# Design and Implementation of Teaching Assistant System for Mechanical Course based on Mobile AR Technology

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*Abstract*—Augmented reality technology has become a hot spot in many fields because of its unique real-time interaction and the ability to add virtual objects in 3D video space. To enable students better understand and master traditional mechanical courses and solve the limitations of the courseware teaching method, a teaching assistant system based on Vuforia platform is designed and developed by combining augmented reality technology with existing teaching methods. On the smartphone application side, the 3D model of parts can be displayed by scanning mechanical engineering drawings, which can rotate, zoom, and section view the model. It realizes 3D visualization and interactive operation of 2D drawings in textbooks and achieves the purpose of image, diversity and efficient teaching. The results show that this method can not only promote the cognition of spatial relations based on visualization, but also create a situational learning environment based on experience, which can effectively improve the learning effect of courses and enhance students' interest and enthusiasm in learning.

*Keywords*—*Augmented reality; teaching assistance; mechanical teaching; visual operation*

## I. INTRODUCTION

The rapid development of the new generation information technology has promoted the diversification of teaching resources. Improving teaching quality and learning efficiency is the basic requirement of modern education [1]. As an important factor to improve teaching quality and learning efficiency, teaching resources have attracted more and more attention [2-3]. The traditional teaching methods of the plane textbooks have obvious limitations. At present, some innovations have been made to the teaching media, such as using 2D codes and other methods to link to assistant resources on web pages. However, this form is generally not well accepted by students, and it is necessary to find a way to solve this problem that is more attuned to the needs and habits of today's students. The courses of mechanical specialty mainly study mechanical parts, mechanisms, mechanical transmission and other related contents, which have the characteristics of many knowledge points, many concepts and difficulty in understanding [4-5]. However, students seldom have the opportunity to contact related equipment and parts during their school years, which brings certain difficulties to students' learning. Even if students search through the Internet, the existing teaching resources do not have many 3D solid models related to textbooks, so students need to have a strong sense of space.

Augmented Reality (AR) register 3D information in a real environment [6-7]. It superimposes computer-generated virtual information into the real world so that virtual enhanced information and real scene information coexist, complement, and superimpose with each other, thus strengthening users' senses and cognition of reality [8]. With the development of mobile technology, the popularity of smart phones and tablet computers has provided a solid material foundation for the wide application of mobile AR technology in many fields, showing great potential in military, medical visualization, education, construction machinery, book design and so on [9-11]. Based on the teaching needs of mechanical discipline and the purpose of improving the current teaching methods, this paper designs a teaching assisted learning system based on mobile AR technology.

In order to explore the influence of mobile AR technology on mechanical teaching effect and to expand and supplement digital teaching means, in this study, an AR assisted teaching system is designed first, and a teaching experiment is designed around AR system, which is verified and analyzed from three aspects: software function, teaching effect and influence on teaching. The results of this study can be used as a reference for teaching researchers using augmented reality.

## II. LITERATURE REVIEW

### A. Augmented Reality

AR is developed from virtual reality [12]. It realizes the effective combination of the real world and computer-generated virtual objects. By superimposing the computer-generated virtual objects on the real scene in real time, users can feel the real and virtual scene information at the same time, so as to realize the combination of virtual and real. AR technology has been applied in many fields, such as aerospace, military, education, medical treatment, video games, manufacturing and so on.

AR technology has three main characteristics: it combines the real and the virtual, it interacts in real-time, and can be executed in three dimensions [13]. The core of AR technology is the rapid recognition and spatial positioning technology. At present, the mainstream AR recognition applications are

mainly Google's ARCore, Apple's ARKit and Qualcomm's Vuforia. The comparison of the three development engines is shown in Table I.

TABLE I.        COMPARISON OF COMMON AR DEVELOPMENT ENGINES

| Development engine | Functions | Operation platform |
|---|---|---|
| ARCore | Motion tracking, environment understanding, light perception | Android |
| ARKit | Multiple face tracking, motion capture, and real-time augmented reality | IOS |
| Vuforia | Image recognition based on natural feature points, extended tracking, model target | IOS & Android |

Mobile AR is a branch of AR technology. Traditional AR systems mostly take wearable external devices as the carrier, which is difficult to carry and difficult to maintain. Due to the continuous development and update of mobile terminal devices, mobile terminals have powerful processors, high-definition cameras and convenient touch screen operation [14]. These functions provide a convenient platform for the development of AR systems for mobile devices. On the basis of inheriting the key technologies and core problems of traditional augmented display technology, mobile AR technology combines the portability and mobility of mobile devices, greatly promotes the development of mobile AR applications, and makes the application field broader and the interaction means more humanized.

### B. Augmented Reality in Education

This interactive means based on the real world and enhanced by virtual data provides a new teaching method for educators, which has a strong guiding significance for the abstract content teaching. Through AR technology, learners can enter an environment that is highly simulated with reality and dynamically learn in vision and interaction.

At present, the application of AR technology in the field of education is gradually expanding. Colleges and educational institutions are committed to promoting the deep integration of information technology with higher education and vocational education. AR technology will bring a positive impact on teaching content, models and learning methods [15].

AR technology can create an intelligent learning environment to adapt the educational content to students' personalized learning. To improve students' practical skills, based on emphasizing the theoretical knowledge in textbooks, AR technology is used to show the relevant knowledge in an information-based 3D way. Literature [16] research shows that adopting AR technology assisted teaching can improve students' learning efficiency and information understanding ability. Literature [17] uses AR technology in creative design courses to improve the learning motivation and creativity of students. Literature [18] developed an AR mobile application for engineering students, and the statistical data indicate that the application positively affects learning. An interactive teaching system based on mobile AR technology is designed and implemented, the case study shows that stimulate students' spatial imagination and learning interest [19]. [20-23] show that AR helps students improve their skills and knowledge in physics, biology, mathematics, art and architectural topics. A large number of empirical studies show that augmented reality technology has great potential and application prospects in learning support and teaching.

### C. Advantages of using Augmented Reality in Education

*1) Rich interactive means to create mobile learning environment:* AR emphasizes the combination of virtual and real, superimposing virtual objects on the real world, which is a supplement to the real world. It allows users to see the real world. For some abstract cognitive knowledge, AR can transform it into specific situations. Different knowledge can shape different situations, so that students can obtain learning knowledge more directly.

Traditional teaching methods are generally divided into two links: classroom teaching and after-school practice. When students encounter difficulties, they often have to understand and digest them by themselves which is also difficult to solve problems in time. Moreover, AR can realize mobile learning and break the restrictions of teaching conditions. Even if not in class, students can immerse themselves in the learning situation again through mobile AR technology. It solves the blind area of understanding caused by the unclear expression of some teachers [24]. Through electronic devices and books, students can learn anytime and anywhere, realizing seamless and continuous mobile learning.

*2) Stimulate learning interest and reduce cognitive difficulty:* In many university basic courses, there are some knowledge that is difficult to describe in words. For example, engineering drawing of mechanical major and some courses of other majors that require students to carry out spatial imagination. For some students whose space imagination is not strong enough, this undoubtedly hinders their learning. For some students with strong space imagination, even if they can imagine most of them, some details are still unimaginable, which will make students feel frustrated without timely answers. AR technology can directly and vividly express the abstract things in three-dimensional form. Through the combination of virtual and real, it is more conducive to students' understanding and memory, improves students' autonomy and reduces the requirements for learners' cognitive transfer ability. This interactive way greatly improves students' learning participation, meets students' curiosity, and makes learning simple and natural.

*3) Deepen immersive learning and strengthen knowledge cognition:* In the classroom, teachers should reflect the application scene of knowledge as realistically as possible and be related to the social practice scene of human beings. Mobile AR technology organically combines virtual and real, which makes the cognitive scene closer to the effect carried out outdoors. Compared with traditional teaching resources, the biggest advantage of AR teaching is reflected in the constructed immersive learning environment [25-26]. The three-dimensional immersion teaching created by AR enhances learners' sense of experience, enables students to learn more quickly, further deepen their cognition of knowledge and achieve in-depth learning.

In the existing literature, some researchers have noted the limitations of AR in the field of education. Traditional AR systems are mostly based on wearable external devices, which are difficult to carry and maintain. Without a well-designed student interface and guidance, AR technology can be too complex to use. The various devices that provide AR applications can cause other technical problems. In this paper, mobile AR is used as the technical support to develop the teaching assistance system for engineering drawing courses. Mobile devices such as mobile phones and tablet computers are used to design and develop the teaching assistance system. Teachers can quickly deploy AR content, which is simple, stable and has high platform support.

## III. PROPOSED TEACHING ASSISTANT SYSTEM

### A. Overall Design

The teaching assistant system based on mobile AR technology is mainly used to assist teaching. Its purpose is to strengthen students' imagination of 3D graphics and improve students' thinking conversion ability between 3D space and 2D plane. The system consists of three modules: information input module, fusion display module and information interaction module, as shown in Fig. 1.
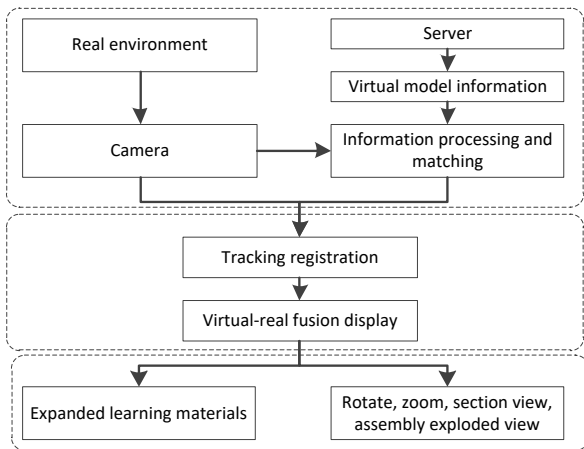


Fig. 1.    Overall Design of the Proposed System.

The information input module collects the feature point information of engineering drawings in the real environment through the camera, then processes and matches them to obtain the virtual model information on the server side. The fusion display module tracks the real-world position of virtual model in real-time according to the matching and identified information from information input module, and performs superposition fusion display of real and virtual information. In the human-computer interaction module, the user interacts with the teaching assistant system through interface touch control and can perform operations such as rotation, zooming, section view of parts and explosion diagram display of assembly parts. At the same time, the user can view relevant parts introduction, network reference materials and other expanded information.

### B. Development Environment

The system uses Unity3D as the development platform, builds 3D models through SolidWorks software, and uses AR technology to realize the interaction between touch instructions

and the 3D model nested in the screen through Vuforia AR Toolkit. The software running system is Android. The specific development platform and tools are shown in Table II.

TABLE II.    DEVELOPMENT PLATFORM AND TOOLS

| Tools | Functions |
|---|---|
| Unity3D | Rendering Interaction and Software Development Platform |
| Android NDK | Data Communication between Android and Unity3D |
| Vuforia SDK | Software Development Toolkit |
| XAMMP | Database |
| SolidWorks | 3D modeling |
| Deep Exploration 6.3 | 3D model format conversion |

### C. Development Process

The implementation of the system mainly includes three steps: Creating a database; Objective management; Resource integration and publishing. The system implementation flow is shown in Fig. 2.
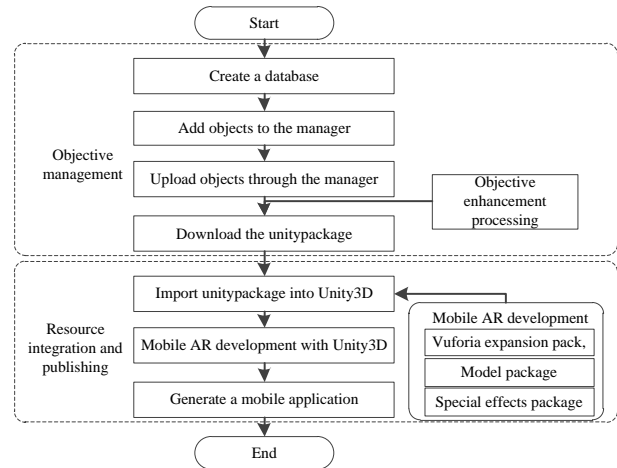


Fig. 2.    System Implementation Flow.

*1)* Create a database.

*2)* Objective management. Create a 3D model, add and upload identification point data, model data, references and other data to the objective manager.

*3)* Target enhancement processing. Improve the recognition effect through data enhancement.

*4)* Setup of the development platform. Importing Vuforia AR Toolkit, model package and special effects package into Unity3D, and setting a series of initial values such as camera direction and lighting system.

*5)* Unity3D mobile AR development. Write Unity3D camera identification code and C# script for model controlled interaction.

*6)* Generate mobile application. The Unity3D project is exported as an Android project. The secondary development of mobile APP is carried out in Android Studio include complete the UI design, cache management module and communication module.

## D. Implementation of Key System Functions

*1) Fusion display function:* The 3D modeling software SolidWorks is used to model the display parts. Because of the different recognition formats of each software, the SolidWorks 3D model is converted into .fbx file through DeepExploration software and imported into Unity3D software. Register on Vuforia website, create a cloud database and manage markers. In this system, pictures are used as markers, and the recognized objects of image target are set as 3D models of parts. The image implementation mechanism of Vuforia is completed by detecting the matching of natural feature points on the image. The feature point data of the picture or the image in the target manager is collected and then stored in the database. When the application runs, the feature points of the image are detected in real-time and the feature points of the picture stored in the data center are matched. After identifying the corresponding results, adjust the model size, position and light illumination with the predefined configuration, and then display them on the screen. The recognition effect of the display function is shown in Fig. 3.

*2) Rotate, zoom and section function:* The zoom is realized by the localScale() function. Firstly, the initial positions oPos1 and oPos2 of the fingers are recorded. When at least one finger moves on the screen, the real-time positions tPos1 and tPos2 of the fingers are checked. Finally, the model is enlarged or reduced by comparing the distance between the starting and ending positions where the fingers stay. The effect of model scaling is shown in Fig. 4, where the aperture represents the finger movement path.
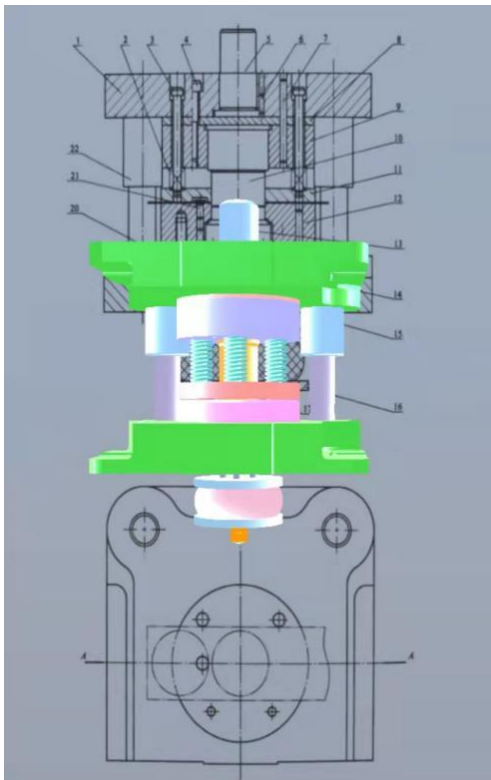

Fig. 3.    The Recognition Effect of the Display Function.
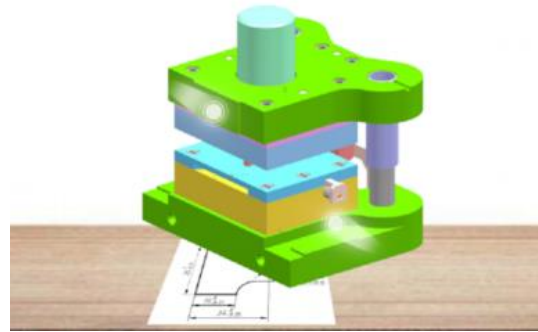

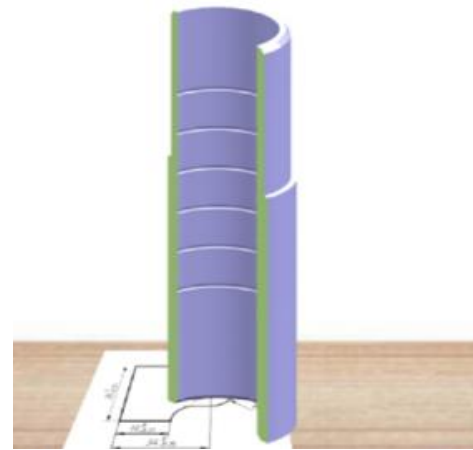Fig. 4.    Model Scaling Implementation Effect.


Fig. 5.    Section View Effect.

Since section display cannot be directly carried out in Unity3D, it is necessary to set "true/false button assembly" to convert the overall model to the section model by establishing another parallel and independent section 3D model. The effect achieved in section view is shown in Fig. 5.

## IV. EXPERIMENTAL DESIGN

In order to verify the influence of the AR teaching assistant system on the teaching effect of mechanical drawing course, 154 undergraduates from Henan Institute of technology were selected as research participants. According to the large class teaching, 154 students were divided into experimental class and control class. The control class adopts the traditional teaching mode. First, the students are required to preview the knowledge before class. During the teaching process, the teachers teach the knowledge through books and PPT, and answer the questions raised by the students. Smart phones are not allowed to be used in the course of class. The experimental class adopts the AR teaching assistant system to carry out teaching activities. The specific steps are knowledge Preview - Teacher Explanation - Deep Learning - Question Answering - Opinion Feedback. First of all, students preview around the knowledge points arranged by teachers in advance. When encountering unimaginable models, they can deepen their understanding with the help of AR teaching assistant system. Teachers use teaching strategies that match technology and content to teach. Then, students enter the deep learning link.

Through the four links of cognition, construction, transfer and application, students can independently understand knowledge, and then solve problems, explain the problems that students haven't digested. Finally, students put forward the deficiencies in the teaching link, so as to promote better teaching improvement next time.

In order to better understand the effect of AR teaching assistant system in the process of mechanical drawing teaching, the teaching effect is analyzed by score analysis and questionnaire survey. At the end of the semester, the teaching effect is judged by analyzing the results of the two classes. Each student in the experimental class is required to fill in a questionnaire. From the two dimensions of learning cognition and product experience, the questionnaire sets up five aspects: exploratory learning, learning interest, User satisfaction, resources abundant degree and students' willingness to use. The questionnaire settings are shown in Table III.

TABLE III. CURRICULUM SATISFACTION QUESTIONNAIRE

| Category | Questionnaire |
|---|---|
| Learning cognition | 1. Using AR teaching assistant system in the classroom is more conducive to exploratory learning |
| | 2. Using AR teaching assistant system can improve the interest in learning engineering drawing |
| User experience | 3. The function of AR teaching assistant system meets the teaching requirements |
| | 4. AR teaching assistant system is abundant in teaching resources |
| | 5. I am willing to use AR teaching assistant system to assist learning |

## V. EXPERIMENT AND RESULT ANALYSIS

### A. Practical Application of AR Teaching Assistant System

Through AR technology, image recognition and stereo presentation methods, this system displays stereo effects through 3D modeling, directly converts the plan into 3D objects, and enhances the interactivity in the learning process.

Taking the mechanical drawing course as an example, the application scenario of this system is introduced. Students scan the engineering drawings by opening the App on the mobile phone, and the 3D model of the displayed part is fused on the screen, as shown in Fig. 6. After the mobile phone screen is loaded with the 3D model, even if the camera is moved to other positions, the 3D model can still stay and be displayed, as shown in Fig. 7. On the mobile phone screen, students can rotate, zoom, and section model through gestures. Through 3D display from various angles, students can be helped to analyze and understand the correlation between 2D engineering drawings and 3D entities model, thus improving the learning effect.

In the process of classroom theoretical teaching, by setting specific identification pictures, the virtual 3D model is superimposed on the real teaching scene, and various parts and mechanisms are presented in front of students. Let the students observe the movement process of the 3D structure or principle of the mechanism from a close and all-around angle to deepen their understanding of the textbook knowledge.
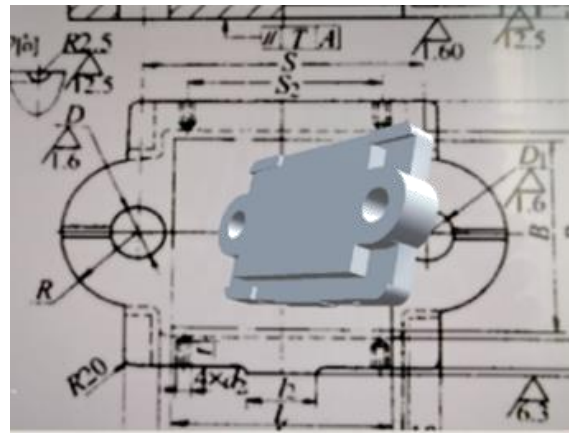


Fig. 6. Scan Drawings to Obtain 3D Models.



Fig. 7. Effect of Removing Background Drawing.

### B. Teaching Effectiveness Analysis

The teaching effect of mechanical drawing course in the spring semester of 2020-2021 school year is shown in Table IV. There are 78 people in the control class and 76 people in the experimental class. The control class adopts the traditional paper teaching mode, while the experimental class adopts the AR assisted teaching system. Comparing the final examination results of the two classes, the average score of the experimental class is 84.24, and the pass rate is 100%, which is better than that of the control class. The Standard deviation of the experimental class is 9.17, which is less than 15.31 of the control class, indicating that the distribution of students' score is more concentrated. Through the statistical analysis of teaching effect, it can be concluded that after using AR assisted teaching, the results of students in the experimental class are better than those in the control class. Through the questionnaire survey, we know the students' recognition of AR assisted teaching, and most students are satisfied. Most of the gains of students focus on the enhancement of autonomous learning ability, the deepening of classroom participation, the solid mastery of knowledge, the improvement of problem-solving ability and so on. From students' feedback, it can be found that students have high recognition of AR assisted teaching mode.

TABLE IV. TEACHING EFFECT OF AR ASSISTED TEACHING

| Index / Group | Fractional segment (Grade) | | | | | Average score | Pass rate | Standard deviation |
|---|---|---|---|---|---|---|---|---|
| | [100-90] | (90-80] | (80-70] | (70-60] | (60-0] | | | |
| Experimental Class (76 students) | 27 35.5% | 27 35.5% | 16 35.5% | 6 35.5% | 0 0% | 84.24 | 100% | 9.17 |
| Control Class (78 students) | 5 6.4% | 22 28.2% | 25 32.1% | 13 16.7% | 13 16.7% | 72.35 | 83.33% | 15.31 |

TABLE V. DATA ANALYSIS OF CURRICULUM SATISFACTION QUESTIONNAIRE

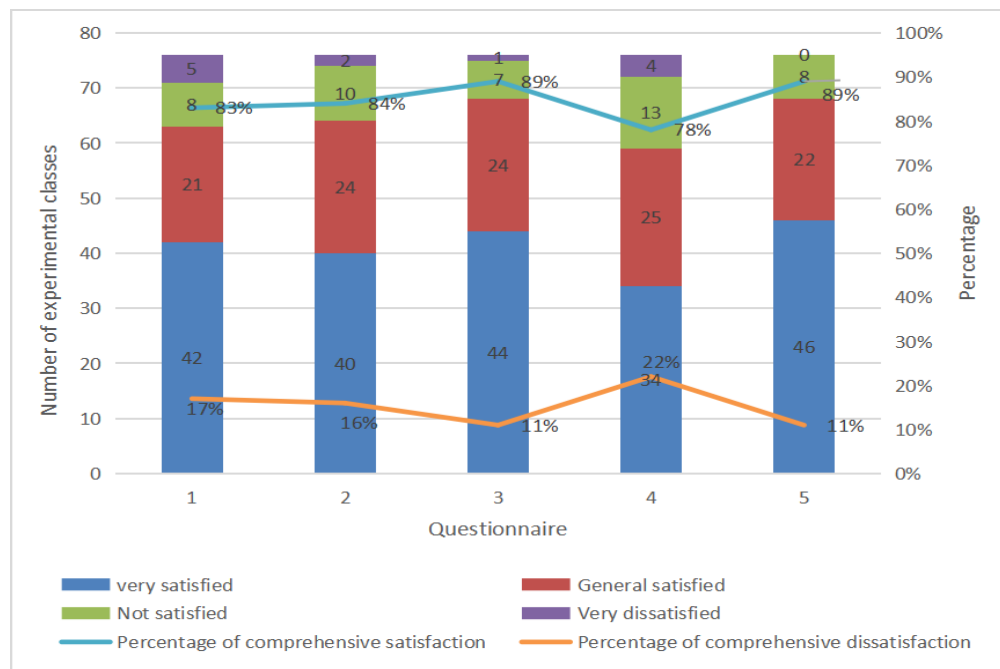| Questionnaire Evaluation | Very satisfied | Generally satisfied | Dissatisfied | Very dissatisfied |
|---|---|---|---|---|
| 1. Using AR teaching assistant system in the classroom is more conducive to exploratory learning | 42 | 21 | 8 | 5 |
| 2. Using AR teaching assistant system can improve the interest in learning engineering drawing | 40 | 24 | 10 | 2 |
| 3. The function of AR teaching assistant system meets the teaching requirements | 44 | 24 | 7 | 1 |
| 4. AR teaching assistant system is abundant in teaching resources | 34 | 25 | 13 | 4 |
| 5. I am willing to use AR teaching assistant system to assist learning | 46 | 22 | 8 | 0 |



Fig. 8. Questionnaire Statistical Analysis Results.

After the examination, a questionnaire was distributed to the students in the experimental class. See Table III for questions 1-5 in the questionnaire. For the five questions in the questionnaire, students can choose four grades: very satisfied, generally satisfied, dissatisfied and very dissatisfied. A total of 76 questionnaires were distributed, and 76 were recovered, with a recovery rate of 100%. After inspection and verification, 76 valid questionnaires were found, with an effective rate of 100%. The statistical results of the questionnaire are shown in Table V. In terms of improving exploratory learning ability, 42 students expressed very satisfied and 21 students were generally satisfied, while only 8 and 5 students chose dissatisfied and very dissatisfied respectively. It shows that students agree that AR teaching assistant system can improve

their exploratory learning ability. Similarly, it has been highly evaluated in improving learning interest, satisfaction with the system and usability. However, the richness of software models is slightly lower. Some students believe that the models and resources in courseware and after-school exercises need to be further improved. For more intuitive data analysis, convert the table into a chart, add the very satisfied and generally satisfied people to calculate the comprehensive satisfaction percentage, add the dissatisfied and very dissatisfied people to obtain the comprehensive dissatisfaction percentage, and draw the questionnaire statistical analysis results chart as shown in Fig. 8. It is obvious from Fig. 8 that the AR teaching assistant system has been recognized by most of the students in the experimental class.

In the process of questionnaire survey, the author also interviewed the teachers. The instructor said that most students had not been exposed to AR before the experiment, but thanks to the popularity of smart electronic devices such as smart phones, students' information literacy was relatively high, so the installation and use of teaching assistance system were relatively smooth. By using the assistant learning system, students can understand knowledge more easily, their interest and confidence in learning have been improved, the frequency and efficiency of classroom teaching interaction have become higher, and the teaching quality has been significantly improved compared with the traditional teaching mode.

## C. Influence of AR on Engineering Drawing Teaching

Contemporary college students have many new characteristics. As a generation growing up in the digital environment, they can skillfully use electronic products and have a strong curiosity about new things. As a popular field in recent years, AR technology is introduced into teaching to create mobile learning environment and more opportunities for autonomous learning for students. It will also arouse students' interest, make students understand knowledge more easily and learn happily.

Integrating AR technology into some courses with higher learning difficulties will make students' learning easier and make the classroom more efficient. From another point of view, it will also reduce teachers' teaching pressure and make teachers easy to teach. The setting of every model and scene in augmented reality is carefully considered by teachers, which has certain demonstration, typicality and guidance. Students can study anytime and anywhere, reducing the disadvantages of being unable to concentrate on their study caused by external conditions. Compared with traditional learning methods, under the same time investment cost, students using AR technology assisted learning can immerse themselves in deep learning faster, so as to achieve better learning effect.

In the future, AR assisted instruction technology can be further extended to the process of experimental teaching. Due to the lack of experimental resources, colleges and universities have limited laboratory opening time, places and number of experiments which leads to the unsatisfactory effect of students' hands-on operation. Some mechanical equipment is expensive and dangerous, so it cannot be carried out in reality. Using AR technology can carry out some experiments that cannot be realized or dangerous in the real environment to solve this problem. AR technology is used to convert the required experimental equipment and instruments into digital models, import and create a virtual database, and realize virtual simulation experiment operation, which can provide students with a more flexible experimental environment and course arrangement while reducing consumables and maintenance costs. Moreover, through virtual operation, students can more accurately understand the experimental principle and content, and carry out design experiments to realize the differentiated cultivation of students, so as to implement the educational concept of "student-centered".

## VI. Conclusion

AR technology can realize the superposition and supplement of virtual enhancement information and real scene information, which provides a new way for the current mechanical course teaching and development. In view of the strong practicality of mechanical courses, the traditional teaching method is too simple, and it is difficult for students to establish stereoscopic impression. A mechanical course teaching assistant system based on mobile AR technology is designed and developed. Through the integration of AR technology and traditional paper teaching materials, the 3D visualization and interactive operation of parts and mechanisms in teaching materials are realized to achieve the purpose of diversity and efficient course teaching.

According to the experimental results and questionnaire analysis, the proposed system has a beneficial impact on students' learning effect and learning motivation. The academic performance of the experimental class is significantly higher than that of the control class. Because the AR based teaching method is more likely to improve students' attention and interest, the questionnaire results show that students are more satisfied with the AR teaching method and expect to have a more functional and perfect software system. The above results show that introducing AR technology into mechanical course can make up for students' lack of practical exercise. Through the combination of AR technology and mechanical course teaching, students can better understand and master the principle of mechanical structure, manufacturing and assembly process, use and operation, and promote the cognition of spatial relationships based on visualization. This teaching method can stimulate students' learning enthusiasm and improve innovative ability and engineering consciousness.

Information technology has a revolutionary influence on the development of education, has become a new wave of educational reform, and provides new ideas for the further development of teaching and learning. This paper is a practical exploration of the application of AR in the field of education. The mobile learning mode based on AR technology has the advantages of interactivity, mobility and sharing that traditional learning does not have. The auxiliary mobile learning platform based on AR technology still has a lot of development space. In the next step, it can be studied and developed in multi-disciplinary and interactive functions.

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