a curriculum. SenseTime (2018) worked with East China Normal University, to write the first textbook series for high schools - Fundamentals of Artificial Intelligence. The content in these series is aligned with AI courses in higher education, hence they focused on techniques and skills. The series are appropriate for student with higher academic abilities or stronger engineering knowledge. This curriculum adopted content and product approaches. Moreover, Williams and colleagues (2019) from Massachusetts Institute of Technology examined different AI learning activities with robots on children learning. Their ideas focused on more process and praxis approaches. In sum, these studies did not useful guidance us to design AI formal curricula for K-12, but provided crucial but fragmented findings in the research of AI K-12 curriculum design. Therefore, there is neither existing established curriculum nor well-defined content knowledge for secondary schools. To address the global initiative, it is essential to conduct research on the curriculum design so that this educational innovation can be sustained. Curriculum design approaches could inform researchers and curriculum designers how to planning a quality and sustainable curriculum (Chiu & Chai, 2020; Kelly, 2009; Marsh & Willis, 2003).
This Study

Research Question and Participants

Teacher perspectives are very essential to make sense of the emerging AI technology for curriculum designing (Chiu, 2017; Chiu & Churchill, 2016; Cope et al., 2020;). Accordingly, this paper used the four major curriculum design approaches – content, product, process and praxis – as a framework to investigate the views of AI teachers’ curriculum and teaching experience on key principles for designing AI curriculum for K-12 education. The research question is “How do the four approaches relate to the curriculum design?”.

The participants were 24 teachers from 12 Hong Kong middle schools (2 from each school), and designed and taught their own school-based teaching units of AI. The average age of the teachers is 30.5 years old; 20 teachers are male, and 4 are female. The schools were located in different districts and varied in socioeconomic backgrounds and academic standards.

Method

A qualitative method was adopted to achieve this study goal. Sixty-minute individual semi-structured interviews with the teachers were conducted to understand what, why and how they taught the units. Documented data including their teaching materials (plans, slides and worksheets), meetings minutes, emails, teacher reflections and student work, were collected. To analyze the data, this paper used thematic analysis to identify the essential components of AI curriculum because the analysis usefully summarizes key features of a large body of data, and highlights similarities and differences across the data set; therefore, offers a useful method for working within participatory research paradigm and informing curriculum development (Braun and Victoria, 2006).

Results and Discussions

The final thematic map devised in the results consisted of two themes: (i) content and product and (ii) process and praxis, hence this paper posited 6 key principles - definition, relationale, impact (content and product), flexibility, learning, communication (process and praxis) - in designing AI curriculum, See Figure 1. The followings explains the 6 subthemes (key principles).

![Figure 1 The final thematic map](image-url)
Theme 1: Curriculum as Content and Product

All the AI teachers highlighted that there was no existing and appropriate content for their teaching. Majority of them shared that the content and learning outcomes should be Knowledge in AI (what AI is), Process in AI (e.g. how AI works) and Impact of AI (social good and ethical use). See the following expert.

“I did not have any appropriate content for my students to learn. The existing textbooks we bought were not too technical and professional.” (Teacher 1)

“Students should know who the background and history of the AI technologies.”
(Teacher 4; Knowledge in AI)

“Students should learn about how the computer develops the ability, which includes modeling, statistics and learning algorithm. ... They also should learn how AI technologies process data in different aspects.” (Teacher 5, Process in AI)

“I believe my students should learn about societal and personal impact of AI locally and globally.” (Teacher 8, Impact of AI)

“My students should consider ethical issues from different perspectives of stakeholders including developers, policy makers and users. They should not only explore ethical issues from different perspectives, but also develop principles for the ethical design and deployment of AI-based technologies.” (Teacher 10, Impact of AI)

Theme 1.1: Definition - What is AI?

This paper analyzed all the data such as teaching slides, school-based teaching materials and teacher interviews, and showed that the definition of AI should comprising (1) Development of AI: The impact of AI in our everyday life is more sophisticated, from the business and entertainment to your mobile phone and social media; from providing online help to recognizing our voice and face. More integration of AI technologies in our everyday lives will be seen relatively soon. Students should understand the history and development of AI: fourth industrial evolution and its changes of workforce, evolutions of technologies including big data and deep learning, as well as the future development. (2) Learning from data: AI refers to the ability of a computer to perform tasks that are similar to that of human learning and decision making (Shubhendu and Vijay, 2013). Students should learn about how the computer develop the ability, which includes modeling, statistical inference and learning algorithm. To train better model and/or algorithm, this requires cloud computing to process tremendous amounts of data.

Theme 1.2: Work - How do different AI technologies work?

The analysis further indicated that perception and technical skills should be included when teaching how AI technologies work. (1) Perception: “Human learning and decision marking” is one of the core knowledge in AI, i.e. it requires computers to perceive our world by collecting data. Perception is ability to organize, identify, interpret the sensory data to represent and understand the presented information. Students should understand how AI technologies process data in different aspects including see, hear, speak, think, create and reasoning through experiencing, interacting and coding. (2) Technical skill: AI is about so much more than coding. Students should be able to perform some mathematical operations and train classifiers / models by drawing upon main machine learning libraries, and be acquainted to the notion of Neural Networks. For example, adding AI elements to existing computer applications and/or students’ own work.
Theme 1.3: Impact - How do AI technologies affect our society and life?

Finally, the analysis further showed that impact and ethics of AI are very important in K-12 education. Therefore, the two suggested areas in the analysis are (1) Global and local impact: AI technologies solve real world problems for us on a daily basis and it has the capability to turn every interaction into an endless learning process. They have been making negative and positive impact in our world, society, and personal lives. All teacher teaching adopted an approach of “explainable AI – from local explanations to global understanding” (Lundberg et al, 2016), which make connections between the subject and the students’ life. Students could have better understanding of the societal and personal impact of AI by combining many high-quality local explanations that allow to represent global understanding. (2) AI ethnics and human bias: AI ethnics and human bias is another core knowledge in the all teacher teaching. Their goal is to train students to be an ethical designer. AI technologies that computer engineers view as ethical may be seen as unethical by the users. For example, “Google fixed its racist algorithm by removing gorillas from its image-labeling tech”. Students should consider ethical issues from different perspectives of stakeholders including developers, policy makers and users. They should not only explore ethical issues from different perspectives, but also develop principles for the ethical design and deployment of AI-based technologies.

Theme 2: Curriculum as Process and Praxis
In this theme, the analysis suggested three subthemes - learning, communications, and flexibility.

Theme 2.1: Learning - How do students learn AI knowledge and concept?
All the teaching suggested two important areas that can facilitate student AI learning. They are (1) Knowledge structure: The structure informs how to learn AI knowledge and concept in an effective way because it promotes self-regulated learning. The 5-stage structure is (i) raising students’ awareness by building associations between real-world applications of AI and their daily experiences, (ii) providing foundational understanding that connects student current learning to cutting edge applications, (iii) facilitating student understanding of how different AI technologies work through experiencing, interacting and coding accessible AI applications, (iv) engaging students with appropriate design challenges, and (v) preparing students to be ethical and responsible local and global citizens. This knowledge structure can scaffold and bridge the new learning by allowing going back into previous and drawing it forth. (2) Authenticity: How authentic of the learning design is crucial for AI education due to its abstract nature. Students should learn AI with reference to real-world applications which they are likely to encounter in their daily experiences (Chiu & Chai, 2020). Learning by design that is an emerging paradigm in education and it is advocated as the key instructional approach to cultivate students as ethical designers, developers and users of AI technologies (Tsai et al, 2013). Students should design solutions with authentic problems and examine their designed solutions with reference to AI ethical principles. Being grounded in authentic learning, students should develop better historical and contextual understanding of AI.

Theme 2.2: Communication - How do teachers/teaching materials communicate with students?
All the AI teachers reported that AI terminologies are unfamiliar to the teachers/students and may be too technical for general education. They suggested (1) using consistent terminology
to facilitate the communications between teachers and students. In AI teaching, there are many
different technical and abstract terminologies such as Big data, cloud computing and machine
learning. The terminologies are too new, rigid and rigorous for school general education;
sometimes, different terminologies are used to describe the same concepts. Therefore, it is very
different for most students to comprehend the relevant concepts and knowledge well when using
inconsistent terminologies. Curriculum should not be presented as finished abstractions, but
should include the student preconceptions and should incorporate how the students view their
own world and language (Chiu & Churchill, 2015; Chiu & Mok, 2017; Chiu & Chai, 2020). The
inconsistent and abstract terminologies become one of main obstacles in teaching them all
technical knowledge. Accordingly, using consistent and familiar languages facilities the
communications between teachers and students. For example, using “Input, process and output”
to demonstrate the learning mechanism throughout the curriculum, i.e. how AI learn and process
data. (2) using graphical representations. A picture is worth a thousand words. Using graphical
representation to present and explain abstract terminologies, knowledge and concept could
facilitate teacher teaching and student learning in the curriculum (Chiu & Churchill, 2015; Chiu
& Mok, 2017; Chiu et al., 2020). For example, a diagram with a timeline we designed represents
and explains the definition and develop of AI. This diagram also gives the students an overview
of whole curriculum. These two subthemes are evidenced by the following excerpt.

“I used diagrams to explain what machine learning is.” (Teacher 2)
“I found many terms so abstract in AI, and needed to suggest new ways to explain them to
my students.” (Teacher 10)

Theme 2.3: Flexibility - How does the curriculum address the needs of schools and
students?

All the teacher teaching reported that it was necessary to revise their teaching materials
and improve pedagogy in cycle; therefore, flexibility is very important. The majority suggested
that using module and level up approach would offer high level of flexibility to revise the
curriculum. In the approach, all the teaching units should have no prerequisite knowledge and
show the learning path, see the following excerpt.

“There is no way that I will not revise the teaching materials. I have a lot to improve.”
(Teacher 3)
“The teaching units must be explicitly designed for a specific goal (module). ... The units
should provide students with a clear learning path learn by themselves. (level up)”
(Teacher 5)
“Module-based curriculum should be adopted. Easier to choose the unit for teaching and
revising.” (Teacher 7)

The analysis suggested that the flexibility – module and level up design approach - is very
important in designing a new technology subject that requires extra tools and resources for
teaching and learning. It is because (1) School environment: Flexibility is very important for
school education. This design approach should offer maximum flexibility for school teachers to
teach the curriculum, based on their school environments and students’ interests and
competencies. The schools and teachers are able to balance “breadth” (i.e. broad coverage of
awareness, knowledge and ethical issues across the modules) with “depth” (i.e. choosing to deep-
design into a module to cover the technical aspects, interactions through hands-on activities and empowerment through innovative system implementations) in a flexible way. The curriculum is associated with AI teaching and learning tools for developing technical skills. Different schools have different resources, the curriculum should be flexible that allows teachers to make decisions in the best interest of individual schools and students. The teachers can select the tools that are suitable for the school classroom environments and are easily assessed by their students. This will maximize the student learning. (2) Students’ need: This approach allows high level of flexibility for teachers to design the best programmes for their students to fit their school culture and learning ability. For example, teachers who wants their students learning more about social issues, they can pick more modules in social impact and future work. The level-up content shows a pathway of learning in term of knowledge structure, which can direct and guide student learning. In other words, the teachers can decide what to teach, when to teach them, and how long to spend teaching them.

Conclusion and Limitations

Designing an appropriate AI curriculum seems remarkably challenging — particularly at K12 general education school level. This paper had considered difficulties in catering to the needs and interests of diverse students and schools, and posited the two themes and six key principles for designing the curriculum.

Currently, some emerging AI teaching practices in schools are about coding non-AI applications, for example, remote control appliances - adding microchips to a device. Such practice did not cover the main concepts of AI and may not be beneficial in equipping students with basic understanding and to get them ready for an AI infused world. The author hopes to contribute to the creation of appropriate K-12 AI curriculum with the six principles. However, the main limitation is that the six principles are not tested in the field; it is suggested future studies should examine the applications of the six principles.

References


