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Research on Intelligent Assistant Teaching System for National Musical Instruments Based on PSS

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Abstract: In order to improve the efficiency and quality of the teaching service of the national musical instruments, a design method of product service system (PSS) for national musical instruments is proposed to build a tool for integrating teaching resources, autonomous practice feedback, and social interaction. The basic characteristics of the national musical instruments of the balance between the improvement and the inheritance of traditional music is summarized, the shortcomings of digital transformation of national musical instruments under the condition of smart technology are compared and pointed out, there is still room for development in precision teaching services. Based on the design method of PSS, the musical instrument products and teaching services are integrated into an overall solution, a model of teaching service and value co-creation is constructed. A service process is formed with the song as the basic teaching unit and gesture skill training as the key. The human-smart system collaboration mode is analyzed. The smart product subsystem and teaching service subsystem are established. The relationship among the stakeholders is discussed. The prototype scheme of the smart assistant teaching system of Pipa based on this method is built up to verify.

Keywords: product service system, musical instrument design, Intelligent Instrument, human- system collaboration, digital transformation

1. Introduction

With a long history and profound cultural accumulation, national Musical Instruments are important cultural treasures of the Chinese nation. The education of national Musical Instruments is not only a key path to understand the history and culture of the nation, but also a solid foundation [1] for the inheritance, innovation and cultural confidence of China's aesthetic education culture. However, in China's music education market, there is a huge gap between Chinese and western instrument education and training scale. Compared with the largest number of piano children in the world, the scale of national musical instrument training represented by zither, pipa and erhu is still small and its influence is insufficient [2]. One of the important reasons is that the traditional teaching of national Musical Instruments focuses on music inheritance and cultural precipitation, and the digital transformation of education is relatively lagging behind, and the lack of docking with digital platforms and intelligent technologies. In 2017, the Notice of The State Council on the Issuance of a New Generation of Artificial Intelligence Development Plan was released, which focused on the intelligent education scene and emphasized the promotion of the whole process application [3] of artificial

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intelligence in teaching, management, resource construction and other aspects, and the intelligent development of national musical instrument teaching was imperative.

Product Service System (PSS) is a business model and design concept that creates value for users by organically combining products and services, generating personalized services through data connection, and providing new development space [4] for the industry. Based on PSS, this paper constructs an intelligent assistant teaching system for national Musical Instruments. Through comparison, it shows that the intelligent design of national Musical Instruments is insufficient and puts forward intelligent teaching service process and human-machine collaborative division of labor to enhance learning efficiency. By defining the intelligent system, the service blueprint is constructed to coordinate multi-stakeholder resources to improve the learning experience. Research on testing the prototype system in pipa teaching to assist efficient autonomous practice.

2. Overview of musical instrument design

2.1 Design of national Musical Instruments

The design of national Musical Instruments is a process of integrating many aspects such as music culture, music performance, instrument appearance and production technology to create a unique device that conforms to the characteristics of national temperament. Musical instrument design is not only influenced by music theory, instrument performance, music history, music education and other theories, but also related [5-6] to acoustics, mechanics, materials science and other basic theories, through the combination of ergonomics, formal aesthetics, material technology manufacturing and other design theories to achieve productization [7]. The design and transformation of ethnic Musical Instruments such as Erhu, Guqin and pipa focus on the needs of players, composers and audiences, and seek a balance [8-9] between improvement and innovation and inheritance of the characteristics and traditions of ethnic music. On the one hand, the traditional timbre and shape characteristics of the instrument are maintained. On the other hand, it has made a qualitative leap in the performance of intonation, range, and volume. As a complex system evolution, the design of national Musical Instruments ADAPTS to the needs of contemporary music and the impact of market development trends, combined with sensors, multimodal data, music analysis algorithms and other intelligent technologies become inevitable.

2.2 Current situation of intelligent Musical Instruments

Intelligent musical instrument is a comprehensive product service system solution [10] that combines artificial intelligence and other technologies with the classical acoustics and playing skills of traditional Musical Instruments through instrument ontology, sensors, intelligent algorithms and network links. Intelligent musical instrument system integrates audio analysis, automatic playing, instrument learning and other functions to improve the learnability, usability and performance [10 11] of Musical Instruments. Firstly, combining with the original musical instrument playing mode, mechanical and electronic technology and digital synthesis technology, the new timbre, pitch and rhythm of electronic music are added to form a new music rendering style. Secondly, screen interaction, keyboard equipment and human-computer interaction are used to virtualize, providing different customized performance modes of traditional Musical Instruments and performances combined with a variety of art forms. Finally,

through cameras and sensors, timely feedback is provided to users, adaptive teaching is provided, and the learning efficiency of Musical Instruments is improved. On the other hand, the intelligent musical instrument system uses APP to extend the whole life cycle value and commercial closed loop of Musical Instruments, and adds personalized services such as game teaching, interest community, and network broadcast. It plays an increasingly important role in the development and promotion of modern music culture, as shown in Table 1.

Table 1. Intelligent musical Instrument Products and Their Service Features

Type	Typical products	Service Features
Smart string instrument	Smart guitar, smart ukulele Typical brands: Take Fire, Populele, etc	Guitar fingerboard light guide, instrument body has inlaid type LED display system. APP online guidance and question answering, community interaction, software tuning, gamification practice.
	Stringless guitar Typical brands: Kitara, Strandberg, etc	Multimedia touch screen, elastic rubber, the number of strings and sound effects can be adjusted according to the user's wishes, and headphones and loudspeakers can also be connected. With an app, you can combine a digital instrument with an emulator.
	Intelligent zither, intelligent pipa Typical brands: Dunhuang · Luo LAN, Yi Guzheng, Chenyu, etc	The instrument is equipped with Bluetooth device and APP connection, forming prompts and feedback. The APP also provides music lovers with functions such as online video learning, consultation and appointment with teachers.
Smart keyboard Instrument	Smart piano Typical brands: Yamaha, The ONE, Find, Baldwin, etc	The piano is equipped with an indicator light to display the key position synchronously and practice with the light. APP built-in professional teaching videos, series of tutorials from shallow to deep, gamified piano practice, timbre changes.
Intelligent blowing instruments	Electric blowpipe Typical brands: Ielts Lok, Roland, etc	The blowpipe comes with 10 timbres, one key to octave, intelligent sound, and comes with 2 fingers.
	Electric harmonica Typical brands: Mozca, etc	The harmonica has 78 built-in timbres, rich playing skills and rich interfaces.
Smart Percussion Instrument	Electronic percussion instruments Typical brands: Roland, Cherubs, etc	The instrument is connected to the APP through Bluetooth to learn, simulate the real drum percussion effect, and the interface is rich and widely compatible.
	Somatosensory percussion instrument Typical brand: AeroBand	Self-created exclusive teaching APP, MIDI software adaptation.

In short, intelligent Musical Instruments have made innovations in timbral communication, performer creation, learner practice, and interaction freedom. However, the proportion of intelligent systems based on Chinese national Musical Instruments is relatively low, the construction of systems with teaching as the core function is still not perfect, and there are still many opportunities for the development of intelligent assistant supported by multimodal data. It has become an important direction[12] to build a precise teaching service scene, improve man-machine collaborative teaching, and promote the new teaching mode of Musical Instruments.

3. Construction of an intelligent system for national Musical Instruments

3.1 Product Service System Approach (PSS)

Product service system approach (PSS) is a design concept [13] that integrates products and services to form an overall solution and realize user value at a deeper level. Intelligent technology promotes the evolution of product service system, further strengthens the coupling degree of tangible products and intangible services to form a digital ecosystem[14], and creates value [15] in many aspects of economy, experience and industrial ecology. The auxiliary teaching system of national Musical Instruments based on PSS is a musical instrument learning platform combining software and hardware formed by this design concept, which is a tool for integrating teaching resources, autonomous practice feedback and social interaction. The research of the system breaks through the limitation of the single function design of the traditional musical instrument system, introduces a variety of high-quality educational resources more widely, reshapes the interactive experience between teachers and students, and can play the following three roles:

1) To construct a co-creation model of musical instrument teaching service and value. On the one hand, intelligent auxiliary system perceives user data and brings value to users. On the other hand, users increase teaching content and data, which is conducive to the iterative development of intelligent system.

2) Improve the efficiency of musical instrument teaching. Artificial intelligence based on data analysis can partially replace the repetitive labor work of guidance and feedback, which can solve the problems of high cost and low efficiency of the original one-to-one music teaching.

3) form multi-level resource linkage[16] of stakeholders. Through the network platform, business, resources and man-machine are widely connected to promote the evolution of industrial ecology and new folk music culture that keep pace with The Times.

The construction of the assistant teaching system of national Musical Instruments mainly includes five aspects: service process, human-machine collaboration mode, intelligent system, stakeholders and service blueprint. The following sections discuss one by one.

3.2 The construction of intelligent service process

According to the characteristics of musical instrument teaching objectives and teaching cognitive process, the intelligent teaching service process is constructed by taking single music teaching as the basic teaching unit and focusing on playing movement skills training. The design of the service process can determine the system function, sort out the core business, and optimize the user experience, which is mainly divided into four stages:

- Stage 1: Music theory knowledge learning, students contact with Musical Instruments. In familiarizing with music score, rhythm, pitch and other conceptual foundations, students experience the melody, timbre and harmony of music, understand the historical context behind the music, and lay the foundation for the training of playing movement skills. The teacher's main task is to teach the main points of knowledge, and students need to master the basic concepts for later application of coordinated movements.

- Stage 2: teachers play demonstration, students feel the essentials. The teacher plays the instrument for demonstration, and the students are required to observe the sequence of the teacher's actions. In the process of students' own operation, the teacher prompts students by refining words to help students pay attention to the key points of the instrument in rhythm, movement and posture.
- Stage 3: Autonomous training of playing movement skills, students associated with the application. Students were trained independently by combining music theory knowledge, teacher's playing demonstration, their own experience and other information. In the process of playing movement skills training, students need to maintain the sensitivity to rhythm, strengthen the control of arm, wrist, shoulder and waist posture, and effectively coordinate and control finger types, shapes, and left-hand coordination.
- Stage 4: Instrument learning community interaction, students exchange and share. In the process of musical instrument learning and performance, students use to upload their own videos and various learning resources to learn from each other, learn from and share with each other, and form a mutually promoting learning atmosphere.

3.3 Man-machine collaborative teaching mode

On the basis of building the service process, the human-machine division of labor is further refined and analyzed. The human-machine collaboration relationship established by teachers, students and AI systems is a form[17] of development of hybrid enhanced intelligence, and is one[18] of the key links to realize the personalized, accurate and large-scale teaching mode centered on students, which lays the foundation for the formulation of the teaching mode under the conditions of intelligent technology, as shown in Table 2.

Teachers led the teaching process and paid attention to cultivating students' humanistic feelings and interest in learning. Teachers complete the multi-level demonstration and teaching of social and psychological attributes, emphasize the cultivation of music quality and aesthetic concept, and strengthen the contact with students while dealing with students' emotions, attitudes and values. At the same time, students can master the playing skills by themselves, and enhance the learning ability[19] of independent design, monitoring, adjustment and reflection through metacognition and self-assessment. In the process of communication with teachers and peers, students can obtain humanistic care and social interaction, and improve their comprehensive quality of music. Under the guidance and collaboration of AI in autonomous learning, students 'personalized learning experience is improved.

AI takes the advantages of the fineness, quantity and efficiency of machine processing information, and runs diagnosis, feedback, intervention and reflection through the teaching process[20], and supports both teaching activities of teachers and students. AI acts as a teaching assistant on the teacher side, supporting the integrated teaching design, learning emotion awareness, and ability evaluation in the big data environment, and optimizing the teaching effect. Through semantic retrieval, big data mining and other intelligent technologies, AI forms the knowledge service ability of national Musical Instruments and enhances students 'interest in learning music knowledge. AI acts as a learning partner on the student side, realizes message recommendation, resource recommendation and learning path planning, feeds back learning situation, and improves learning efficiency. AI forms strategy guidance through

artificial intelligence technologies such as gesture recognition and emotion recognition, traces back the root causes of problems such as music recognition, rhythm, and finger-pointing, gives targeted tips and feedback to students' shortcomings in autonomous learning, and adjusts the practice focus individually.

Table 2. Cooperative teaching mode of teachers, students and AI system

	Students	Teachers	AI Technical support
Stage 1	Students learn before class, master the basic music theory foundation, clarify the operation corresponding to the concept, carry out the pre-class test, and reflect on the remedy	Teachers split teaching objectives, optimize the key points of knowledge, import and review excellent teaching resources, and organize pre-class tests	**Teachers:** assist the overall preparation of lessons, help the course test, through the course test can find students' individual differences and problems **Student side:** provide teaching resources and provide analysis of test results
Stage 2	Students listen to lectures collectively, observe the key points of musical instrument playing, conduct group study, and experience musical instrument playing in person	Teachers demonstrate and teach in person, accurately diagnose students' performance tips and feedback, fully interact with students, and give individual guidance according to the situation	**The teacher side:** created AR and VR teaching environment, increased teaching video demonstration data records, student behavior records, and analyzed the learning situation of teaching key points **and difficulties** **Student side:** AI-assisted demonstration forms tips and feedback, 3D animation strengthens the content information, and reduces the work burden of teachers
Stage 3	Students practice independently and fully apply the knowledge points and performance skills learned in class. Individual study, through variant practice, strengthen the standardized training of playing gestures and so on	Combined with data feedback, teachers found specific problems in students 'independent practice, and gave strategy guidance and personalized task direction. Teaching reflection was carried out to form new teaching strategies	**Teachers:** feedback students' autonomous training and learning status to teachers through multimodal data. For the evaluation of autonomous practice test, variant practice suggestions were put forward **Student side:** assisted autonomous practice in the arrangement of learning content, frequency, intensity and timing. The training efficiency was improved by tracing the root causes of problems such as music recognition, rhythm and fingering
Stage 4	Students make use of different online and offline environmental conditions to communicate, gain mutual support from peers, and gain all-round improvement through the discussion of experiences, opinions, and knowledge	Teachers cultivate folk music culture and ecology, guide students' music aesthetics, and realize the pleasant feeling of learning and spirit	**Teachers:** build a social network based on musical instrument playing interest, use web crawler technology to collect public opinion data, and activate online communities and user viscosity **Student side:** recommend online communities, forums and learning partners according to students' interests and learning priorities

3.4 The construction of intelligent support system

Based on determining the process and man-machine mode, the system framework of auxiliary teaching of national Musical Instruments is formed based on PSS, and the corresponding functional service business is completed. The assistant teaching system of national Musical Instruments consists of two parts: product subsystem and service information subsystem. The product subsystem completes the functions of basic playing, interface interaction and multimodal data acquisition, which includes the following three parts:

- National musical instrument ontology. Based on continuing the traditional characteristics of national Musical Instruments, maintaining the sound principle, material structure and operation mode of the existing Musical Instruments, the instruction and data exchange equipment are added to form the playing basis.

- Interactive display equipment. Based on regular natural interactive operation, the teaching content is vividly displayed through the display device.
- Data acquisition sensors. Multi-modal data of students are collected through video, audio, electromyography, and other sensors, which lays the foundation for software services. Among them, the gesture playing of the ethnic pluck instrument is very rapid and complex, and the gesture data are collected by data gloves, forearm sensors and distance sensors. The camera is used to obtain the learners' facial expression and body posture data to comprehensively understand the playing state. Wearable devices were used to understand heart rate, electroencephalogram (EEG), electrodermal signal, and user activity and engagement.

According to the intelligent service process, the service information subsystem establishes multiple ports such as students, teachers, and comprehensive management for support, and the characteristics of data storage and intelligent analysis in the whole process. Taking students as the main service object, this paper focuses on the self-training module of playing movement skills in the service information subsystem, which mainly includes three parts:

- Autonomous training adjustment system. Set teaching strategies and contents according to the teaching objectives of plucking instrumental music and arrange the learning and training process. According to the collection of individual training feedback system, personalized adjustment and revision of stage goals were carried out to match personal ability and based on gradually breaking through the learning comfort zone.
- Self-directed training prompt system. In the process of autonomous practice, multi-channel prompts such as monitors, wearable devices and speakers can reduce students 'cognitive load and strengthen their memory. According to the score teaching procedure, multiple intuitive prompts for language, rhythm and key points are set to facilitate the training of collaborative skills such as remote ensemble and music.
- Independent training feedback system. Through the information collection system, the individual characteristics of rhythm, fingering, and body posture in the playing process of the music are collected, and the shortcomings compared with the expert teachers are quickly pointed out, and the reasons for the playing problems are reasoned, to reduce the ineffective training. The feedback includes comparing the errors in the playing sub-items and the differences in the overall playing analysis.

3.5 Stakeholder analysis

Due to the significant increase in the complexity of product service systems, the auxiliary teaching system of national Musical Instruments cannot be completed by a single party. Therefore, identifying and analyzing the organizations and individuals with important interests in the system will play an important role in optimizing resource allocation, establishing cooperative relationships, and reducing system risks. The stakeholders of the national musical instrument teaching assistance system include four levels: core users, product service providers, ecological chain enterprises and social environment, as shown in Figure 1. In the service process, the data flow organically coordinated multiple stakeholders, and the system integration formed a significant value spillover effect [21], which promoted the positive iteration of the ecology of the instrument education industry.

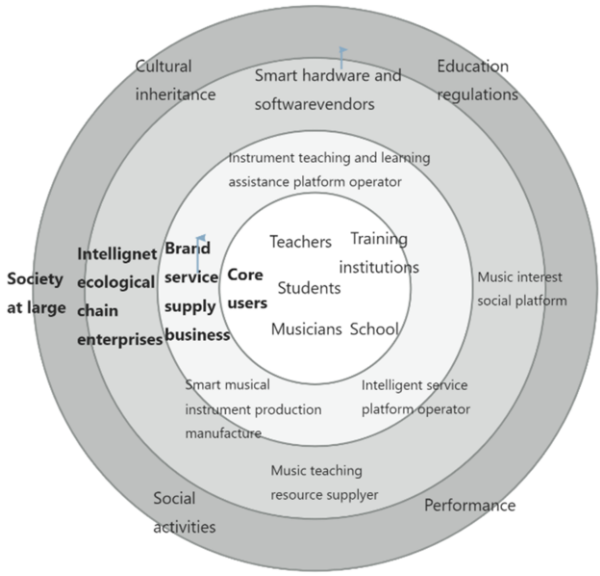

Figure 1. Schematic diagram of core stakeholders

3.6 Blueprint of Intelligent Teaching services

The service blueprint shows the whole picture [22] of the system service user process through the user behavior layer, the foreground layer and the background layer, as shown in Figure 2. According to the specific scene of musical instrument teaching, it is extended to student behavior activity layer, teacher behavior layer and background intelligent support layer, which illustrates the relationship between teacher and student activities, the connection between online and offline links, and the support relationship of intelligent system.

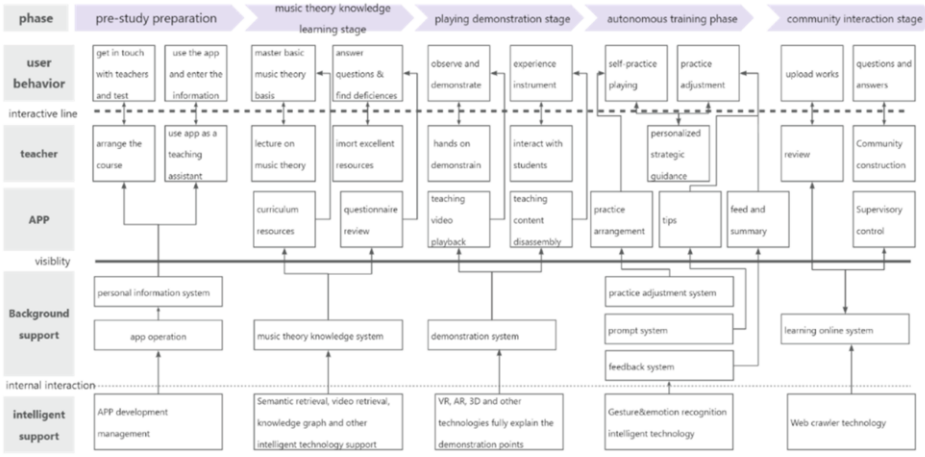

Figure 2. Blueprint for Intelligent Teaching Services

4. Intelligent auxiliary teaching system for Pipa

4.1 Teaching background of pipa

The pipa is a traditional plucped musical instrument with a history of more than 2,000 years in China. Its playing skills are complex and varied, among which fingers directly affect the timble, range, volume and emotional expression of the performance [23]. The teaching of the lute is still mainly based on the traditional mentoring system, which is based on the one-to-one, hand-by-hand and tone-to-tone teaching mode. It takes a long time to practice the playing details of the fingering movement, strength, and string touching way, which leads to [24] the high cost of lute enlightenment teaching and the difficulty of teaching promotion. The study uses user portraits to construct a typical user model, as shown in Table 3, which reflects that the core problems focus on the lack of effective feedback and supervision after class practice, resulting in low practice efficiency and difficulty in skill improvement. The intelligent assistant teaching system for lute is constructed around the key features of user portraits, which improves the efficiency and interest of autonomous practice of lute playing skills and extends the teacher's offline teaching to autonomous learning after class.

Table 3. Typical User Portrait of Pipa Teaching

	● Age: 12, Gender: Female ● 6 months experience in learning the pipa with some interest ● Family members have no relevant music background and cannot provide the necessary background knowledge and learning resources
Needs and Goals	● Feel and experience the pipa playing, enrich the life after school, and hope to become the main way and channel to be happy and relaxed in my spare time ● Master the pipa playing proficiently, practice one skill, participate in the artistic performance activities sponsored by the school, and make new friends ● Make full use of your potential to prepare for the exams, competitions and further studies
User Behavior Characteristics	● Go to the training class near your home every week, and learn from the teacher for 3 hours ● After class, you need to arrange time to complete the practice homework required by the teacher ● Keep practicing the piano for more than half an hour every day under the supervision of parents
User pain points and obstacles	● Fingering is complex, and the knowledge points taught by the teacher are easy to forget. It is hoped that there will be professional guidance after class ● I cannot get corresponding support without teaching resources. I want to know the situation of other friends playing Musical Instruments ● After class, I don't know whether my fingers are correct or not. Blind practice misses the opportunity for growth ● The high cost of pipa teaching makes it an important expenditure for interest cultivation

4.2 Pipa intelligent auxiliary product subsystem

The pipa product subsystem is shown in Figure 3 on the basis of the intelligent technical support system in Section 2.4, which includes the following three aspects: First, the intelligent pipa retains the original musical instrument characteristics, adds indicators and microphones, and exchanges data with the smart TV through Bluetooth; Secondly, wearable devices represented by data glove and forearm bracelet are used to capture the motion characteristics of fingers and forearm more accurately, which is the premise of intelligent fingerings recognition. Finally, smart TV with a camera not only connects smart terminals with the cloud, but also provides an immersive learning environment.

Figure 3. Pipa product subsystem

4.3 PIPA intelligent auxiliary information service subsystem

The lute information service subsystem is mainly composed of four basic functional modules, including lute music theory knowledge learning, playing demonstration, movement training and autonomous training, and instrument learning community interaction. The system is oriented to children or adult beginners. The design of the TV interactive interface adopts the layout of magnetic disk to highlight the use function. The interface color style is soft and elegant Chinese ancient style, creating an elegant national artistic atmosphere, as shown in Figure 4.

Select from the above four modules to focus on the autonomous training service process of playing movement skills. A user journey diagram is constructed from the perspective of students, and the changes of student-centered lute teaching mode are illustrated through user goals, behaviors, system service contact points, emotional states and system support [25], as shown in Figure 5.

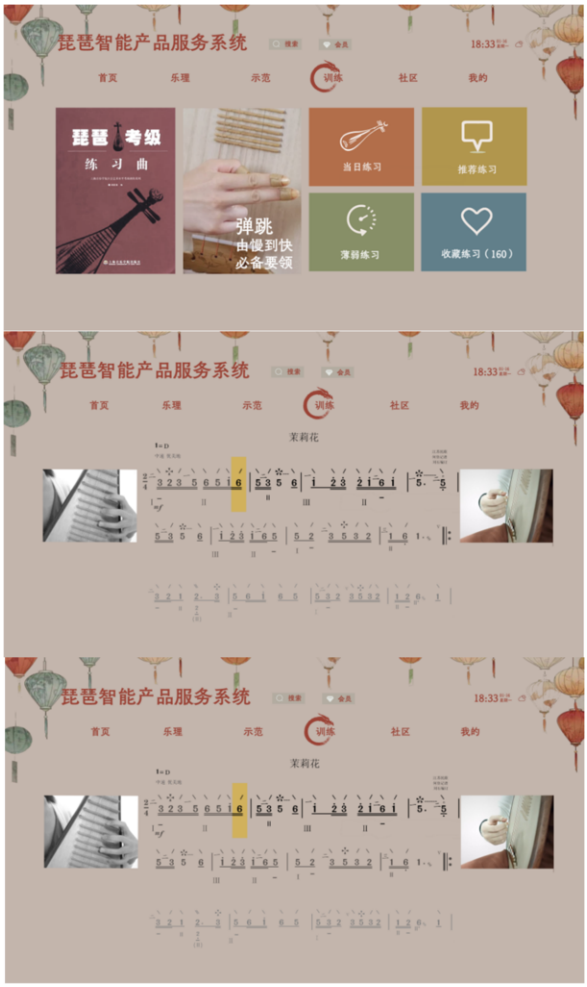

Figure 4. Pipa service subsystem autonomous training interface (adjustment, prompt, feedback)

5. Conclusion

China's national Musical Instruments have a long history and rich cultural connotation. The education and popularization of national Musical Instruments is one of the important links in inherits and carries forward the excellent traditional culture and cultural power. The intelligent product service design method provides a new development space for the intelligent and digital transformation of national musical instrument teaching. The design of national Musical Instruments needs to break through the limitations of playing devices and evolve and develop toward the ecological evolution and development [26] of teaching service industry based on intelligent technology. Taking the pipa instrument as an example, this paper establishes an intelligent musical instrument product service system and scheme, which provides new ideas for the intelligent universal teaching of ethnic plucking instruments by obtaining multimodal data. It is foreseeable that with the deepening of intelligent technology into the teaching scene, the teaching quality and service experience of national Musical Instruments will be further improved and developed.

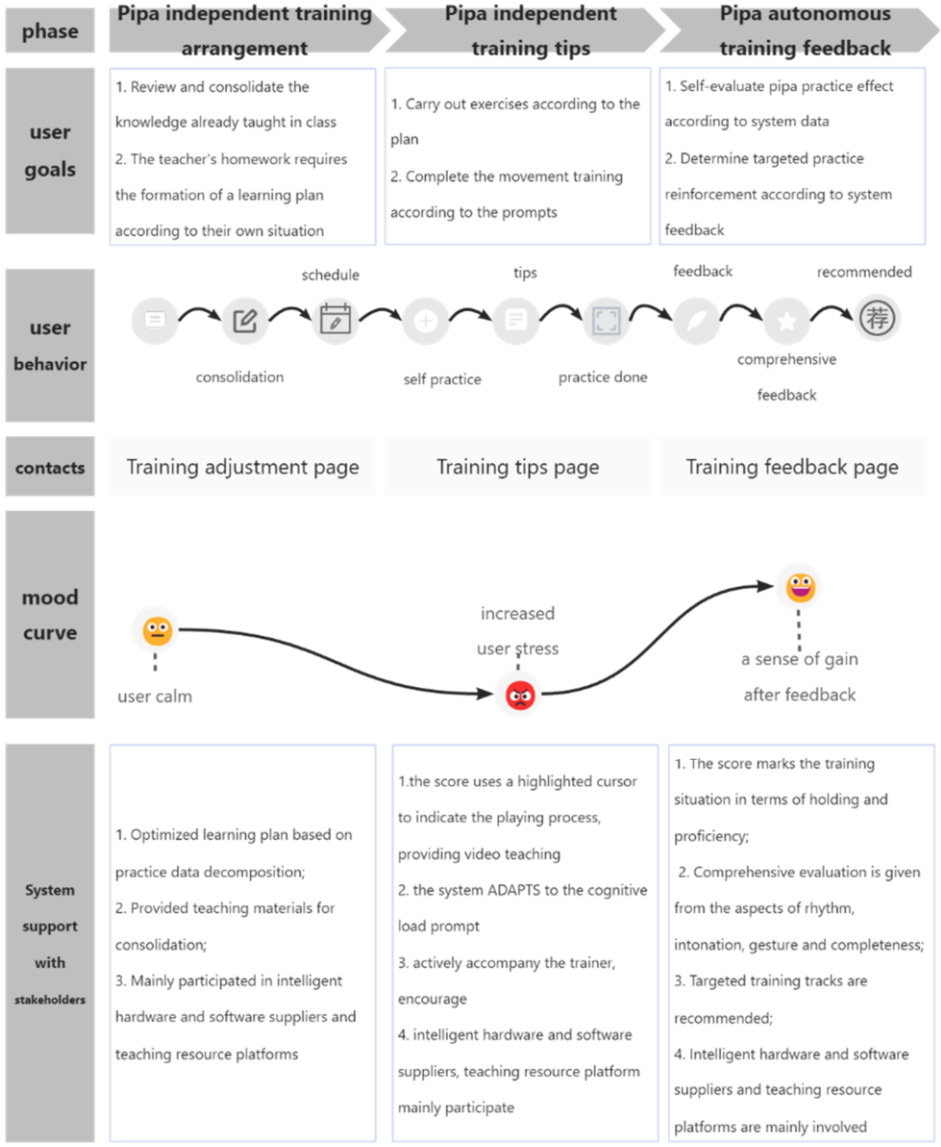

Figure 5. User Journey Map of the Autonomous Practice Module for Pipa Playing Action Skills

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