Develop AI Teaching and Learning Resources for Compulsory Education in China

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Abstract

Artificial intelligence course has been required to take for compulsory education students in China. However, not all teachers and schools are fully prepared and ready. This is partially because of the lack of adequate teaching and learning resources, which requires a major expenditure of time and effort for schools and teachers to design and develop. To meet the challenge of lacking appropriate resources in teaching and learning AI from grade 1 to grade 9, we developed AI knowledge structure and instructional resources based on Chinese national curriculum for information science and technology. Our comprehensive AI syllabus contains 90 core concepts, 63 learning indicators, and 27 teaching and learning resources, which have been implemented. The resources have been taken as model courses in teacher training programs and an exemplary course has been implemented in primary schools that verified the effectiveness of our resources.

Introduction

Artificial intelligence (AI) course embedded in information science and technology has been required to take for compulsory education students in China, due to the newly released national curriculum for information science and technology (Ministry of Education of The People's Republic of China 2022b). Chinese national curriculum of compulsory education is a series of comprehensive curriculum that Chinese students should learn from grade 1 to grade 9. In other words, more than 158,000,000 students in 207,200 primary and junior high schools (Ministry of Education of The People's Republic of China 2022a) are supposed to take at least one class hour of information science and technology (including AI) per week.

According to the national curriculum, information science and technology subject accounts for 1%-3% of 30-34 class hours per week (40-45 minutes per class hour), and AI course accounts for much of the content in the independent information science and technology curriculum. However, teachers and schools are not ready yet. This is partially because of the lack of adequate teaching and learning resources, which requires a major expenditure of time and effort for schools and teachers to design and develop. Since AI used to be an elective course that set up by best teachers in elite schools, most in-service teachers do not have solid ground of AI-related content, technological, and pedagogical knowledge (Koehler and Mishra 2009). In general, even if teachers are willing to develop AI courses and resources from scratch, most of them do not have enough time or sufficient capability. Related to this, most schools do not equip with dedicated software, hardware, or classroom for now.

To meet the challenge of lacking appropriate resources in teaching and learning AI from grade 1 to grade 9, we develop AI knowledge structure and teaching and learning resources based on Chinese national curriculum, which defines the content and standards of AI course. Our comprehensive AI course syllabus contains 90 core concepts, 63 learning indicators, and 27 teaching and learning resources. Teaching and learning resources include lesson plans, slides, demos, games, assignments, printable worksheet, half-done block-based programming projects, demonstrative python-based programming projects, instruction manuals, operation videos, quizzes, rubrics, etc. All instructional resources are free and open. Teachers and learners can easily access through a browser, which can save software and hardware investment for schools. By cooperating with Tencent, the largest AI company in China, we develop and release the AI knowledge structure, as well as teaching and learning resources (https://coding.qq.com/ai/), as shown in Figure 1. Teachers can re-design lessons based on our generalized instructional design, so that they can save time and incorporate expertise from other researchers.

In this paper, we will present a list of well-designed resources for teaching AI as a required course in compulsory education, which are developed and organized based on Chinese national curriculum. The resources have been taken as model courses in teacher training programs that gained teachers' high satisfaction. Furthermore, an exemplary course has been implemented in a primary school and verified the effectiveness of our resources.

AI Knowledge Structure

Our AI knowledge structure is based on the new Chinese national information science and technology curriculum. The new Chinese national curriculum had been developed by subject experts, subject education experts, in-service teach-

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Figure 1: User interface of resource website

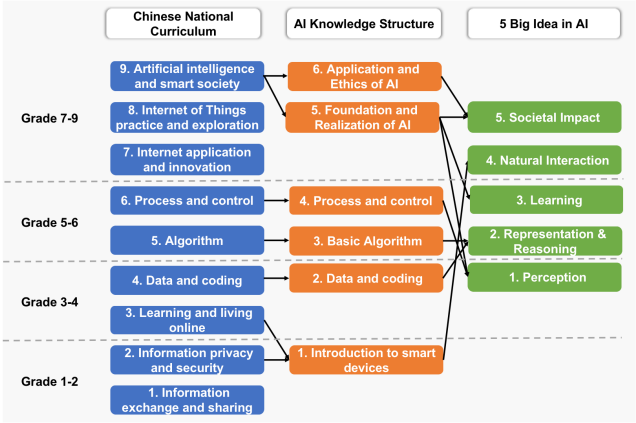

Figure 2: Relationship diagram of national curriculum, knowledge structure and 5 big ideas in AI

ers, and education administrators for 3 years. There are two parts in the knowledge structure, which are core concepts and learning indicators. Core concepts are highly AI-related concepts selected from the information science and technology curriculum. Learning indicators are learning objectives that indicate what students should know or what students should be able to do. Our knowledge structure is also compatible with the five big ideas of AI for K-12 (Touretzky et al. 2019), including perception, representation and reasoning, learning, natural interaction, and societal impact.

In core concepts, we build AI knowledge structure with 6 modules, which are partially corresponded to the 9 modules in the new information science and technology curriculum and focused on five big ideas in AI. AI courses in 6 modules are designed for students from grade 1 to 9, as shown in Figure 2.

Module 1 to 4 are technical foundations of Module 5 and 6. From the perspective of 5 big ideas, we encourage students to get associative perception of AI through natural interaction with AI applications in Module 1. Based on that, Module 2 to 4 go into detail through representation and reasoning, perception, and learning, and these modules answer questions about what is data and how to describe data, what is algorithm and how to describe and apply algorithm, and how machine learns, respectively. Then in Module 5, we focus on AI technology to introduce core concepts including machine learning, natural language processing, computer vision, etc. Furthermore, Module 6 emphasizes AI societal impact such as information cocoon, algorithm bias, data security, etc.

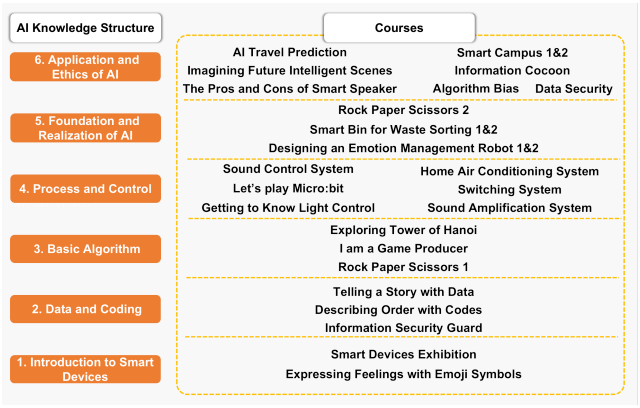

Figure 3: Courses for 6 modules

Teaching and Learning Resources

To reflect and implement our core concepts and learning indicators, we elaborately design teaching and learning resources as courses based on project-based learning (Kokotsaki, Menzies, and Wiggins 2016). The courses aim to foster four core literacies according to the national curriculum, namely information awareness, computational thinking, digital learning and innovation, and information society responsibility. In each course, students are inspired to practice self-inquiry through project-based learning and explore answers in multiple fields of studies. The topics of resources are mainly chosen from the national curriculum like the *I am a Game Producer* and *Exploring Tower of Hanoi*, and others come from students' daily life like the *Smart Bin for Waste Sorting* and *Rock paper scissors*.

To be specific, we design 27 courses in 6 modules as shown in Figure 3. It is worthy to mention that there are course series labeled with numbers of 1 and 2 with increasing difficulties, like *Smart Campus* in Module 6: *Application and Ethics of AI*. In each course, we provide authentic learning context through real-world questions and practices for students to be actively engaged in the learning process, which culminates in project outcomes. For example, in the course *Smart Bin for Waste Sorting* (Song et al. 2022) in Module 5: *Foundation and Realization of AI*, students will be able to design and program their own smart bins for waste sorting through speech recognition and image recognition, which reflects core literacies of information awareness, computational thinking, and information society responsibility, as well as big ideas of perception, natural interaction, and societal impact (Touretzky et al. 2019).

For each course, abundant multimedia ready-to-use resources are built for the whole teaching and learning process. Various types of resources are developed and allocated to meet necessary requirements of course design, concept

Usage of Resources	Types of Resources
Course Design	Lesson Plan
Concept Teaching	Slides
Learning Engagement	Questionnaire, Warm-up Game, Demonstration Video, Flow Chart, Record Table, Quiz
Project Outcome	Rubric, Instruction Manual, Codes

Table 1: Resources Types

teaching, learning engagement, and project outcomes. Overall, we list all types of our resources in Table 1 and will elaborate the resources in the following parts.

Lesson Plan To operationalize our national standards and learning objectives, we use backward design (Wiggins, Wiggins, and McTighe 2005) to plan lessons and units. In lesson plans, we list duration, objectives, activities, tools, and materials in teaching AI. The teaching activities are structured based on project-based learning in context of students' daily life to engage students in problem solving. Taking course *Rock Paper Scissors 2* in Module 5: *Foundation and Realization of AI* for example, the driving question is how to design an automatic rock paper scissors game by means of computer vision (CV). To solve the driving question, three sub-questions are proposed and would be solved in three separate class hours, namely "How to play rock paper scissors?", "What is computer vision?" and "How to train a gesture recognition model for rock paper scissors?". The learning indicators are "knowing the basic technology and applications of CV", and "programming rock paper scissors game in python". The interdisciplinary course involves fields of math, information science and technology, and AI, especially CV as a typical technology in perception.

Slides We develop slides for each lesson, in which typical stages are introduction, new concepts instruction, hands-on practice, review, etc. Figure 4 shows a preview of slides in the course *Rock Paper Scissors 2* in Module 5: *Foundation and Realization of AI*. Slide 1 in the introduction session introduces game rules. Slide 2 and 3 are shown in the new concepts teaching session where teachers will introduce the core concepts of computer vision, including how computer reads images, CV basic technology like image classification, object detection, image segmentation, and image generation, as well as CV typical applications like optical character recognition (OCR), face recognition, and pose estimation. Slide 4 is in hands-on project session to explain how to train a gesture recognition model.

Questionnaire Students are encouraged to do in-person survey to deeply understand the driving question. In the course *Information Cocoon* in Module 6: *Application and Ethics of AI*, we provide a questionnaire to guide students to be aware of personalized recommendations and information cocoon, and find out methods to break through it. In the

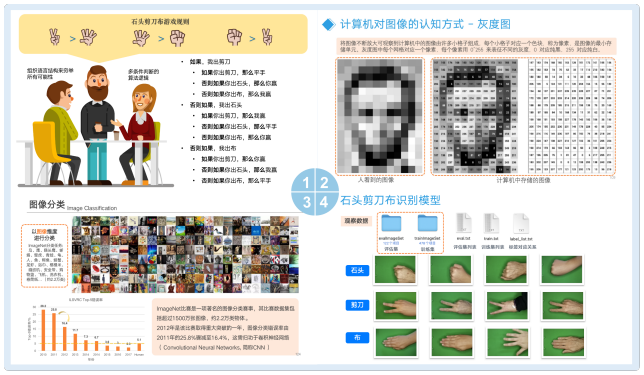

Figure 4: Slides of *Rock Paper Scissors 2*

Figure 5: Warm-up game of *Smart Bin for Waste Sorting*

questionnaire, students are required to explore which Apps have personalized recommendations function, what my favorite topics are, what contents the App recommended, and figure out the answer of "Do different Apps recommend the same things to me?". Through the survey, students are expected to stay sober with recommended contents and notice that there is a choice to turn off the function and breakthrough the information cocoon.

Warm-up Game Gamification is an attractive approach for students to stimulate motivation and get involvement to learning (Zainuddin et al. 2020). In the course *Smart Bin for Waste Sorting 1* in Module 5: *Foundation and Realization of AI*, we develop a warm-up game for students to get familiar with waste sorting rules, as shown in Figure 5. Students could get instant feedback when making each choice and accumulate scores when making the right choice.

Demonstration Video When it comes to challenging games or tasks, we record and provide demonstration videos to assist students. In the course *Exploring Tower of Hanoi* in Module 3: *Basic Algorithm*, we develop the game via python programming with self-painted animation displayed on the screen, as shown in Figure 6. The difficulty of the game corresponds to the number of plates. The difficulty raises significantly when the number of plates increases. We self-record the demonstration video, optimal solution of six-plate tower of Hanoi game, to challenge students and raise students' interests.

Flow Chart When the course involving programming practice, it is significant for students to describe the algorithm logic clearly before hands-on programming. We en-

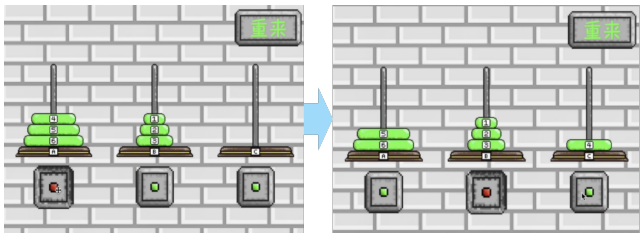

Figure 6: Demonstration video of *Exploring Tower of Hanoi*

Figure 7: Quiz of *Expressing Feelings with Emoji Symbols*

courage students to firstly describe algorithm in natural language, and then move on to flow chart description. In the course *I'm a Game Producer* in Module 3: *Basic Algorithm*, we offer semi-finished flow chart template form with hints of natural language description, flow chart symbol explanation, and sample chart of three basic logical structures. Students are requested to fill charts with conditional statements, operation terms, and operation results according to the hints provided.

Record Table We also supply different record tables to assist students in various activities, such as experiment, discussion, formula derivation, etc. It tends to be unoriented when students are exposed to blank paper. Therefore, we design structured forms to guide students in problem-solving. In the course *Exploring Tower of Hanoi* in Module 3: *Basic Algorithm*, we provide the table for students to record their attempts of steps serving as raw data for the following algorithm induction.

Quiz Quizzes are provided to draw students attention and assess students' understanding in or after the course. In the course *Expressing Feelings with Emoji Symbols* in Module 1: *Introduction to Smart Devices*, we prepare beginner course talking about symbolic representation. As shown in Figure 7, we design animated quiz to ask students to choose the appropriate emoji symbols to express feelings in statements.

Rubric At the end of some projects, students are required to accomplish and demonstrate the project outcomes that would be evaluated by teachers and classmates. We prepare detailed rubrics for students and teachers to evaluate project outcomes. In the course *Data Security* in Module 6: *Application and Ethics of AI*, the project outcome is a brochure of data security. To evaluate the brochure, the rubric contains both content and design indicators, in which score ranges from 1 to 5 marked as improvement required (1-2 scores), good (3 scores), and excellent (4-5 scores). For example, the generalization, richness and innovativeness of the brochure content are considered, as well as the operability, form innovation and aesthetics of brochure design are counted.

Instruction Manual In case students could not keep up with the class or work on hands-on project in self-learning, instruction manuals are provided, in which multi-level tasks and goals, step-by-step instructions and samples are specified. In the course *I'm a Game Producer* in Module 3: *Basic Algorithm*, we break the task of building a matchstick game down into five progressive sub-tasks. In the instruction manual, the reference solution of each sub-task and guidance are specified, including how to access the pre-programmed codes, where to find the target blocks, and the expected results of the sub-tasks.

Codes For the courses involving programming practice, we also construct programming resources such as demonstration codes, and half-done programming project with preliminary environment setting up and data labeling. We adopt Tencent Coding to build our programming resources, where both block-based programming and python-based programming language are supported. The platform also provides cloud computing resources for Jupyter notebook, where Pytorch and Tensorflow, professional deep learning frameworks, are available. Meanwhile, the platform embeds typical AI blocks in block-based programming environment, such as automatic speech recognition (ASR), pose estimation, and image classification, as well as hardware blocks to operate Arduino and Micro:bit.

We provide both Jupyter notebook codes and block-based programming codes. For python programming, we adopt Jupyter notebook, an interactive computing environment, to help students write and run codes step-by-step with instant feedback. In the course *Rock Paper Scissors 2* in Module 5: *Foundation and Realization of AI*, students are expected to program the game featured with automatic gesture recognition in python. To train and utilize gesture recognition model, necessary resources are provided, including Jupyter notebook demonstration codes, training and evaluating images sampled from the Kaggle's public dataset (Bruère-Terreault de la, Julien 2018), text files of images' name list and correspondent labels. In Jupyter notebook demonstration codes, a framework of model training and deploying is constructed where an image classification model based on Pytorch is trained and finally deployed into the rock paper scissors game. Students are not expected to understand the codes in detail, but experience the real model training process by simply clicking on the "run" button for each cell in the notebook.

In addition, block-based programming is a powerful environment for beginners to easily understand and implement basic functions in AI. In the course *Designing an Emotion Management Robot 2* in Module 5: *Foundation and Realization of AI*, students are asked to utilize image classifi-

Figure 8: Block-based programming of *Designing an Emotion Management Robot*

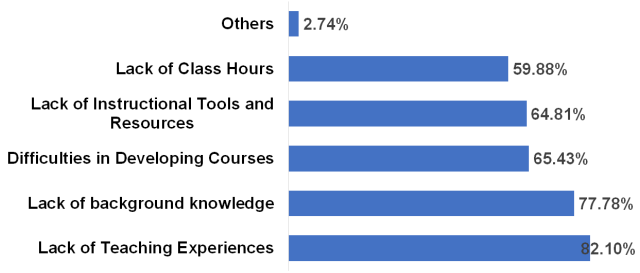

Figure 9: Difficulties in teaching AI

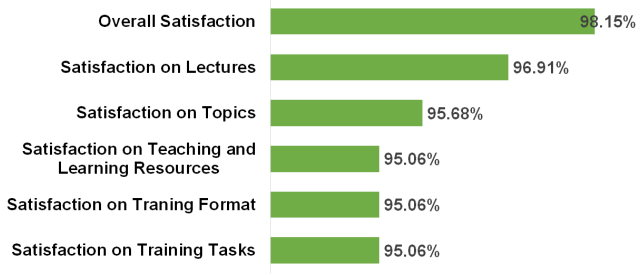

Figure 10: Satisfaction with the teacher training program

cation related AI components to build, train and deploy an emotion classification model via block-based programming. As shown in Figure 8, when negative emotion is detected, the robot would play relaxing music. On the opposite, the robot would request the user to describe the cheerful day and record with ASR block. We provide semi-finished codes and specific instructions to help accomplish the task.

Besides, we also design mechatronics courses by means of micro-controller such as Micro:bit. Students could deliver programs to the hardware in block-based programming and intuitively experience the power of control. In the course *Getting to Know Light Control* in Module 4: *Process and Control*, students are expected to design a dual-controlled light via both lightness and sound intensity. We provide guidance of building single-controlled light and encourage students to seek ways to combine the control rules and implement via block-based programming.

Teacher Training

Although students in grade 1 to 9 are required to take AI courses, specialized AI teachers are insufficient in China. Currently, most AI teachers are full-time information science and technology, science, or comprehensive practice teachers who lack of AI literacy. According to a survey that we conducted, 192 participating teachers revealed that teaching AI is mainly challenged by lack of teaching experiences, lack of background knowledge, difficulties in developing courses, lack of instructional tools and resources, and lack of class hours, as shown in Figure 9. To prepare teachers' readiness in teaching AI in compulsory education, we aim to train at least 3,000 qualified AI teachers in three years with our teaching and learning resources. AI teachers could be trained through online, offline, or blended learning. Affected by the COVID-19 epidemic, most of our training activities were conducted online. We have trained more than 900 teachers who are teaching or going to teach AI from 22 provinces in China.

To solve the problems that teachers encounter in teaching AI, we design our 2-day teacher training program particularly, as shown in Table 2. The program consists of five parts. Part 1 targets the difficulty of lacking AI background knowledge, introducing core concepts and basic technologies in the areas of using AI and teaching AI in K-12 education. Part 2 aims to resolve difficulties in developing AI courses, illustrating rules to design effective AI courses. For example, teachers should select core concepts instead of cutting-edge concepts as learning content in AI courses. Part 3 demonstrates the use of instructional tools and resources in AI courses, which might alleviate the problem of lack of tools and resources for AI teachers. In Part 3, exemplary courses are chosen from 27 courses that listed before according to which grade the participating teachers teach in. Part 4 is an optional session, which is designed especially for teachers with no block-based or python-based programming experiences. In part 5, teachers are expected to do an independent project to design their own AI lessons. All participating teachers regardless of comfort level with AI technology are encouraged to design and share their own AI lessons and units.

According to the survey, 192 participating teachers were very satisfied with the teacher training, as shown in Figure 10, including lectures, topics, teaching and learning resources, format, and tasks of the teacher training program. Especially, some participating teachers noted:
"The teacher training contains theory and practice, which is easy to have hands-on experiences for in-service teachers."
"The exemplary courses are very close to the students' daily lives."
"The content of the exemplary courses is moderately difficult for students to learn."

Classroom Implementation

In order to evaluate the effectiveness and improve the quality of the resources, the course of *Smart Bin for Waste Sorting* was chosen to be implemented in primary schools. Taking one primary school in Beijing as an example, 20 stu-

No.	Topic	Abstract
Part 1	Artificial intelligence and K-12 education	Introduce core concepts and basic technologies in the areas of using AI in K-12 education and teaching AI in K-12 education.
Part 2	Design AI courses	Introduce and illustrate rules in designing effective AI courses. **Group discussion:** How to teach AI?
Part 3	Implement AI courses: Exemplary course 1	Introduce the exemplary course: 1) Explain concepts and technologies behind the course, 2) Demonstrate the use of tools and resources in the course.
	Implement AI courses: Exemplary course 2	Introduce the exemplary course: 1) Explain concepts and technologies behind the course, 2) Demonstrate the use of tools and resources in the course.
	Implement AI courses: Exemplary course…	The exemplary course would be selected according to schools, grades, and subjects of participated teachers.
Part 4 Optional	Kid-friendly programming platform	This optional module is designed for teachers with no block-based or python-based programming experiences to use the platform.
Part 5	Design my AI lessons	Guide teachers to design their own AI lessons, including but not limited to lesson plans, demos, and programming tasks. **Group discussion:** How to design AI lesson?

Table 2: Teacher training program

Group	N	Mean	S.D.	t	p
pre-test	20	61.62	11.81	-2.268	0.035*
post-test	20	68.19	9.44		

*$p<0.05$,** $p<0.01$

Table 3: Paired t-test on knowledge assessment

dents in grade 4 took this course for 8 weeks, one class per week and 45 minutes per class. Both pre-test and post-test were conducted to evaluate students' AI knowledge and computational thinking. In terms of computational thinking, Chinese elementary students computational thinking scale (Zhang et al. 2020) with a reliability coefficient of 0.928, 23 questions were designed across five capability dimensions, namely creativity, critical thinking, problem solving, algorithm thinking, and cooperation. Furthermore, six class assignments were given to evaluate the programming abilities of students and a survey was conducted to understand students' interests in learning AI and their satisfactions with the teaching methods.

As shown in Table 3, the participants gained significant learning progress (t=-2.268, p=0.035) in learning AI knowledge. Students' computational thinking level also showed improved, especially in problem-solving dimension (t=-2.153, p=0.044), as shown in Table 4. In addition, students expressed strong interests in AI (mean=4.074) and high degree of satisfaction (mean=3.74) after the course. The results revealed significant growth of AI knowledge and computational thinking skills of the students.

Group	N	Mean	S.D.	t	p
pre-test	20	22.10	5.19	-2.153	0.044*
post-test	20	23.95	4.63		

*$p<0.05$,** $p<0.01$

Table 4: Paired t-test on problem-solving of computational thinking

Discussion and Conclusion

Our work makes great contribution to teachers' resources and training in the context of new national curriculum for information science and technology in China. The AI knowledge structure organizes our teaching and learning resources systematically. The resources of 14 online exemplary courses are developed that requires no software installation. To better facilitate teachers, a series of AI teacher training programs are provided.

In the future, more courses will be developed, verified and iterated to strengthen our AI knowledge structure. Taking the design experiences in other countries (UNESCO 2022), we will continue improving the current knowledge structure. For teaching and learning resources improvement, high-quality resources can be used for reference, such as RAISE (RAISE 2022) and Day of AI (Day of AI 2022). More teachers will be encouraged to participate in design-based research to shorten the time of developing the customized AI courses. We will train at least 3,000 AI-related teachers in three years, meanwhile design and develop more high-quality AI resources for K-12 schools in China.

Acknowledgments

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