The Current Status, Practice, and Promotion Routes of Programming Ability of Secondary School Students in Rural Areas

—A Case Study of a Students' Practice Activity in Summer Holiday of Peking University

JIA Jiyou[1], RUI Jingshu[2]
(1. Department of Education and Technology, Graduate School of Education, Peking University, Beijing, China 100871; 2. School of Electronics and Computer Science, Peking University, Beijing, China 100871)

Abstract: This paper describes the design and practice of programming instruction for rustic middle school students during a student practice session at Peking University. Analysis of pre-test and post-test data shows that, despite the lack of programming literacy, rural middle school students still have some programming knowledge; after a short training session with hands-on activities, their programming skills improved considerably. The written feedback from students indicated that the game-based instruction was constructive and that they enjoyed it. On these grounds, this paper points out that in rustic schools with scarce ICT teachers, inadequate class hours, and to-be-improved teaching quality, social practice activities for college students are a quick and efficient way to improve the programming skills of rural secondary school students. The blended teaching methods of teachers and intelligent online tutorial systems can fully utilize the computers and internet access that rustic schools are already equipped with. Additionally, this paper has put forward policy suggestions and recommendations, hoping to provide a reference for the development of programming education and artificial intelligence education and the realization of education equity in China.

Keywords: rural school; college students' social practice; voluntary ICT teacher; programming education; computational thinking

Introduction

Artificial intelligence education is the education of artificial intelligence knowledge, including concepts, fields, implementation techniques and methods, applications, and impacts. The concepts, fields, applications, and impacts of AI can be introduced and popularized in relevant school curricula such as languages, science, and information and communication technologies (ICT). However, to learn the implementation techniques and methods of AI, students must have certain logical and imaginative thinking skills, mathematical knowledge, and English knowledge. Artificial intelligence education needs to be adapted to the different developmental stages of students. For example, programming education at the preschool and elementary school levels can use visual programming methods (such as Scratch); it integrates various forms of robots as carriers to combine hardware with software and cultivates students' interest in basic programming knowledge. Programming education at the secondary school level can teach students advanced programming languages, such as Python.

Most of the domestic research on programming education for secondary school students focuses on the history and current analysis of programming education, curriculum model design, and theoretical discussions. There are few empirical studies on programming education practice, mostly master's theses whose subjects are city schools and students. Not many journal articles are about Information Communication Technology (ICT) courses or programming education in rural elementary and middle schools, most of which are theoretical discussions lacking in-depth field investigation and rigorous empirical research.[1][2][3]

In February 2019, the "China Education Modernization 2035" issued by the Central Committee of the Communist Party of China and the State Council put forward eight basic concepts for advancing the modernization of education, one of which is to "put greater emphasis on education for all". This "for all" concept is to ensure that every student receives high-quality, comprehensive education, including programming education, which is the foundation of artificial intelligence education. To this end, this paper takes a rural junior high school as an example to investigate the programming ability of secondary school students in rustic areas, and uses the voluntary teaching social practice activity of college students at the school as an example to examine how to improve rural junior high school students' programming ability.

1. Research Content and Methods

This study mainly consists of two aspects: (1) an investigation of the foundations of rural students' programming knowledge and computational thinking, and (2) the methods and effects of teaching programming knowledge and computational thinking to rural students through summer social practice activity.

The research method was mainly based on the survey, quasi-experimental research, and statistical data. Surveys are used to collect attitudes, opinions, and suggestions from respondents by means of questionnaires. Quasi-experimental research is a common research method in education science to measure the effect of a teaching method or technique on the students. The statistical method uses statistical analysis software such as SPSS to analyze the collected data and discover the patterns.

2. Research Process

(1) Programming Teacher and Programming Education Company

As part of the 2019 Summer Social Practice at Peking University, ten undergraduate students went to a rural junior high school in Henan Province for seven days, teaching courses voluntarily on computer science, psychology, sex education, and handicrafts, which were not subjects for the Chinese exams. A sophomore student from the School of Electronics Engineering and Computer Science at Peking University with strong programming skills and a passion for programming education, interned at a programming education company in Beijing to learn about the content and design philosophy of the company's programming education courses and taught the Scratch course to the students. Hereinafter we will refer to this student as the programming teacher and this company as the programming education company.

(2) Teaching Materials and Online Tutorial System

The teaching materials come from the Scratch programming education curriculum of the programming education company targeted at elementary school students (4th to 6th grade) with no previous coding experience. The programming teacher taught to rural junior high school students the first and second lessons of the "Introduction to Scratch" course (containing seven lessons), covering the following topics: sequential execution, loop structures, the concept of events, the concept of coordinates, and the use of code blocks to control the movement (e.g., "move 10 steps" block), orientation (e.g., "turn right/left for 15 degrees" block), and the costume (e.g., "switch costume to costume2" block) of the character.

To support the course, the company designed an online tutorial system. Each lesson consists of two videos and an exercise: the first video tells students what problems they encounter and what tasks they need to complete according to the scenario; the second video is specific about what code blocks they need to use to complete the task and gives them some tips; the exercise is a coding practice for students. After they click the "submit" button, if their answers are correct, the system will prompt "pass!"; otherwise, the system will pop up "Try Again!" and give them a hint based on the error. Students need to work through the questions until they are correct to enter the next lesson. There is a Q&A window in the practice session where a human online instructor will answer the student's typed-in questions.

(3) Research Object and Experimental Conditions

The three principals of the rustic middle school attached great importance to this practical activity. The classes were offered to students enrolled in the school, as well as students from neighboring villages, who have signed up voluntarily. The principals recommended the program to parents and students through their parent's WeChat groups, and both students and parents enthusiastically signed up for the program. A total of 143 students in the three grades of junior high school signed up for learning, about 50 in each grade.

The school equipped each classroom with an electronic whiteboard and a multimedia computer with Internet access. It also has a computer room with 20 computers and Internet access. However, the school does not have a teacher who can teach computer courses, so the room is vacant all year round.

(4) Pre-test

On August 1, 2019, the students came to school and they were grouped by grades (7th, 8th, and 9th) to take a paper-based pre-test so that the programming teachers could understand their programming foundation and other related information.

The pre-test questions are selected from a test paper for recruiting interns and employees from the programming education company. It contains 20 single-choice questions, mainly examining basic programming knowledge and computational thinking ability, and involves knowledge on sequence structure, the loop structure, conditional judgment, logical operations, variables and constants, broadcasting, timing, etc.

And three additional open-ended questions are designed to examine relevant information about the students:

(A) Have you ever taken a computer class in elementary school? If so, what did you learn?

(B) Have you heard about coding/programming? Talk about what you know about programming. (Feel free to write anything, such as a story you heard, or a short story about programming that happened to you).

(C) After answering the above questions, what do you expect from the junior high school programming class? What kind of teaching format and content do you want?

The pre-test took a total of 60 minutes, and most students were able to turn in their papers in 45 minutes. We chose a control group of interns recruited by the programming education company who have taken the test with the same content. In terms of average performance, the 7th grade, 8th grade, and 9th grade gradually increased. The results of the independent sample T-test showed that the difference in performance between the three grades and the control group was statistically significant ($p<0.0001$); the difference in performance between the 7th and 9th grades, the 8th and 9th grades is statistically significant ($p<0.01$); but the difference in performance between the 7th and 8th grades was not significant ($p=0.655>0.05$). The youngest group of 7th graders had 46.9% of programming knowledge, 8th graders had 49.9%, and 9th graders had 58.5%. The control group of corporate interns averaged close to 100% correct rate. Students in this rural middle school did not perform as poorly on the programming test as one might expect, averaging nearly 50% across all three grades. In terms of dispersion, the standard deviation of the three grades was not very large.

The responses to the three open-ended questions indicated that the vast majority of students had no prior computer literacy or programming experience.

Table 1 Information about students who participated in the pre-test

Group	control group	7th grade	8th grade	9th grade
Number of participants	44	52	43	48
Number of participants	19.11(95.6%)	9.38(46.9%)	9.98(49.9%)	11.71(58.5%)
Average score (percentage)	1.17(5.8%)	3.24(16.2%)	3.09(15.4%)	3.25(16.2%)
Standard deviation (percentage)	19(95%)	10(50%)	10(50%)	12(60%)
Median score (percentage)	15(75%)	2(10%)	2(10%)	4(20%)
Minimum (percentage)	20(100%)	15(75%)	15(75%)	17(85%)
No computer literacy (percentage)		42(80.8%)	34(79.1%)	0(0%)
With computer literacy (percentage)		8(15.4%)	9(20.9%)	0(0%)
Unanswered (percentage)		2(3.8%)	0(0%)	48(100%)
Never heard about programming (percentage)		45(86.6%)	36(83.7%)	0(0%)
heard about programming (percentage)		1(1.9%)	7(16.3%)	0(0%)
Unanswered (percentage)		6(11.5%)	0(80.8%)	48(100%)

(5) Teaching Process

During the seven-day program, the 7th and 8th grades each had two classroom sessions of 240 minutes (4 hours) of programming instruction, with three 40-minute classes each afternoon. In the 9th grade, there were two 40-minute computer lab sessions for a total of 80 minutes, where each student had a computer to log in to the online tutorial system of the education company and self-studied with the system, followed by four 40-minute classroom classes for a total of 160 minutes. The total class time was the same for all three grades, i.e., 240 minutes.

During the classroom sessions, the programming teacher first wrote, explained, and demonstrated on the whiteboard. Then, she used the online tutorial system to play the video files, open the practice page, and ask the students to work on the exercise. To ensure fairness and provide opportunities for every student, the teacher will select students who have not been on the podium before from those who raised their hands. In the end, the teacher will summarize the questions according to their answers and mistakes and suggest other solutions.

(6) Post-test

At the end of the week, each student took the post-test in the computer lab on a rotating basis (due to the limit of 20 computers in total). In addition to the 20 single-choice questions that were identical to the pre-test, the post-test included 30 new single-choice questions focusing on computational thinking, which were slightly more challenging to answer. The post-test results are shown in Table 2.

There was a gradual increase from 7th to 8th grade and from 8th to 9th grade in terms of average score. The independent sample T-test showed statistically significant differences ($p<0.0001$) between the three grades and the control group; between 7th and 9th grades ($p<0.01$); but not between 7th and 8th grades or between 8th and 9th grades ($p>0.05$).

The 7th graders mastered 51.6% of the questions, the 8th graders 59.2%, and the 9th graders 63.1%. The control group of corporate interns averaged close to 100% mastery. Note that the highest score for grades 7, 8, and 9 is higher than the lowest score of 36 for the control group. In terms of dispersion, the degree of dispersion among the three grades is still small.

Table 2 Comparison of total scores of students participating in the post-test

Group	control group	7th grade	8th grade	9th grade
Number of participants	46	52	42	49
Average score (percentage)	46.9(93.8%)	25.8(51.6%)	29.6(59.2%)	31.6(63.1%)
Standard deviation (percentage)	2.9(5.8%)	8.8(17.6%)	9.5(18.96%)	8.4(16.9%)
Median score (percentage)	47.5(95%)	26(52%)	31(62%)	34(68%)
Minimum (percentage)	36(72%)	9(18%)	9(18%)	13(26%)
maximum (percentage)	50(100%)	43(86%)	43(86%)	49(98%)

Because the first 20 questions of the post-test were the same as the pre-test, they were isolated and analyzed separately, and the results are shown in Table 3.

The results showed that the performance of the 7th, 8th, and 9th graders gradually increased. The results of the independent sample T-test showed that: the difference between the three grades and the control group was statistically significant ($p<0.0001$); the difference between the 7th and 9th grades was statistically significant ($p<0.01$); the difference between the 7th and 8th grades was statistically significant ($p<0.05$); but the difference between the 8th and 9th grades was not significant ($p>0.0001$).

The average scores on the last 30 questions of the post-test gradually increased in grades 7, 8, and 9. The independent sample T-test showed that: the differences between the three grades and the control group were statistically significant ($p<0.01$); the differences between the 7th and 9th grades were statistically significant ($p<0.01$), but the differences between the 7th and 8th grades, and the 8th and 9th grades were not statistically significant ($p>0.05$).

Table 3 The score comparison of the first 20 questions of the post-test participants

Group	Control group	7th grade	8th grade	9th grade
Number of participants	46	52	42	49
Average score (percentage)	19.1(95.6%)	10.4(51.7%)	12.3(61.5%)	12.8(64.2%)
Standard deviation (percentage)	1.2(5.8%)	3.7(17.6%)	3.9(19.5%)	3.9(19.4%)
Median score (percentage)	19(95%)	11(55%)	13(65%)	13(65%)
Minimum (percentage)	15(75%)	3(15%)	2(10%)	4(20%)
Maximum (percentage)	20(100%)	19(95%)	19(95%)	20(100%)

Because the first 20 questions of the post-test were the same as the pre-test, it was possible to compare the differences between the pre-test and post-test, as shown in Table 4.

All grades showed a significant improvement in post-test scores compared to pre-test scores. The 8th grade showed the most significant improvement: P-value of the T-test is less than 0.01, the average score is increased by 25.7%, and the effect size of post-test to pre-test is 0.71, indicating that the effect of teaching is pronounced. The 7th and 9th grades showed similar improvements, which were greater than 10%. The overall improvement for all three grades was 14.5%, with an effect size of 0.416, close to the medium size and significant ($p<0.01$). These statistical results indicated that college students' support in teaching programming to country schools in summer social practice has a substantial promotion on acquiring programming knowledge by rural students, looking at test scores' improvement.

Table 4 T-test results of post-test and pre-test paired samples

Group	All three grades	7th grade	8th grade	9th grade	Control group
P-value	0	0.044	0	0.047	1
Number of participants	131	47	41	43	43
Average of pre-test	10.4	9.6	9.9	11.8	19.1
The standard deviation of pre-test	3.28	3.22	3.12	3.11	1.17
Average of post-test	11.9	10.6	12.4	13	19.1
The standard deviation of post-test	3.91	3.7	3.94	3.77	1.17
The effect size of post-test with respect to pre-test	0.416	0.287	0.71	0.348	0
Increase percentage	14.5	10.4	25.7	10.2	0

The post-test was a computer-based test, and the time spent on the problems was recorded in seconds. The records showed that 8^{th} grade took the least amount of time (2139s on average), while 7^{th} grade (2583s on average) and 9^{th} grade (2308s on average) took more time. There was also no significant difference between the time spent in eighth and ninth grade ($p=0.313>0.05$); the time spent in the lower-scored 7^{th} grade was significantly higher than that in 8^{th} grade ($p=0.011$), but not significantly different from that in 9^{th} grade ($p=0.129>0.05$).

(7) Summary of feedback from the students

At the end of the program, the programming teacher asked students to submit written reflections and summaries voluntarily. A total of 120 submissions were received, representing approximately 83.9% of the total number of participating students. Thirty-five pieces of feedback (29.2%) referred to programming lessons. We analyzed the texts in detail and found that they could be summarized as follows:

(A) programming was a new subject that they were never exposed to before;
(B) the teaching method of watching animation videos and breaking through levels was exciting, just like playing video games;
(C) the hands-on instruction from the programming teacher helped students to overcame their fears and timidity to try programming.

3. Conclusion and Discussion

Summarizing the above research process and the results of quantitative analysis, the following conclusions can be drawn.

The programming teachers used Beijing High-Tech Programming Education Company's written questions for the job interview to test the students' programming knowledge. The job-seeking college students' scores were used as reference (the control group) for the scores of junior high students.

Although the rural middle school students had not systematically taken ICT courses, their average scores on the paper-based pre-test were close to 50% of the full score, indicating that the rustic middle school students' programming skills were not zero or even poor. The higher the grade, the better the test scores were, reflecting stronger the programming skills. The 9^{th}-grade students' pre-test scores were significantly higher than the pre-test scores of the 8^{th} and 7^{th} grades. The degree of dispersion within each grade is not great. Some individual students' score is 85% out of the full score, which is higher than the lowest score of the control group.

After 240 minutes of programming instruction, rural middle school students showed significant improvement in their programming skills as measured by the written post-test scores. Regarding the same questions' score only, all three grades' overall progress was 14.5%, with an effect size of 0.416, which was close to the medium size and was significant ($p<0.01$). The 8^{th} grade showed the greatest increase, with a mean value of 25.7% and an effect size of 0.71. It can be seen that the programming education provided by the college students' summer practice effectively improved the computer programming knowledge of rustic junior high school students. Some students have full marks or close to full marks. Regarding the results of all content in the post-test, some junior high school students' scores were also close to full marks, significantly higher than the lowest scores of the control group.

Both 7th and 8th graders did not have computer lab sessions; instead, they studied collectively with the programming teacher in a classroom setting. The 9th graders spent one-third of their time studying individually with the online tutorial system and two-thirds of their time studying collectively with the programming teacher in a classroom setting. However, there was little difference in post-test between the two learning styles. Thus, the online tutorial system can be used as a tool for assisting learning in the absence of teachers with a similar effect as human teachers, consistent with previous research results. [4] This hybrid teaching method also fully utilizes the infrastructure like computers and internet access that the government has already equipped rural schools with, avoiding wasting resources on education informatization construction.

The students' written feedback demonstrated that they enjoyed the programming class, not only because it was their first exposure to the new subject but also because the game-based teaching approach and online tutorial system are novel.

The reasons for these findings are discussed and analyzed in detail.

Although rustic junior high school students did not take systematic ICT courses, their overall performance on a written test equivalent to the Beijing high-tech company's recruitment test exceeded expectations: some junior high school students even outperformed college-graduate job applicants. This finding differs greatly from the description of rural students' ICT and programming knowledge and abilities in previous research in China. As indicated from the content of programming test questions, these questions were ostensibly a test of the programming ability, but actually they were more of a test of the reading comprehension and logical thinking skills that students have been trained through math, physics, Chinese and English courses. The higher the grade, the stronger their reading and logical thinking ability become. Therefore, even though they have not studied programming systematically, rural middle school students with some reading abilities and logical thinking skills can still score considerably well on the programming test, and their scores increase with the grade.
After obtaining all-subject scores at the end of the last semester from the principal, we analyzed the Chinese, math, and English scores related to the participants' programming scores. The results were as follows:

(A) The correlations between the pre-test and post-test scores in all three grades are significantly positively correlated with the scores of the three subjects and their totals at the level of 0.01 ($p<0.01$). This indicates that junior high school students with better individual or overall scores in Chinese, mathematics, and English perform better on the pre-test and improve more on the post-test. In other words, they have a better foundation and learn more efficiently in programming.

(B) In the 7th and 8th grades, the correlation coefficients between math scores and pre-programming test scores are the largest (0.52 and 0.69, respectively), while in the 9th grade, the correlation coefficients between English scores and pre-programming test scores are the largest (0.59). The correlation coefficients between the total scores of the three subjects and the pre-programming test scores of the grade are higher than the correlation coefficients between the individual subject scores and the pre-programming test scores.

(C) In three subjects, mathematics has the highest correlation coefficients with post-test scores (including total scores, the first 20 questions, and the last 30 questions) of the three grades. In the 7th and 8th grades, the correlation coefficients between math scores and post-test scores are even higher than the correlation coefficients between the total scores of the three subjects and the post-programming test scores.

The above three results of correlation analysis showed that the junior high school students' Chinese, mathematics, and English scores and their total scores indicate the basis for their learning of programming knowledge, and all of them had a positive impact on the learning effect of programming knowledge; mathematics and English have the greatest impact on programming learning.

In this study, the testing of rural middle school students' programming knowledge and ability is limited to paper-based or internet-based tests in the form of single-choice questions, rather than real-time programming on computers. Despite its limitation, we cannot deny that theory guides practice and that students' logical thinking ability and theoretical foundations will guide their practice on the computer. In future research, we will examine students' ability to operate on the computer and analyze how they relate to the school curriculum.

4. Policy Recommendations

Based on the analysis and reflection of programming education in PKU students' summer practice activities, we propose the following policy recommendations to provide a reference for the development of programming education and artificial intelligence education in China and the realization of education equity.

Programming education for elementary and middle school students is an essential component of artificial intelligence education in both city and country. It is a crucial embodiment of the concept of "education for all," educational equity, and balanced development, to which education administrations should attach great importance.

The programming knowledge of primary and secondary school students is highly and positively correlated with mathematics, English, and Chinese. The students, urban or rustic, with training in reading and logical thinking, have some programming foundation and are ready for more professional programming and artificial intelligence education. Education management departments need to prioritize artificial intelligence education, especially in country schools. More importantly, they need to integrate the education of artificial intelligence with the conventional education curriculum.

Given the status quo of the lack of ICT teachers in rustic schools, a highly efficient and feasible way to provide programming education for country students is to organize social practice activities with outstanding college students. Such activities can not only effectively teach programming and artificial intelligence to rural students, but also help college students understand the basic situation of elementary education in China. Education administrators, colleges, and universities should provide support in terms of policies and funds.

As for the specific form of programming education, if the number of teachers is enough, it can be mainly taught by human teachers; however, if the number of teachers is insufficient or the teaching quality needs to be improved, the mixed teaching method combining teachers' teaching with students' self-study through online teaching system can also be adopted. The blended teaching method can make up for the shortage of teachers and poor teaching quality in rural schools and make full use of the computers and internet access in rustic schools.

References:

[1] Wang Caihong. Discussion on Problems and Countermeasures of computer education in rural primary schools [J]. Curriculum education research, 2014 (31): 148-149

[2] Fan Lima, Xu liangjuan. Programming teaching in rural primary schools under the concept of maker Education [J]. Digital teaching in primary and secondary schools, 2018 (7): 56-57

[3] Xu Deliang. Maker education lights up rural innovation education in remote and weak counties [J]. Information technology education in primary and secondary schools, 2017 (4): 67-69

[4] Jia Jiyou, Meng Qingquan. Evaluation and selection of intelligent teaching system [J]. Digital education, 2019, 5 (3): 1-9