Paving the Way for Novices: How to Teach AI for K-12 Education in China

Jiachen Song,[1] Linan Zhang,[1] Jinglei Yu,[1] Yan Peng,[2] Anyao Ma,[1] Yu Lu[1*]

[1] Advanced Innovation Center for Future Education, Beijing Normal University, Beijing, China
[2] Shenzhen Honggui Primary School, Guangdong, China
song.jiachen@bnu.edu.cn, zhanglinan@mail.bnu.edu.cn, yujinglei@bnu.edu.cn, pyan17@qq.com, maanyao@mail.bnu.edu.cn, luyu@bnu.edu.cn

Abstract

In response to the trend that artificial intelligence (AI) is becoming the main driver for social and economic development, enhancing the readiness of learners in AI is significant and important. The state council and the ministry of education of China put AI education for K-12 schools on a high priority in order to foster local AI talents and reduce educational disparities. However, the AI knowledge and technical skills are still limited for not only students but also the school teachers. Furthermore, many local schools in China, especially in the rural areas, are lack of the necessary software and hardware for teaching AI. Hence, we designed and implemented a structured series of AI courses, built on an online block-based visual programming platform. The AI courses are free and easily accessible for all. We have conducted the experimental classes in a local school and collected the results. The results show that the learners in general gained significant learning progress on AI knowledge comprehension, aroused strong interests in AI, and increased the degree of satisfaction towards the course. Especially, our practices significantly increased computational thinking of the students who were initially staying at a lower level.

Introduction

AI education has attracted considerable attentions from government, schools, academia and industry in China. In July 2017, China's state council released the *Next Generation Artificial Intelligence Development Plan* (Roberts et al. 2021). This national-level strategy outlined that China aims to prompt AI courses in basic education, higher education, and vocational education to improve the general public's awareness and application of AI (Lu et al. 2020) and meanwhile foster AI talents (Kahn et al. 2020). In recent years, 344 universities and colleges in China have set up four-year AI major or program for undergraduates. Meanwhile, the ministry of education of China has revised the national level AI-related curriculum standards for senior high schools (Grade 10-12) and is currently working on the curriculum standards for compulsory education (Grade 1-9).

While AI education is a hot topic in China, teaching AI in K-12 education faces special challenges compared to higher and vocational education. This is partially because in K-12 education, there are more than 373 thousand teachers teaching information technology and 178 million students, where most teachers and students do not equip with enough background knowledge and skills to break the barriers in teaching and learning AI courses. Besides, the majority of elementary and middle schools in China are equipped with computers connected to Internet, but they are normally lack of dedicated hardware, such as GPU, to train real AI models.

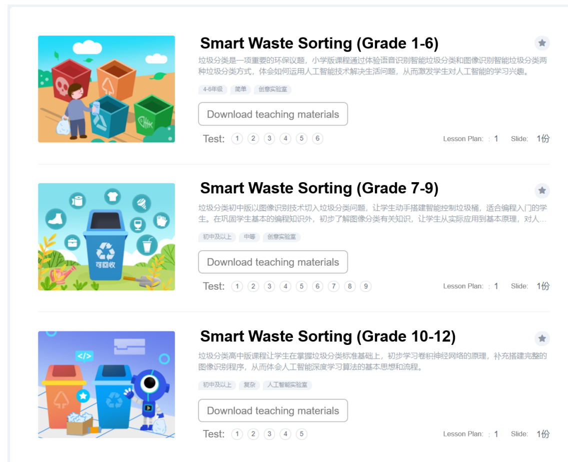

Figure 1: The AI Curriculum on the Topic of Smart Bin

To address these issues, we designed an AI curriculum for K-12 schools, built on a popular online programming platform, called Tencent Coding (coding.qq.com). Our AI curriculum is composed of a series of courses and is structured under the theme of smart campus, which is directly related to students' daily lives. More specifically, we choose *Smart Bin* as a topic to build a better intelligent environment of campus, *AI Tutor* as a topic to assist students' learning, and *AI Partner* as a topic to support better campus life. These courses are designed for different grades, such as *Smart Bin* topic consists of courses for first to sixth graders, seventh to ninth graders, and tenth to twelfth graders respectively, as shown in Figure 1.

To meet teachers' needs in teaching AI, we collaborated with the experienced teachers to provide teaching materi-

[*] Corresponding author

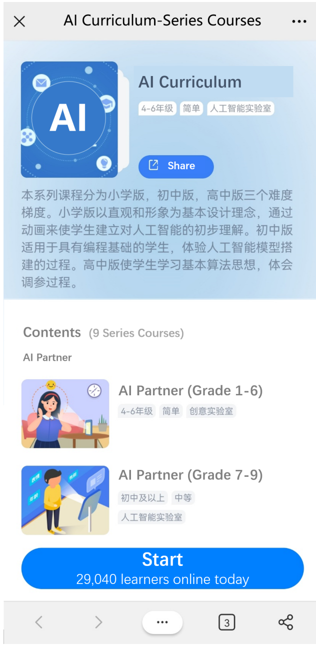

Figure 2: The AI Curriculum on Mobile Devices

als including lesson plans, slides, tests, block-based programming codes and animations, etc. All teaching materials are free and easily accessible for in-service school teachers. Teachers can use the teaching materials to teach directly, or take the teaching materials as a starting point to design their own lessons and courses. Based on the teaching materials, we organized training programs to help local teachers learn how to design and provide AI courses and how to use the block-based programming platform.

To meet students' needs in learning AI, we provided well-designed online courses to develop students' AI knowledge and skills. Our AI curriculum is designed based on five big ideas (Touretzky et al. 2019), including perception, representation and reasoning, learning, natural interaction, and societal impact, as the core concepts to organize discrete knowledge and skills in the field of AI. The breadth and depth of the course content are selected according to students' prior knowledge and cognitive level. Given that a large number of elementary school students are lack of computer operation or block-based programming skills, an optional preliminary module is designed as a stepping stone to learn AI. Furthermore, we adopt project-based learning (Blumenfeld et al. 1991; Krajcik and Shin 2014) to guide students solving problems through learning by doing, along with the fascinating games and animations to demonstrate the core concepts in AI.

To reduce the hardware cost in teaching and learning AI, we launched our AI courses online and no infrastructure investment is imposed on local schools and authorities. The free programming platform is developed by Tencent company specifically for 6-18 year-old students. On the platform, there are block-based, JavaScript-based, Python-based, and C-based programming laboratories, as well as the

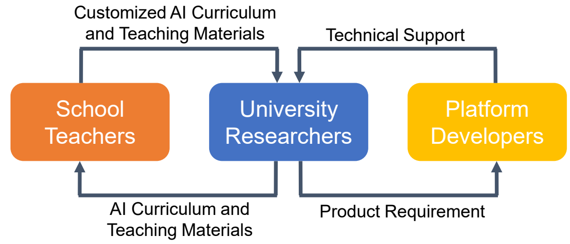

Figure 3: Tripartite Cooperation of Schools, Universities and Industry

trained AI models for speech recognition, gesture recognition, image classification, and word embedding. The trained models cover areas in computer vision, speech recognition and natural language processing. We constantly collect suggestions from teachers and researchers, and provide to platform designers to continuously customize and improve the platform for better supporting AI course teaching. Meanwhile, Tencent provides the remote technical support for researchers and teachers. The platform has a mobile version to facilitate students' learning as well, as shown in Figure 2.

In short, we have built tripartite cooperation of schools, universities, and industry in designing and implementing AI courses for K-12 students, as shown in Figure 3. Following this cooperation model, we have launched a number of courses and modules online for teachers and students to access freely. Meanwhile, we organized multiple teacher training programs and activities, benefiting teachers from 22 provinces in China. In the following sections, we will take the *Smart Bin* course (Grade 1-6) as an example to illustrate how we design different modules and what we find in the process of the course implementation.

Exemplary Course for Elementary School

The *Smart Bin* course consists of eight modules (Module 1-8) and one optional preliminary module. Module 1 introduces the background knowledge of waste in student's daily lives. Module 2 to 7 introduce the core AI concepts including speech recognition, speech synthesis, image recognition, and machine translation. After the instruction part in each module, students could accomplish the coding tasks, as class assignments, to fulfil different functions of the smart bin for waste sorting and recycling. Module 8 is designed for review. Eight modules are organized as shown in Figure 4. Furthermore, the optional preliminary module is designed for students without computer skills or block-based programming skills, in which students could learn the basic computer operation skills, such as starting and setting a browser, logging in and using the block-based programming environment and platform.

Module 1 – Waste Sorting 46 cities have implemented the waste sorting and recycling in China since 2020. Four categories of waste sorting are recyclable, food, hazardous, and other waste. However, people often have difficulties in managing these four categories correctly when facing the

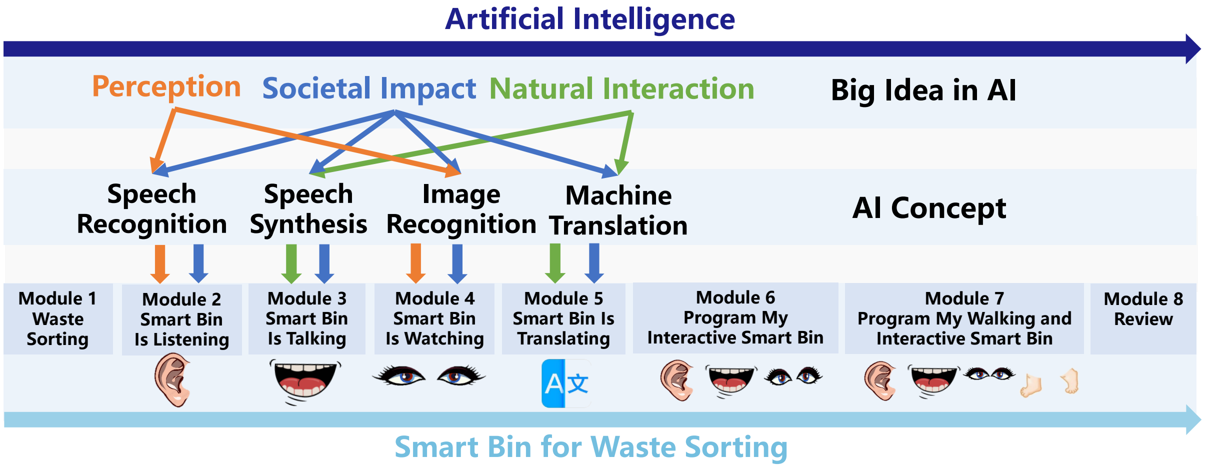

Figure 4: The Structured Eight Modules under Smart Bin Topic

four different waste bins. In this module, students are taught to classify the four categories of waste correctly.

Module 2 – The Smart Bin is Listening Sometimes it is confusing to decide which bin the waste should go to, especially for the very young and the elderly. In this module, students are taught to learn speech recognition and its application on the smart bin. Specifically, the smart bin can identify waste items by using speech recognition, which can be implemented by students using the block-based programming. At the end of the module, students are taught to be aware that the speech recognition technology brings not only positive impacts, but also negative impacts on information security and personal privacy.

Module 3 – The Smart Bin is Talking After the smart bin could identify the waste item by "listening", it can also talk to students and let them know which category the current waste item belongs to. In this module, students are taught the speech synthesis and its application on the smart bin, which can be implemented using the block-based programming as well. At the end of the module, students are guided to discuss the impacts of speech synthesis in social context, such as speaking function for people with disabilities.

Module 4 – The Smart Bin is Watching In this module, students are taught the image recognition and its application on the smart bin. Furthermore, they will be guided to discuss what may affect the accuracy of image recognition, such as the quality and quantity of images for training. Through programming, students would realize that the smart bin can identify the waste item by "watching". At the end of the module, students are guided to discuss the positive and negative societal impacts of image recognition.

Module 5 – The Smart Bin is Translating In this module, we advance the smart bin to identify the waste item by "listening" to not only Chinese, but also English. To introduce machine translation, the teacher will compare human translation and machine translation, and then demonstrate how to compile a machine translation program via blocks. Finally, students would discuss the positive and negative impacts of machine translation to develop their critical thinking regarding AI.

Module 6 – Program My Interactive Smart Bin In this module, students would design an interactive smart bin by taking advantage of the functions implemented in the previous modules, i.e., "listening", "talking" and "watching". The assignment is broken down into two progressive steps, firstly watching and talking, secondly watching, talking, and listening, which scaffolds students to build their own smart bin.

Module 7 – Program My Walking and Interactive Smart Bin In this module, students would be able to design an advanced smart bin that can not only interact with people by "listening", "watching" and "talking", but also move to the given locations. The programming assignment is divided into three steps, namely calling the smart bin, moving the smart bin, and identifying the waste.

Module 8 – Review In this module, students would be able to compare the similarities and differences between human intelligence and machine intelligence to gain a deeper understanding of AI. After that, the teacher would go through AI concepts introduced in the course, including speech recognition, speech synthesis, image recognition and machine translation. Finally, students will discuss how to get on well with the current and future AI applications in their daily lives.

Supporting Materials To support AI curriculum implementation, we develop the teaching materials for teachers and students, including lesson plans, slides, tests, and half-done block-based programming projects. In addition, instructional micro-lectures and manuals are given to facilitate students building blocks.

Curriculum Implementation

We cooperated with a teacher who is teaching information technology for third grade students in an elementary school

Figure 5: Students Learning the Course in Computer Room

in Shenzhen, China. We supported the teacher with preliminary *Smart Bin* (Grade 1-6) course and teaching materials, and helped her customize the course considering the local students' prior knowledge and cognitive level. Each module is formed as a 45-minute lesson, and the entire *Smart Bin* course lasts four weeks, where two lessons are given per week.

Participants and Methods 94 third grade students registered in two gender-balanced classes and participated in the *Smart Bin* course. All lessons were held in a computer room, where each student worked on an individual computer and was taught by the teacher without AI teaching experience, as shown in Figure 5.

Both pre-test and post-test were conducted to evaluate students' AI knowledge and computational thinking. Furthermore, six class assignments were given to evaluate the programming abilities of students. Furthermore, a post-survey was conducted to understand students' interests in learning AI and their satisfactions with the teaching methods. In addition, an online interview was conducted with the teacher at the end of the *Smart Bin* course, to mainly understand her satisfaction with the instructional design, online platform and the tripartite cooperation mode. We also collected the school administrators' attitudes regarding teaching AI in elementary schools from the teachers' perspective. All the tests, surveys and the interview were conducted online.

Knowledge Test Design At the very beginning and the end of the *Smart Bin* course, students took tests on AI applications and AI societal impacts in daily life, such as image recognition, speech recognition and speech synthesis. The questions were designed according to the learning objectives of each module. For example, one question examining the applications of speech recognition in pre-test is given in Figure 6, and one question in post-test is given in Figure 7. There are 17 scored single and multiple-choice questions in the pre-test, 21 scored single and multiple-choice questions and one unscored open-ended question in the post-test. The open-ended question aims to learn students' opinions

Q: Which of the followings use speech recognition?	
Choices	Ratio of answers
A. Music recognition (right answer)	43.41%
B. Dialect synthesis	23.08%
C. Voice changer with effects	33.52%

Figure 6: Question Related to Speech Recognition in the Pre-test

Q: Which of the followings is right?	
Choices	Ratio of answers
A. Speech recognition could only recognize Chinese.	8.51%
B. Speech recognition could recognize image.	8.51%
C. Speech recognition could convert speech to text. (right answer)	81.91%
D. Speech recognition could only recognize girls' voice.	1.06%

Figure 7: Question Related to Speech Recognition in the Post-test

on the given course. To generate the comparable scores between pre-test and post-test, we converted the full score of both in the same scale, 100 points in total.

Class Assignment Design Right after the teacher's instruction, students were given around 20 minutes to worked on programming assignments in classes, where the instructional micro-lectures and manuals are provided. Figure 8 demonstrates the assignment of Module 3 that targets on implement a "listening" and "talking" smart bin by using the block-based programming.

Survey Design A total of 36 questions are designed in the post-survey. According to 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. To evaluate students' interests in AI and their satisfactions on the course design, 5 questions (Hwang and Chang 2011) and 8 questions (Chu, Hwang, and Tsai 2010) originated from the corresponding questionnaires were selected, each on five-point Likert scale with the reliability coefficient of 0.89 and 0.91 respectively.

Results

Performance Evaluation 20 out of 98 students' submissions were excluded from the study results due to the lack of corresponding pre-test and post-test data, duplicate submissions, and anonymous submissions. Table 1 gives the t-test results on the knowledge assessments in pre-test and post-test. In general, the participants gained significant learning progress (t=-3.272, p<.01) on AI knowledge after the course.

For class assignments, 45 students with valid submissions

Figure 8: Block-based Programming Assignment in Class

Test	N	Mean	SD	*T-test*
Pre-Test	78	55.04	14.98	**-3.27****
Post-Test	78	61.67	18.13	

***p<0.01*

Table 1: Paired T-test on Knowledge Assessment

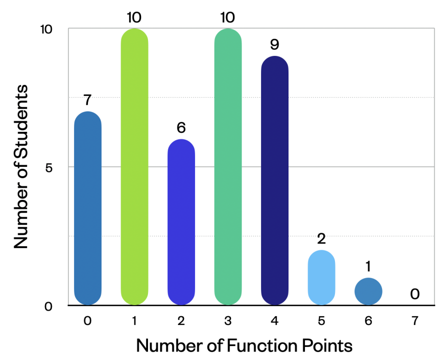

Figure 9: Distribution of Students in Number of Function Points

were collected for analysis. Students' assignments are evaluated based on the number of implemented functions, such as "listening" and "talking". Each function is scored 1 point, and 7 points in total. The evaluation result is given in Figure 9. We see that the variation among students' performance is relatively large, and only three students obtained more than four points. The majority of the completions are not constrained by the first few class assignments, and a collection of the completed assignments are illustrated in Figure 10.

Survey Analysis Table 2 demonstrates the paired t-test results on computational thinking (CT). The CT pre-test data were divided into two groups by the mean value of Chinese elementary students which is 84.8 (Zhang et al. 2020). The number of students initially with a lower CT level was 42 and the number of students initially with a higher CT level was 36. Group members in the post-test were the same as the pre-test. Interestingly, the initially lower CT level group (LG) increased significantly (t=-2.770, p<.01), while the initially higher CT level group (HG) decreased (t=5.712, p<.01). One possible reason is that our course is more effective and suitable for the students with limited CT capabilities.

Group	Test	N	Mean	SD	*T-test*
LG	**Pre-Test**	42	72.78	8.33	**-2.77****
	Post-Test	42	78.06	11.85	
HG	**Pre-Test**	36	93.56	5.34	**5.71****
	Post-Test	36	82.39	11.65	

***p<0.01*

Table 2: Paired T-test on Computational Thinking

In addition, students expressed strong interests in AI (mean=4.33) and high degree of satisfaction (mean=4.14) on the course, especially the teacher's instruction, instructional

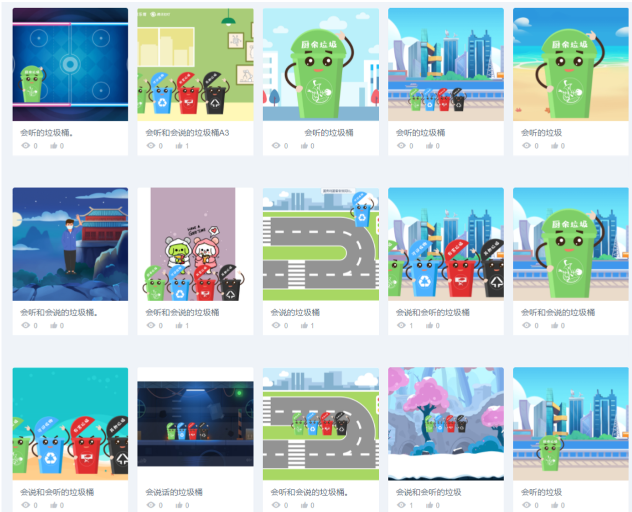

Figure 10: Collection of Students' Assignments

micro-lectures and manuals, as well as scaffolding assignments. Moreover, the answers of the open-ended question shows positive attitudes towards the AI course. For examples:

"The smart bin could provide people with more convenience, especially for elder people."
"Programming could help improve my thinking."
"I found the courses very interesting."
"I still want to learn AI courses in the future."

Interview Feedback In the interview with the course teacher, we have several findings. Firstly, the teacher's attitudes towards the *Smart Bin* course and block-based programming platform are overall positive. Secondly, students present significant variation on technical and programming skills. Some students have already learned the programming skills, while some students even have difficulties in logging in the programming platform. Thirdly, the tripartite cooperation is valuable because teachers are commonly lack of practical AI curriculum, teaching materials and programming platforms. Novice teachers in teaching AI require professional guidance, necessary training, as well as reliable and affordable open online platforms. Lastly, the public schools are willing to set up AI courses, but they are currently lacks of national-level curriculum standards and textbooks.

Conclusion and Future Work

In this paper, we present the AI course series developed for K-12 education in China. By cooperating with teachers and platform developers, we have designed and built high-quality AI courses and teaching materials. We have conducted the comprehensive evaluations on the courses implemented in local schools. The analysis results of the students' assessments revealed that our courses effectively imparted AI knowledge to students and helped build up computational thinking capabilities. Additionally, teachers expressed strong satisfactions on the cooperation mode and the platform.

For the future work, we plan to continue improving *AI Tutor* and *AI Partner* course series for different age groups, implementing the same cooperation mode with more schools and companies, as well as organizing teacher training activities to benefit more teachers. To better support the computational thinking development for students, we will design new class assignments that require collaboration among peers. We also notice that the feedback of students and teachers are quite valuable and helpful for improving the course design. We expect the implemented course series could empower the K-12 AI education in China to step into a new stage.

Acknowledgements

This research is partially supported by the Fundamental Research Funds for the Central Universities and Tencent Coding team.

References

Blumenfeld, P. C.; Soloway, E.; Marx, R. W.; Krajcik, J. S.; Guzdial, M.; and Palincsar, A. 1991. Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational psychologist*, 26(3-4): 369–398.

Chu, H.-C.; Hwang, G.-J.; and Tsai, C.-C. 2010. A knowledge engineering approach to developing mindtools for context-aware ubiquitous learning. *Computers & Education*, 54(1): 289–297.

Hwang, G.-J.; and Chang, H.-F. 2011. A formative assessment-based mobile learning approach to improving the learning attitudes and achievements of students. *Computers & Education*, 56(4): 1023–1031.

Kahn, K.; Lu, Y.; Zhang, J.; Winters, N.; and Gao, M. 2020. Deep Learning Programming by All. *Constructionism*, 281.

Krajcik, J. S.; and Shin, N. 2014. *Project-Based Learning*, 275–297. Cambridge Handbooks in Psychology. Cambridge University Press, 2 edition.

Lu, Y.; Wang, D.; Meng, Q.; and Chen, P. 2020. Towards interpretable deep learning models for knowledge tracing. In *International Conference on Artificial Intelligence in Education*, 185–190. Springer.

Roberts, H.; Cowls, J.; Morley, J.; Taddeo, M.; Wang, V.; and Floridi, L. 2021. The Chinese approach to artificial intelligence: an analysis of policy, ethics, and regulation. *AI & SOCIETY*, 36(1): 59–77.

Touretzky, D.; Gardner-McCune, C.; Martin, F.; and Seehorn, D. 2019. Envisioning AI for K-12: What should every child know about AI? In *Proceedings of the AAAI Conference on Artificial Intelligence*, volume 33, 9795–9799.

Zhang, Y.; Mo, W.; Zhang, Y.; Gao, H.; Li, N.; and Lin, Y. 2020. Development and application of Chinese pupils' computational thinking scale. *China Educational Technology*, (10): 9.