

The Development and Application of Augmented Reality Educational Game in English Learning

Dan Xia

Faculty of Artificial Intelligence in
Education

Central China Normal University

Wuhan, China

danxia@ccnu.edu.cn

Yu Zhang

Faculty of Artificial Intelligence in
Education

Central China Normal University

Wuhan, China

zhangyu98@mails.ccnu.edu.cn

Tongjing Qiu

Faculty of Artificial Intelligence in
Education

Central China Normal University

Wuhan, China

qiotongjing@mails.ccnu.edu.cn

Abstract—This study examines how augmented reality (AR) technology can be integrated into educational games to help students learn English. An AR game system was designed and developed for helping students memorize the English vocabulary by providing interesting pictures and impressive surroundings. The system framework, as well as the design and development process of the game were presented in this paper. A case study of the application and evaluation of the game was implemented. In detail, a questionnaire was designed according to the general evaluation methodology of educational games. In this study, the questions of the questionnaire were classified into five aspects: game information, multimedia, interface design, content and feedback. The evaluation results of the game show that the students can memorize the English vocabulary while playing this AR educational game happily. Obviously, the game could increase the learning interests of the students with the aid of the AR technology.

Keywords—augmented reality, educational game, interactive learning environment, English learning

I. INTRODUCTION

The augmented reality (AR) technology integrates the virtual objects and the real world while people can operate in three-dimensional space and can interact in real time. The AR technology extends the real world and can support students in achieving the learning objectives more effectively [1]. Augmented reality is also an educational medium that is increasingly available to young learners such as elementary and secondary school students [2]. And the applications of AR technology promote the development of educational games. The benefits of AR educational games have been recognized by more and more educational researchers. The AR educational games integrate the knowledge learning process into the game and broaden the information of real world by adding virtual information. Recently the applications of AR educational games mostly focus on spreading knowledge about science. For example “Google Butterfly Play” and “AR Dinopark” which are widely played by many people are such AR educational games. The game players of the AR educational games can operate in three-dimensional space and receive feedback in real time in the combination of the virtual and real world. The AR educational games can assist the students in acquiring knowledge more effectively. In this paper a case study which integrated the AR technology into educational game for students to learn English vocabulary is presented. The remainder of this paper is organized as follows. In the second section, literatures on the studies of applying the AR technology in education are

overviewed. In the third section, principles about design and development of the AR educational game are presented. How to develop the AR educational game in this study is described in detail in section four. Application and evaluation are shown in section five. Finally, this paper ends with the conclusion and future work.

II. LITERATURE REVIEW

After the successful applications of the AR technology in many fields, the benefits for promoting studying by applying AR technology in education have also been recognized by the scholars in educational field. The scholars have studied the applications of AR technology in various disciplines, as well as how to apply the AR technology to different teaching and learning environments.

A. Researches on the Application of AR Technology in Natural Science Education

Many scholars focused on how to improve teaching in natural science with the aid of AR technology. To explore how AR could aid science learning, the scholars firstly identified two main approaches of using AR technology in science education, namely image-based AR and location-based AR [3]. The application of these two approaches to science learning may present different burdens. The combination of image-based AR and location-based AR may open up new possibilities for supporting science learning. The scholars also found that young students could develop a conceptual understanding of force, net force, friction and two-dimensional motion after participating in the Learning Physics through Play Project curriculum with a series of AR activities [4]. The scholars studied the effect of diverse approaches of simulation-based instructional design in students’ concept learning about moon phases and made a comparison among 2D animation, 3D simulation, and augmented reality [5]. The result indicated that all of the three approaches could improve learners’ academic performance. But the approach of AR was more effective in the period of concept learning. And students in AR approach showed more fixed attention and higher motivation. During on-the-spot investigation, students used AR application to navigate the pond environment and observed virtual media and information which had been superimposed on the physical pond [6]. The experience demonstrated that students understood the principles of water quality measurement more deeply by the assistance of AR technology. The scholars investigated learners’ collaborative knowledge construction performances and behavior patterns in an AR simulation system [7]. They concluded that the AR system improved learning outcomes. By investigating students’ learning behaviors and behavior

patterns in an AR simulation system and a traditional 2D simulation system, the scholars found that the AR simulation engaged the students more thoroughly in the inquiry process [8]. An experiment to make a comparison between traditional and AR-based class showed that the students who used the AR-based mobile learning approach showed higher levels of motivations in terms of attention, confidence, and relevance dimensions [9]. An experiment conducted in China demonstrated that students generally have a favorable view of AR tools which had a significant complementary learning effect by serving as a computer-assisted learning tool [10]. Furthermore, the experiment showed that the AR tool was more effective for students with lower achievements. The scholars conducted a study to investigate the effects of using of AR technologies in science laboratories on college students' laboratory skills and attitudes towards laboratories [11]. The results showed that the AR technology significantly improved the experimental skills development of college students. The AR technology is very effective in demonstrating the content of Science. The invisible content of science can be visualized by three dimensional reproduction using the AR technology [12]. Moreover, AR technology enables learners to conduct situated learning through providing real-time interaction.

B. Researches on the Application of AR Technology in Humanities and Social Sciences Education

The studies of AR applications in humanities and social sciences focus on language learning, art appreciation, history learning, museums visiting and so on. The scholars examined students' performance, attitudes and cognitive load levels when using AR technology to learn English [13]. Their study revealed that secondary school students were glad to learn English with the assistance of AR. Moreover, it was found that students had low levels of cognitive load during self-directed learning in the AR environment. In a case study on the effect of using an AR system on students' motivation to take a visual art course, the scholars found that AR technology had a positive effect on secondary school students' motivation and satisfaction [14]. AR technology could overlay computer generated auxiliary information in real scenes, which could help the visitors better appreciate the paintings [15]. And the time the visitors focused on the paintings was extended compared to the audio-guided and non-guided participants. Based on augmented reality, role-playing and social networking, scholars proposed an immersive learning framework for human history, in order for students to enhance learning effectiveness about historical battles and wars from the historian's perspective [16]. The scholars developed an educational AR system based on situated learning theory and optimized the library's learning environment with innovative AR interactive technology [17]. Experimental results demonstrated that students' learning performances were improved significantly through AR technology.

C. Researches on the Application of AR Technology in Other Disciplines

There are also some studies on the application of AR technology in engineering technology, medical science and other disciplines. A pilot study of the effectiveness of AR to enhance the use of remote labs in electrical engineering education had been conducted [18]. The developed AR-based lab system (augmented remote lab, ARL) enabled

teachers and students to work remotely in current classroom lab (CL), including virtual elements that interact with real elements. The opinions of teachers and students in this experiment were rather similar and positive regarding the use and possibilities of ARL. The scholars found that mobile AR could greatly enhance the appeal of mobile learning applications in medical education [19]. Considering the diversity of classroom environments, three AR learning environments had been used in real classrooms [20]. The scholars investigated teachers' perception of mobile learning applications in special education classes [21]. The teachers said that they believed edutainment technologies, including augmented reality, Game-based educational programs and animation projects could become mainstream in the future. The scholars developed educational magic toys with virtual objects such as story animations, 3D objects and flash animations by AR technology for early childhood education [22]. The study of context-aware and mixed-reality exploring tool for freshman at a university in the north of Taiwan indicated positive reactions of learning [23]. Based on the findings, the scholars suggested that the proposed AR mobile tourism system be used for a wider range of educational purposes. Scholars applied AR into the education of visualization of 3D models, architecture and building engineering [24]. The study showed that this technology allowed for more direct engagement with the presented content, thereby enhancing the learner's academic achievement. The scholars found that students using AR observed higher levels of flow than those who used web interfaces in the experiment about electromagnetism [25].

To sum up, though the applications of AR technology in education have been extensively studied by scholars in recent years, AR educational games about learning English words have not been fully researched. Therefore, the present study integrated AR technology into an educational game for students to learn English vocabulary. The system architecture, detailed design, application and evaluation of the AR educational game had been researched.

III. PRINCIPLES OF DESIGN AND DEVELOPMENT OF AR EDUCATIONAL GAME

How to integrate the AR technology into the educational games should be considered. The AR educational games should not only entertain but also teach. Several important principles in the design of the AR educational games are listed as follows.

- Firstly, constructing game plot is important in designing an AR educational game. The plot should appeal to learners. The corresponding knowledge can be learned by playing the AR educational game. Moreover, the plot should be interesting enough to maintain the enthusiasms of the learners for a long time.
- Secondly, the human-computer interaction interface must be carefully designed in accordance with the cognitive characteristics of the learners and learners' emotional needs, so that the interactive interface can play its best role in terms of interactivity, experience, authenticity, and immersion.
- Thirdly, the virtual objects should be integrated into the real world naturally. The virtual objects should also be displayed in an appropriate form. So that the

learners can immerse themselves while they playing the AR educational game .

IV. DEVELOPMENT OF THE AR EDUCATIONAL GAME IN THIS STUDY

A. Introduction to the AR Educational Game “Super Hero in English Word World”

The AR educational game “Super Hero in English Word World” was designed and developed to promote English vocabulary memorizing for the high-level graders in primary schools by using AR technology. According to the teaching content, English vocabulary was divided into three parts: beginner, intermediate and advanced. Each part was corresponding to a particular situation consists of virtual objects and real world. The learners comprehended and memorized the English words by playing the game. The virtual character in the game needed to defeat the virtual monsters in order to win the game. Learners have to choose the right English words to defeat the monster. But once the learning task was not completed, the character would be trapped in one forest. In the game many AR learning environments corresponding to the English words had been constructed for the learners. Some virtual models corresponding to the English word had been set over the real world to help students learn the English words.

The AR educational game in this study was designed and developed according to the system framework described in Figure 1. At first, theoretical preparation was needed. The theories corresponding to educational game system and the theories about developing software system were both important for the AR educational game in this study. Game based learning theory and digital game design theory had been studied. The development of the game had been divided into five parts: design of game strategy, design and development of interfaces, design and development of functions, making resources and resource storage. The details of the design and development are described in the remainder.

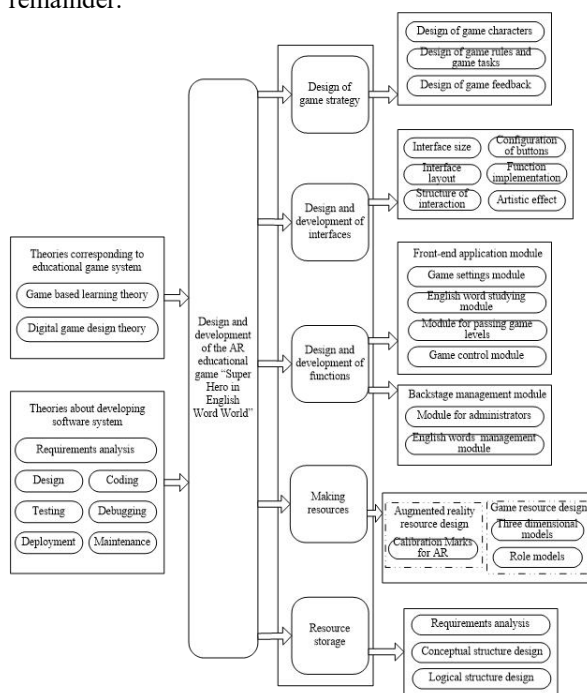


Fig. 1. System framework of the AR educational game

B. Requirements Analysis for the Game

To develop an AR educational game, it is very important to do a detailed analysis of the requirements. In the phase of requirements analysis, some questions should be carefully considered.

- Who are the target population of the AR educational game? The aspects which need to be considered include: the ages, sexual distinction, level of education, learning ability, favourite types of games and so on.
- The teaching content should not only be naturally integrated into the game, but it should also always implement the learner-centered teaching principle and the teaching concept of teaching for fun, so it is critical to use AR technology effectively to present teaching content vividly in order to stimulate learners' interest in learning.
- What role do the players play? What do the players need to do? What are the ultimate goals of the players? What challenges will the players face? Is the scene of the game realistic or illusory?
- The functional requirements of the terminal device that runs the game should be surveyed. Requirements for the way in which players operate should be investigated.

In order to achieve the learning goals better by playing the AR educational game, all aspects described above had been carefully considered for the game in this study. Firstly, the characteristics of the target population of this game had been investigated. The AR educational game in this study was planned for high-level graders in primary school. The pupils at this grade already have the learning ability and flexibility. The pupils can relate the particular situation constructed by the AR technology with the learning contents actively. Ages of the learners are nearly between eight to twelve according to the Chinese national condition. The target population contains both girls and boys. Favourite game types of children at this ages are analyzed by questionnaire survey. The role playing game type had been chosen out of their favourite game types in this case for achieving the learning goals best. Secondly, the teaching contents which conveyed by the AR educational game had been analyzed for constructing the framework of the game. In this study the teaching contents were English words for pupils at high grade in elementary school. A good game strategy described in the following had been designed to naturally integrate the teaching contents into the game. And a proper design scheme for digital resources had been inquired to better present the teaching contents by AR technology. Thirdly, the game was set in a illusory world which mixed the real world and virtual world. In order to win the game the learners needed to answer questions about English vocabularies. Lastly, the AR game in the study was planned to run on ordinary mobile terminals in China. Learners could operate through screen of the mobile terminals when playing the game.

C. Game Design

The overall system architecture of the AR educational game was constructed according to the game objectives. The system architecture of this game contained design of game strategy, design of user-interface, design of function

modules, design of resources and design of database. The design of game was based on the principles of design and development of AR educational game.

1) *Design of game strategy*: The story of the AR educational game takes place in the real world where virtual monsters invade. The players can choose their favorite heroic roles which were provided by the game. The health point of the heroic role is related to the number of English words that the player have already memorized. The player needs to memorize enough English words so as to defeat the monsters. The plot of the game is set especially according to the students' interests. The virtual roles and virtual scenes which are superimposed on real scenes by AR technology can stimulate learners' desire for learning English words[26]. The AR technology applied in this game creates an interesting learning environment that corresponds to teaching contents. Thus the students' cognition and memory of words can be strengthened.

a) *Design of game characters*: The game characters consists of player characters and non-player characters. The player character is a virtual substitute of the player in the game. The player characters are designed based on children's favorite cartoon characters, including boy and girl. Non-player characters are designed on the basis of quirky monster images.

b) *Design of game rules and tasks*: Each game task requires that the learner has already memorized a certain amount of English words at the beginning. The game task in the initial stage is relatively simple so that the learners will not be frustrated. As the game program progresses, the number of English words increases and the difficulty of the English words slowly increases. As a result the difficulty of the game task is increasing progressively.

c) *Design of game feedback*: The experience points of the heroic role will increase when the learner finishes the learning tasks. The experience points can be used not only to rank the learner's performance but also to exchange for learning awards. These rewards will satisfy the learners and stimulate the learners' interests in playing the game to learn English words.

2) *Design of user-interface*: The design of user-interface in the AR educational game in this study consists of six aspects: the interface size, the interface layout, the structure of interaction, the configuration of buttons, the function implementation and the artistic effect. The buttons in the user interface of this game are designed to be of medium size. Buttons are also arranged in order. Hence they are easy to identify. It's easy for learners to understand the meaning of buttons and icons when playing this AR educational game. In the user-interface of this case, every button is associated with the game content and the learning content. Therefore, there is no distractor to interrupt the learner's immersion. The style of each window in the game interface is designed to be consistent. The consistent interface style improves the efficiency of the learners.

3) *Design of function modules*: The functional modules of the game are divided into two important parts. One is the module for front-end application. And the other is module for backstage management. The front-end application

module contains module for game settings, module for English word studying, module for passing game levels and module for game control. In the game settings module, learners can set the background music. In the English words studying module, the learner can control the word learning interface of the learning progress. If the learner is very familiar with the current word, he can learn the next word by selecting the "next" button. After the word learning is completed will enter the module of the game level, in which a hybrid scene will be displayed, mixing the virtual scene and the real world together through AR technology. The generated scenes are designed to test and reinforce learners' English word learning and provide vivid images about English words. Learners can earn health points and experience points from the game characters by correctly answering questions about English words. If learners mess up these questions, the game character's health points are reduced. When the game character's health points are zero, the game is over. This AR educational game can be played in three different modes: beginner mode, intermediate mode and advanced mode. The difficulty of each mode is related to the amount of the vocabulary and the difficulty of the vocabulary. In the module for game control, the learners can control the status of the game. The learners can begin and quit the game in this module. The backstage management module consists of module for administrators and module for English vocabulary management. In the module for administrators, administrators can manage users' accounts and passwords. In the English vocabulary management module, the administrators can edit English words stored in the database through admin login. They can query, add, delete and modify the English words.

4) *Design of resources*: The design of resources consists of augmented reality resource design and game resource design. Both physical resources and virtual resources have to be designed and made. The physical resources are the calibration marks for AR technology. The virtual resources are three dimensional models, role models and so on.

5) *Design of database*: The design of database for the AR educational game in this study contains requirements analysis, conceptual structure design and logical structure design. By analyzing the requirements of the game, the database system needs to store the information of English words. And game system will send English word information stored in the database to the client on the basis of the request sent by the client. In the process of conceptual structure design, all the entities in the database and the relationships between these entities have been designed. The Entity Relationship Diagram has been drawn. In the process of logical structure design, the entity relationship diagram have been converted to a logical structure that conforms to the data models. Thus the relations between forms in the relational database have been formed.

D. Game Development

In the phase three the development platform and development tools about AR technology which were suitable for develop the AR educational game should be selected cautiously. In this case, JDK + Android SDK + Unity3D + Vuforia were chosen to develop the game. Since the AR

educational game in this study was supposed to run on the mobile terminal, the Java language was chosen by the game developers. Unity3D is an ultimate game development platform. And Vuforia is an Augmented Reality Software Development Kit for mobile devices. By means of the image registration capability of Vuforia, developers positioned and oriented virtual objects in relation to real world images when these were viewed through the camera of a mobile device. When the main functional modules had been finished the prototype system of the game was completed.

E. Test and Release

After the development the game should be tested and debugged. 20 volunteers were chosen to play the AR educational game. They were expected to report comments or suggestions about the game. The game was improved according to the comments or suggestions from players. At last, the game was deployed across mobile terminals for users to learn English vocabulary. Figure 2 shows the user interfaces of the AR educational game, the left interface is the game start interface, the right interface is the game answer interface.



Fig. 2. The user interfaces of the AR educational game

V. APPLICATION AND EVALUATION

A total of 62 pupils at fourth-grade participated in this study. They were recruited from a private elementary school in China. The participants' ages ranged from 9 to 11. They were learning English as a foreign language and studied a basic English course for one and a half hours every day in each week during every semester. Detailed operation rules about the AR educational game "Super Hero in English Word World" had been introduced to the students by the developers. The background of the game is communicated to the students at the beginning of the game, while the students can select the game characters to quickly start the game. The students chose virtual characters in the game to start. The learning environment was generated by the AR technology. Each section of the game was corresponding to some English words. Then students played the game respectively. The students had been asked about their game playing experiences. Their answers had been recorded and analyzed. Nearly all the students felt that the game was very novel and funny. And most students were interested in the three dimensional learning environment which was generated by the AR technology. Most students felt that playing this game made learning more efficient. However, they suggested that the storyline could be changed to be more imaginative and graphics of this game could be improved to be more beautiful.

The scholars have studied and developed some evaluative indicators for educational computer games[27]. To evaluate the AR educational game in this study, some significant and valuable indicators have been chosen to design an effective questionnaire. Twelve questions were set up in the questionnaire. And they were classified into five dimensions: game information, multimedia, interface design,

content and feedback. After the students finished the games, written questionnaires were issued to the students. A total of 62 questionnaires were issued and 62 valid questionnaires were recovered. The pupils who participated in the study had good ability to observe, analyze and judge. Therefore, the results of the questionnaire were basically believable. The results of the questionnaire were analyzed and summarized in Table 1.

There are five choices for each answer in the questionnaire. These five choices represent five different levels. Only one option out of the five choices can be chosen when answering each question. Table 1 shows the proportions of the answers to each question in the questionnaire.

The average value presented in the last column of Table 1 is a numerical measure of the learners' perspective on questions in the questionnaire. The corresponding relation between the five answer options in the questionnaire and the numerical measure is as follows: very good=5, good=4, common=3, poor=2, very poor=1. The average value can reflect the quality of the game in the corresponding aspect in this study. If the average value of the corresponding evaluative indicator is larger, the quality of the game is better in that respect. In this way, the AR educational game in this study can be evaluated objectively with a numerical quantization criterion.

As shown in Table 1, the average value for the evaluative indicator in Game information is close to five. This means that the learning subject matter is well documented in the game in the opinions of the students. In the category of Multimedia, all the average values for evaluative indicators are above 3.5. This reflects that the students are satisfied with the multimedia in the game. Data report that the multimedia materials are arranged appropriately and consistent with the learning goals. Most students think the game appeals to them. Similarly, in the category of Interface design, all the average values for evaluative indicators are also above 3.5. The results indicate that the interfaces are well designed and the interface structure is clear. Students can easily understand the gaming screen and operate the game conveniently. There are four evaluative indicators in the category of Content. Only one average value for evaluative indicators is above 3.5. This indicates that the students consider the challenges in the game highly correlated with the learning content. Only well completing the learning tasks of memorizing English word helps to overcome the challenges in the game. All other average values are between 2.8 and 3.5. The data show that the three indicators of the game basically meet the requirements, but need to be improved. The storyline of the game should be revised to be more related to the learning content. The learning content should be better edited so as to be presented in a conceptual order. The resources of the game need to be collated and improved to be more consistent with the storyline. In the category of Feedback, both average values are between 2.5 and 3.5. According to the learners' experiences, they want an appropriate assessment of their learning performance in the game. And the game should report their current status more clearly so that they can adjust their learning status in time. The game can be improved on the basis of the above analysis to promote better learning effects.

TABLE I. EVALUATING THE AR EDUCATIONAL GAME.FROM FIVE CATEGORIES

Category	Evaluative Indicators	Very Good	Good	Common	Poor	Very Poor	Average*
game information	Is the learning subject matter documented in the game?	80.6%	11.3%	8.1%	0.0%	0.0%	4.73
multimedia	Are the multimedia materials in accordance with the learning goals?	24.2%	58.1%	14.5%	3.2%	0.0%	4.03
	Is the game attractive?	9.7%	50.0%	32.3%	4.8%	3.2%	3.58
	Are the pictures, sounds, and animations arranged appropriately?	8.1%	51.6%	29.0%	6.5%	4.8%	3.52
interface design	Is the gaming screen clear and easy to understand?	16.1%	59.7%	17.7%	4.8%	1.6%	3.84
	Is the operation of the game easy to learn?	9.7%	48.4%	29.0%	8.1%	4.8%	3.50
content	Is the storyline of the game in accordance with the activities related to the learning content?	4.8%	25.8%	43.5%	12.9%	12.9%	2.97
	Is the content presented in a conceptual order?	3.2%	17.7%	50.0%	16.1%	12.9%	2.82
	Are the challenges in the game related to the learning materials?	29.0%	56.5%	9.7%	3.2%	1.6%	4.08
	Are the game's resources in accordance with its storyline?	1.6%	25.8%	45.2%	12.9%	14.5%	2.87
feedback	Does the game provide a proper assessment of the user's skills?	3.2%	14.5%	51.6%	17.7%	12.9%	2.77
	Can the game report a user's current status?	9.7%	29.0%	40.3%	9.7%	11.3%	3.16

^a. Note. *average: 5=very good; 4=good; 3=common; 2=poor; 1=very poor;

VI. CONCLUSION AND FUTURE WORK

The AR educational game developed in this study was designed to be educational and entertaining to help upper elementary school students learn English words. The survey showed that by introducing AR technology, the students' feedback on this game for learning English words was good. And students were very interested in the three dimensional learning environment which was generated by the AR technology. According to scholars' research on the evaluation indicators of educational games, a corresponding questionnaire was set up. The results of the questionnaire about this AR educational game were studied. Some evaluations and conclusions about the game in this study were obtained. The game information is well documented. The multimedia resources of the game are arranged appropriately and in accordance with the learning goals. Also the multimedia content is very attractive. The interfaces are well designed. Yet some limitations existed in this game. Aspects related to content and feedback design need to be improved. In the future, we will upgrade this AR educational game continuously and do more research about AR educational games. We will upgrade the storyline and graphics of the game to make them more suitable for the preferences of boys and girls. The regulations, excitation mechanisms and evaluation criteria of the game will be improved. A function module for ranking the learning performances of the learners will be added to the game.

ACKNOWLEDGMENT

This work is supported by the National Natural Science Foundation of China under Grants (61907021).

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