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# *Implementation of Online Piano Teaching System Based on Internet of Things Technology*

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***Abstract:*** More and more parents put their children's education at the center of their lives. As the king of musical instruments, piano is considered the first choice for music education. Due to the ever-increasing demand for piano learning, the teaching tasks of piano professional teachers are increasing day by day, and the traditional one-to-one teaching mode has been unable to accommodate to the fast evolution of piano education. In the context of the Internet of Things, new piano teaching methods that break the traditional piano teaching methods are gradually emerging. The online piano teaching mode is conducive to the optimization of teaching forms and the improvement of teaching efficiency. In order to improve the efficiency of piano teaching, this paper used the Internet of Things technology to study the online piano teaching system. In this paper, the software and hardware functions of the online piano teaching system were explained in detail, and the teaching process of using the online piano system for piano teaching was described. At last, the availability of the teaching system in piano teaching was verified by comparative experiments. The research results showed that, compared with the traditional piano teaching mode, the online piano teaching mode can improve students' learning interest and learning efficiency, and better solve the problems encountered by students in piano learning. This experiment verified the feasibility of the online piano teaching system.

## 1. Introduction

At present, the piano instruction means is mainly based on the individual instruction means, and sometimes the group instruction means is used for piano teaching. Although the development of the above piano teaching system has made progress, there are still some matters in specific instruction forms, such as unified teaching methods and insufficient attention to students' subjectivity. At the same time, despite the strong support of informatization teaching, most music colleges and educational institutions are currently unable to integrate Internet of Things technology into piano lessons, and the application level of online piano lessons has not achieved the expected results. Therefore, it is necessary to employ the Internet of Things skill to conduct research on the online piano teaching system.

Scholars have studied piano teaching methods from multiple perspectives. Y Chen proposed the reform of information network and the construction of piano teaching in colleges and universities, mainly including three aspects, namely, using "micro-class" piano teaching to equip traditional classroom teaching, building a network piano learning environment, and building a "MOOC" piano teaching platform [1]. Demrayak E conducted a study on the applicability of therapeutic stories in piano teaching. Studies have shown that giving music creation time periods suitable for individual differences of students and selecting story topics based on students' interests increases the effectiveness of teaching [2]. Chen S studied piano education through intelligent network, established a piano note recognition algorithm, and realized the transcription, testing and annotation of some piano audio files in piano education [3]. Based on the teaching concept of "Internet + Education", Wang S H pointed out that traditional piano lessons and online piano lessons must be closely linked in order to achieve the goal of cultivating high-quality music education talents [4]. Xie S put forward a feasible path for piano teaching methods in colleges and universities under the "micro era". The purpose is to realize the upgrading of piano professional teaching from teaching concept, teaching content, teaching method, technical means to evaluation system [5]. Although there are many studies on piano teaching, there is no detailed research on online piano teaching.

With the emergence of Internet of Things technology, online technology has been widely used in the field of education. Fu Q conducted research on the integration of smart classroom teaching strategies and traditional classroom teaching models in surgical teaching, which combines the dual advantages of smart classroom teaching strategies and traditional classroom teaching models [6]. Zeng G proposed the integration mechanism of multimedia computer technology and teaching Chinese as a foreign language, thereby promoting the in-depth development of teaching Chinese as a foreign language [7]. Wang L designed and developed an improved system for the network teaching platform based on ASP.NET technology, and the results proved that the basic functions of the designed online teaching platform can be realized [8]. Wang X Q expounded the leading role of micro-video teaching and conducted research on the online teaching method of linguistics [9]. In response to the quality of online teaching videos, Huang H P proposed a video learning effect evaluation scheme based on EEG signals and machine learning, which can improve students' satisfaction in watching teaching videos [10]. Although the Internet of Things technology is widely used in online teaching, there are few studies on online piano teaching.

In order to improve the efficiency of piano teaching and promote the reform of piano teaching methods, this paper used the Internet of Things technology to study the online piano teaching system. In this paper, the functions and principles of the software and hardware of the online piano teaching system were described in detail, and a comparative experiment was carried out to compare the students' learning interest, students' learning efficiency, learning problems, and students' piano level to verify the effectiveness of the online piano teaching system.

## 2. Online Piano Teaching System Based on Internet of Things Technology

(1) Objectives of online piano teaching

The teaching objectives of the online piano teaching method are divided into two aspects [11]. On the one hand, its purpose is to use network technology to solve students' basic problems in advance, improve students' learning ability, and avoid repetition of teachers' activities. On the other hand, the effective use of online piano teaching can improve students' interest in learning to a certain extent, improve students' independent thinking ability and critical thinking ability, and optimize piano classroom teaching.

(2) Introduction to software functions

The online piano teaching software is divided into three sections: textbook library, course

teaching, and communication and interaction.

1) Textbook library

The textbook library contains tens of thousands of world famous songs, popular songs, professional songs, etc., and students can practice these songs freely. The software has a feedback mechanism, which can recommend learning resources according to the students' current piano level, and students can practice independently according to the recommendations [12]. The recommendation mechanism algorithm is as follows:

The online teaching system adopts an adaptive guidance mechanism to demonstrate the relationship between students' understanding level and teaching resources. Students should take a student proficiency pre-test when they log in for the first time. The process of student user cognitive level testing is described as follows [13]:

$$\mathrm{L}\left(\mathrm{u}_{1,}\mathrm{u}_{2},\ldots,\mathrm{u}_{\mathrm{n}}\middle|\theta\right)=\Pi_{\mathrm{j}=1}^{\mathrm{n}}\mathrm{p}_{\mathrm{j}}(\theta)^{\mathrm{U_j}}\mathrm{Q}_{\mathrm{j}}(\theta)^{1-\mathrm{U_j}} \tag{1}$$

$$P_j(\theta)=e^{\theta-b_j}\Big/(1+e^{\theta-b_j}) \tag{2}$$

Taking the logarithm of Formula (2) is:

$$\mathrm{lnL}\left(\mathrm{u}_{1,}\mathrm{u}_{2},\ldots,\mathrm{u}_{\mathrm{n}}\middle|\theta\right)=\Pi_{\mathrm{j}=1}^{\mathrm{n}}[\mathrm{u_j}\mathrm{lnp_j}(\theta)+(1-\mathrm{u_j})\mathrm{lnQ_j}(\theta)] \tag{3}$$

According to the relationship between $P_j$ and $Q_j$, the formula can be simplified to:

$$\mathrm{lnL}\left(\mathrm{u}_{1,}\mathrm{u}_{2},\ldots,\mathrm{u}_{\mathrm{n}}\middle|\theta\right)=\Pi_{\mathrm{j}=1}^{\mathrm{n}}[\mathrm{u_j}\mathrm{lnp_j}(\theta)+(1-\mathrm{u_j})\mathrm{ln}(1-\mathrm{P}(\theta))] \tag{4}$$

Formula (4) can be simplified to:

$$\frac{\partial lnL}{\partial\theta_j}=\sum_{j=1}^{n}[u_j-\frac{e^{\theta_j-b_j}}{1+e^{\theta_j-b_j}}] \tag{5}$$

Then the student ability value can be expressed as [14]:

$$\theta_{k+1}=\theta_k+\Delta\theta \tag{6}$$

$$\Delta\theta=-\frac{\mathrm{f}(\theta_0)}{\mathrm{f}'(\theta_0)}=\frac{\sum_{\mathrm{j}=1}^{\mathrm{n}}[\mathrm{u_j}-\frac{e^{\theta_j-b_j}}{1+e^{\theta_j-b_j}}]}{\sum_{\mathrm{j}=1}^{\mathrm{n}}\frac{e^{\theta_j-b_j}}{(1+e^{\theta_j-b_j})^2}} \tag{7}$$

Among them, $u_j$ is the number of results obtained from the results system.

$$b_j(voting)=\sum_{i=1}^{5}\frac{n_{ij}}{N_j}D_i \tag{8}$$

$$N_j=\sum_{i=1}^{5}n_{ij} \tag{9}$$

$b_j(voting)$ is the weighted average of the difficulty of the j course resource after student users complete the evaluation.

$$b_j(tuned)=\omega\cdot b_j(initial)+(1-\omega)\cdot b_j(voting) \tag{10}$$

$b_j(tuned)$ is the difficulty adjustment value for the j educational resource based on the student collective voting results.

The one-parameter item information function is [15]:

$$I_j(\theta)=\frac{1.7^2}{e^{1.7(\theta-b_j(turned))}[1+e^{-1.7(\theta-b_j(turned))}]^2} \tag{11}$$

Among them, θ is the student's ability value, and $b_j(turned)$ is the adjustment parameter of the difficulty of the recommended resource. When the function takes the maximum value, the resource difficulty represented is the most suitable recommended resource.

2) Course teaching

In the online piano teaching software, teachers can create their own piano rooms, and students can choose to join the class according to their own preferences. After students join the class, the teacher posts the assignment. Teachers can set specific requirements for completing assignments, and can adjust the difficulty of tasks according to students' learning. And after students enter the piano classroom, the interface will reflect the homework assigned by the teacher. Students must complete the homework assigned by the teacher as required, otherwise they cannot submit the homework successfully.

Teachers receive a notification message when student work is uploaded. Teachers can see the completion of student work and give comments based on student performance. Teachers can also manage courses. Once the teacher selects the students, he can add lessons for the students. Figure 1 is a schematic diagram of the operation mechanism of course teaching.

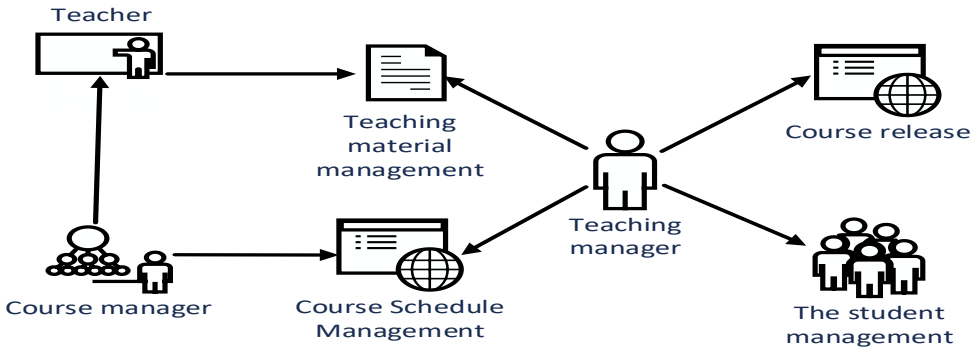


Figure 1: Schematic diagram of course teaching operation mechanism

3) Communication and interaction

The communication and interaction community is the online bulletin board of the online teaching platform. Students can ask teachers about their confusion and questions in the classroom, and learn from each other and answer questions. Teachers can also view and publish information about teaching materials.

(3) Introduction to hardware functions

The hardware takes the traditional piano as the carrier, and connects the hardware with the piano through the mobile terminal. The hardware adopts the Internet of Things technology to achieve accurate error correction and timely detection of learners' basic playing problems. The principle of hardware technology is shown in Figure 2.

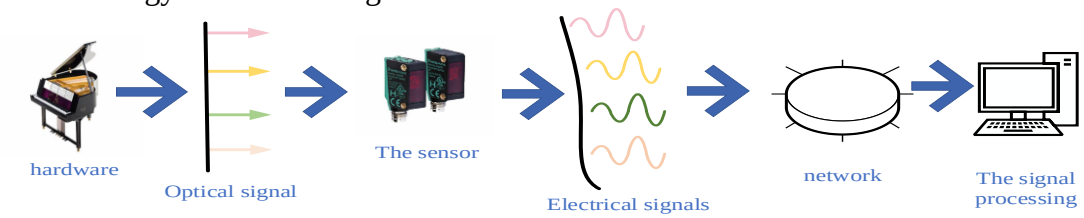


Figure 2: Piano hardware principle

The hardware is placed at the root of the piano keys. The sensor converts the detected optical signal into an electrical signal, and then performs information transmission and information processing to complete signal collection, conversion and analysis [16].

The hardware adopts a reflective all-fiber current sensor. Assuming that the moving position of

the polarizer is at an angle of 45 degrees to the x-axis, the Jones matrix of the incident fiber is [17]:

$$E_{in} = \begin{pmatrix} E_x \\ E_y \end{pmatrix} \tag{12}$$

$$E_X = E_Y = E \tag{13}$$

If $E_{in} = E\begin{pmatrix} 1 \\ 1 \end{pmatrix}$, the transmission matrix in the x-axis direction of the high birefringence fiber can be regarded as:

$$H_{HBx} \cdot H_{in} = \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix} \cdot \begin{pmatrix} E \\ E \end{pmatrix} = E \cdot \begin{pmatrix} 1 \\ 0 \end{pmatrix} \tag{14}$$

Then the light field after the light passes through the quarter-phase retarder is:

$$H_{\lambda/4\_1} \cdot H_{HBx} \cdot E_{in} = \begin{pmatrix} cos45^0 & i\ sin45^0 \\ i\ sin45^0 & cos45^0 \end{pmatrix} \cdot \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix} \cdot \begin{pmatrix} E \\ E \end{pmatrix} = \frac{\sqrt{2}}{2} E \cdot \begin{pmatrix} 1 \\ i \end{pmatrix} \tag{15}$$

Assuming that the deflection angle produced by the Faraday effect in the sensing fiber is $\theta_F$, the transmission matrix of the sensing fiber is:

$$H_{Faraday\_1} = \begin{pmatrix} cos\theta_F & sin\theta_F \\ -sin\theta_F & cos\theta_F \end{pmatrix} \tag{16}$$

$$H_{Faraday\_1} \cdot H_{\lambda/4\_1} \cdot H_{HBx} \cdot E_{in} = \begin{pmatrix} cos\theta_F & sin\theta_F \\ -sin\theta_F & cos\theta_F \end{pmatrix} \cdot \begin{pmatrix} cos45^0 & i\ sin45^0 \\ i\ sin45^0 & cos45^0 \end{pmatrix} \cdot \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix} \cdot \begin{pmatrix} E \\ E \end{pmatrix} = \frac{\sqrt{2}}{2} \cdot E^{i\theta_F} \cdot \begin{pmatrix} 1 \\ i \end{pmatrix} \tag{17}$$

After the light is reflected by the mirror, the transmission matrix of the mirror is:

$$H_{reflector} = \begin{pmatrix} -1 & 0 \\ 0 & 1 \end{pmatrix} \tag{18}$$

$$H_{reflector} \cdot H_{Faraday\_1} \cdot H_{\lambda/4\_1} \cdot H_{HBx} \cdot E_{in} = -\frac{\sqrt{2}}{2} \cdot E^{i\theta_F} \cdot \begin{pmatrix} 1 \\ i \end{pmatrix} \tag{19}$$

The reflected light enters the sensing fiber again, and the transmission matrix is:

$$H_{Faraday\_2} = \begin{pmatrix} cos\theta_F & -sin\theta_F \\ sin\theta_F & cos\theta_F \end{pmatrix} \tag{20}$$

The light field after the light passes through is:

$$H_{Faraday\_2} \cdot H_{reflector} \cdot H_{Faraday\_1} \cdot H_{\lambda/4\_1} \cdot H_{HBx} \cdot E_{in} = \frac{\sqrt{2}}{2} \cdot E^{i2\theta_F} \cdot \begin{pmatrix} -1 \\ i \end{pmatrix} \tag{21}$$

1) Audio-visual model singing function

After the hardware is successfully connected to the mobile device, the software to open the textbook library is used, and the song you want to learn is found, the main interface will display the song details. The so-called "audio-visual" includes two parts: "seeing" and "listening". "Listening" is the speed of listening to music with your ears. However, "watching" has two ways, one is to watch the video played by the player, and the other is to follow the progress of the music to watch the score and listen with your eyes and ears synchronously. The advantage of the former is that the player's body movements and music performance can be intuitively felt, but the disadvantage is that it is easy for students to imitate and ignore the listening and reading of the score. Online teaching focuses on the second form, which clearly shows the music to be learned by the learner. After the learner clicks on the audio and video, the red cursor will be linked to the performance progress, which is convenient for guiding students to keep up with the performance process.

2) Quick spectrum recognition function

The function of reading notation mainly solves the problem of learners' intonation. After the audio-visual is over, students can click on the reading function to practice repertoire. When playing the piano, students should play according to the sheet music. The indicator will stop on the wrong pitch and will not move forward until the correction is correct. At the same time, the spectrum recognition function can also be practiced in sections. Students can choose parting and two-handed forms according to their skill level, set specific score passages, and practice regular passages to improve the overall musical effect.

3) Autonomous error correction function

The purpose of the error correction function is to solve the problem of accuracy and stability of students' music. The error correction mode requires the learner to finish playing at the specified speed without interruption. During the playing process, even if there is a playing error, the learner needs to continue to play the score according to the rhythm. After the playing is over, there will be problems such as wrong tone and wrong rhythm on the scoreboard, and the system will score according to the playing situation.

4) Intelligent scoring function

Whether in notation mode or error correction mode, the program gives a total score that matches the timing, rhythm, and accuracy of the performance after the student's performance. In order to get higher scores, learners will continue to pursue better and faster, which not only improves the enthusiasm of students, but also helps to improve teaching efficiency.

(4) Teaching process

The teaching process is divided into three stages, namely autonomous learning stage, face-to-face teaching stage and consolidation and improvement stage. The teaching process is shown in Figure 3.

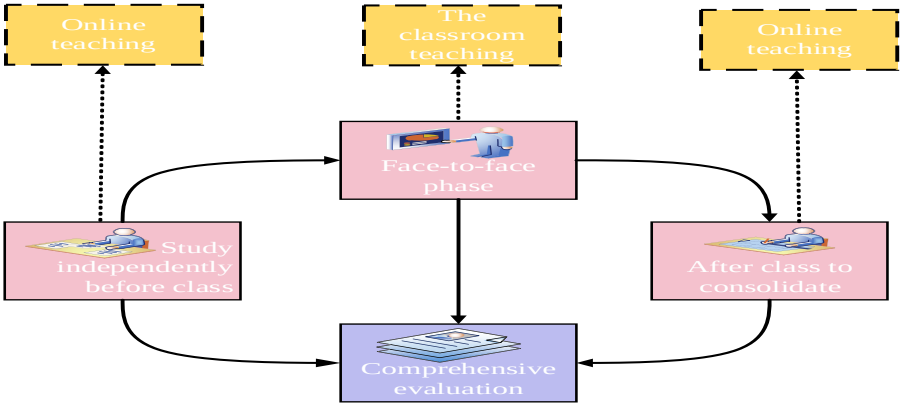


Figure 3: Teaching process diagram

1) Self-learning stage

During this phase, teachers will distribute learning videos and tutorials one week in advance. After students study the teaching materials provided by the teacher and understand the basic content of the course, they can use the teaching materials to practice independently one week before class. The main purpose of this stage of teaching is to allow students to learn basic performance skills through independent practice one week before class, and to be able to play the repertoire easily and regularly, providing sufficient time for face-to-face interaction between teachers and students. This shift in teaching allows students to learn independently based on previous experience.

2) Face to face stage

The face-to-face content of online piano teaching is different from traditional piano teaching. The learner has already mastered the playing skills in the self-learning stage. Therefore, the primary

task of face-to-face education is not to correct mistakes, but more to discuss and communicate between teachers and students. Therefore, the primary goal of face-to-face teaching is to enable students to better absorb what they have learned through teacher-student interaction in the classroom, and to cultivate learners' musical aesthetic ability and musical expression in the process.

3) Consolidation and improvement stage

In the post-class consolidation and improvement stage, learners should combine the knowledge learned during face-to-face teaching with the self-learning knowledge before class, and then carry out consolidation exercises. After the music playing matures, the learners record and upload their own playing videos, and the teacher guides the group members to evaluate the video content, so as to cultivate the learners' critical thinking ability and cooperative inquiry ability.

## 3. Experimental Discussion

One-month piano teaching was given to 50 students with the same level of piano, of which 25 students adopted the online piano teaching method, and the other 25 students adopted the traditional offline teaching method. After the teaching, students and teachers were asked to evaluate students' interest in learning, students' learning efficiency, learning problems, and students' piano level, and then organize and analyze the data.

(1) Students' interest in learning

Students evaluate their interest in learning in the process of piano teaching, and the evaluation results range from 1 to 100. The results are shown in Figure 4.

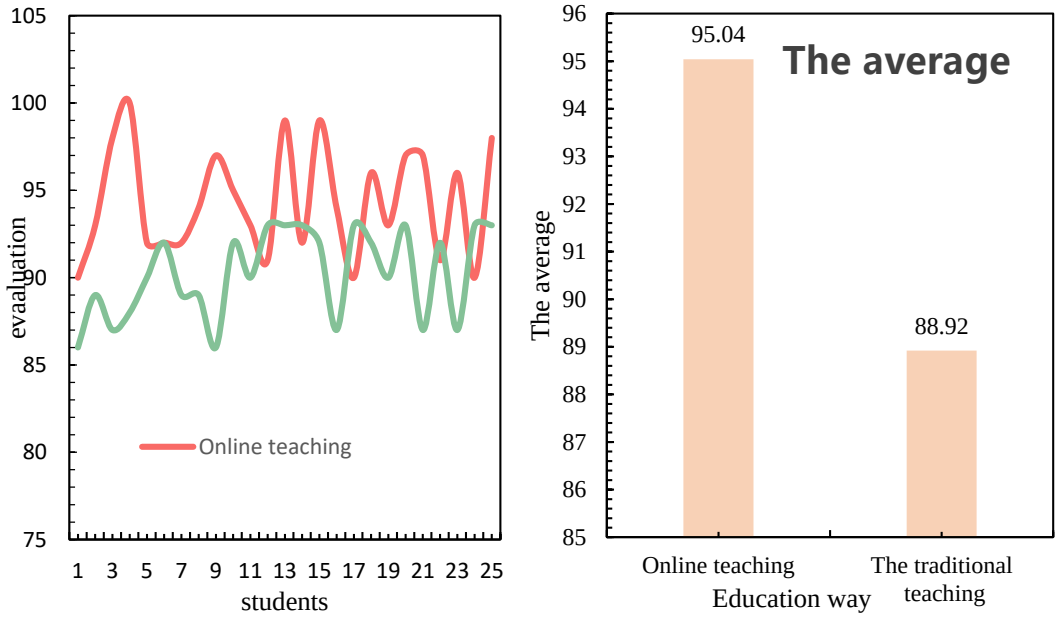


Figure 4: Data graph of students' interest in learning

The comparison data showed that the learning interest of students who use online teaching methods is generally higher than that of students who use traditional teaching methods. The average learning interest of students in traditional teaching is 88.92, and the average learning interest of students in online teaching is 95.04. In traditional piano teaching, a single teaching method is one of the main reasons why students fail to develop a love for piano. The smart piano can clearly show the difficult points in the score on the screen. And by combining the piano with a tablet, students can experience a diverse curriculum that combines exercises and games. It can also correct mistakes by practicing with the lights, allowing students to follow the lights on the keys to master the pieces, which is also a very unique feature of the online piano teaching system.

(2) Student learning efficiency

Teachers evaluate students' learning efficiency in the process of piano teaching, and the evaluation results range from 1 to 100. The results are shown in Figure 5.

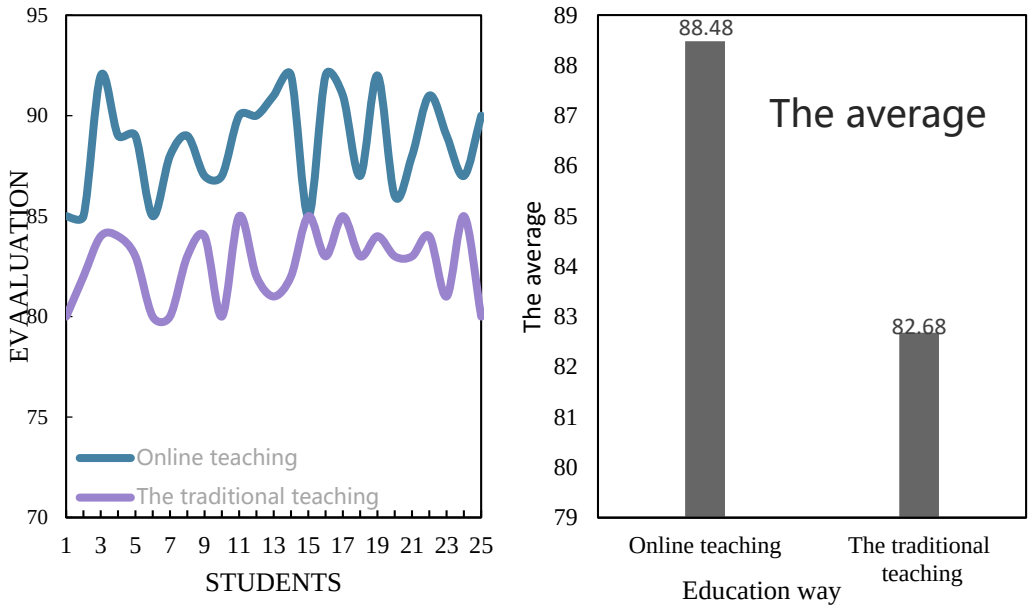


Figure 5: Student learning efficiency data graph

In the traditional teaching method, the average score of students' learning efficiency is 88.48. In the online teaching method, the average score of students' learning efficiency is 82.68. It can be seen that the online teaching method has a great promotion effect on the students' learning efficiency. The interaction between teachers and students in traditional piano teaching can only be expressed through language and body to a large extent, which reduces the learning effect. Online piano teaching overcomes the shortcomings of these traditional teaching models. In the course, the relevant data of students' performance will be recorded through technical means and fed back after the performance, which is convenient for students, parents and teachers to quickly find problems.

(3) Students' learning problems

Difficulties encountered by students in learning mainly include wrong pronunciation, wrong rhythm, problems in reading notation, and problems in hand shape. The problems of students in learning are investigated, and the results are shown in Figure 6.

Among the four common problems for students, the number of students who encountered difficulties in traditional teaching was higher than the number of students who encountered difficulties in online teaching. For the problem of wrong pronunciation and wrong rhythm, the number of people who are troubled by this problem in traditional teaching is 18 and 15, respectively, and the number of people who are troubled by this problem in online teaching is 10 and 8, respectively, indicating that online teaching has a better effect on this problem. In the online piano teaching system, when students practice alone, it can accurately detect wrong sounds and rhythms, and present them in time through mobile devices such as computers. Without the need for teacher guidance, students can clearly understand their own problems. For the problem of reading music, 20 people were troubled by this problem in traditional teaching, and 12 people were troubled by this problem in online teaching. The online piano teaching system uses the built-in electronic piano score, allowing students to watch and listen while practicing to improve their reading ability. Through the use of the functions, students can effectively solve the problem of wrong tone and rhythm before class, and teachers can pay more attention to the guidance of hand shape fingering, skills, music performance and other issues. Therefore, the hand shape problem is also improved.

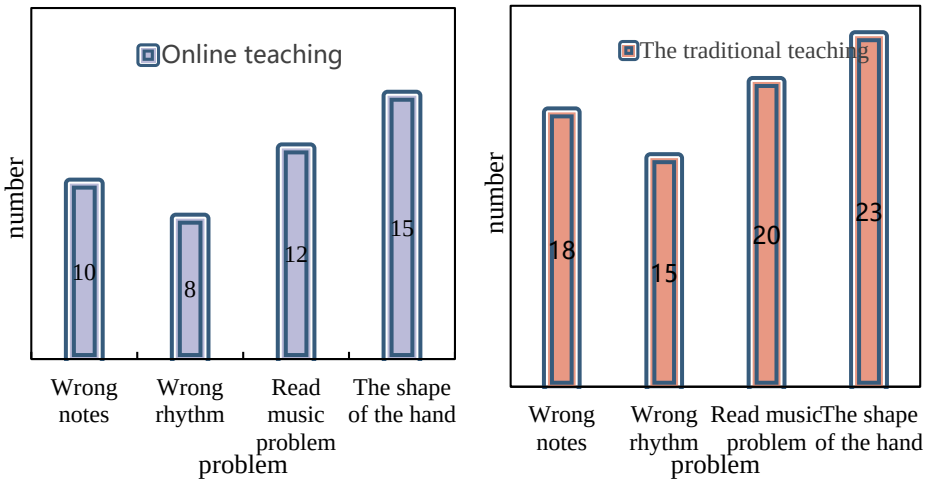


Figure 6: Data graph of student learning problems

(4) Students' piano level

Teachers evaluate students' piano level at the end of piano teaching, and the evaluation results range from 1 to 100. The results are shown in Figure 7.

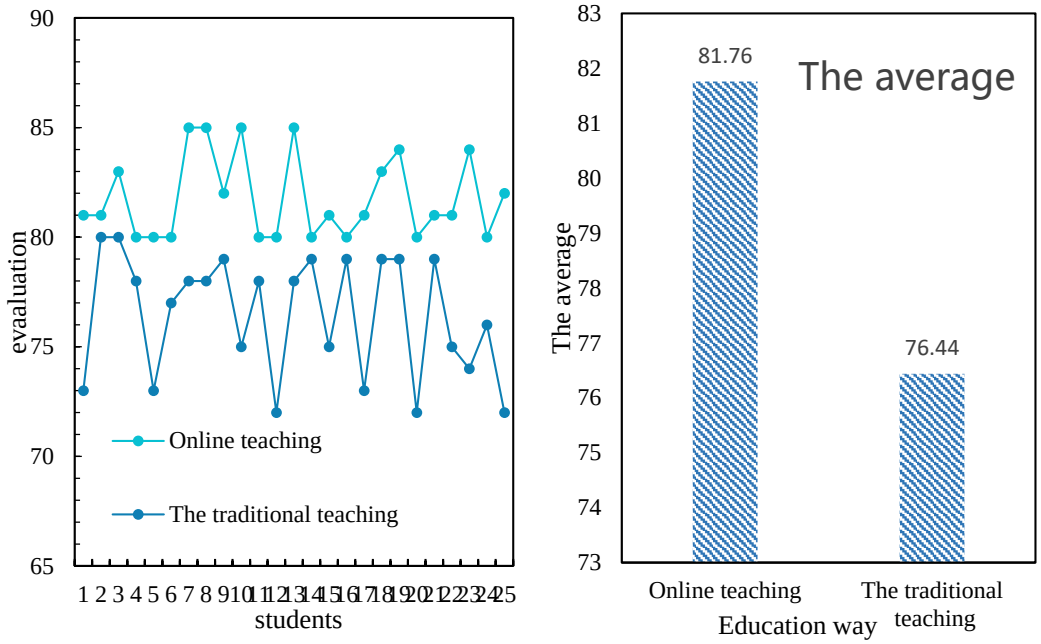


Figure 7: Data graph of piano proficiency of students

After the one-month piano training, compared with the students who received the traditional piano training, the students who received the online training had better overall piano skills, and the average piano skills improved by 6.96%. It shows that the online teaching method is of great help to the improvement of students' piano level. Online piano teaching can record students' practice well through Internet tools, and can report pressure through sensors. It can not only better understand the performance of the students, but also can evaluate the students' situation in the whole performance through intelligent tools, and can give appropriate feedback on the students' psychological state.

## 4. Conclusion

Through the application of Internet of Things technology, this study successfully constructed and verified the effectiveness of online piano teaching system. Through the cooperation of software and hardware, the system significantly improves students' learning interest, learning efficiency and comprehensive literacy. The system realizes the functions of personalized teaching resources recommendation, real-time error detection and feedback, and intelligent scoring, which not only optimizes the teaching form, but also improves the teaching quality. The implementation of online piano teaching mode, for teachers, reduces the repetitive teaching burden, so that they can focus more on the personalized instruction of students and the cultivation of musical expression. In the field of music education, this system promotes the innovation of teaching methods and provides a new path for the modernization and personalized development of music education. Future research can further explore the applicability of this system in different teaching environments and different age groups of students, and how to integrate it more deeply with other educational technologies to achieve a wider range of educational innovation and teaching effect improvement.

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