VREX: Virtual Reality Education eXpansion could help to improve the class experience

(VREX Platform and Community for VR based Education)

Li Ying[12] Zhang Jiong[13] Sun Wei[1] Wang Jingchun[3] Gao Xiaopeng[1]

[1]School of Computer Science and Engineering, Beihang University, Beijing, China
[2]Electrical Engineering, Princeton University, NJ, USA
[3]Dept. for Cyber Online Popularization of Science, Chinese Science and Technology Museum, Beijing, China

[1] ***Abstract*—This paper proposed an innovative education platform-VREX (Virtual Reality based Education eXpansion), with combination of online and offline, to improve the curriculum building and teaching experience. VREX is based on Virtual Reality (VR) and we believe VR can revolutionize the education ecosystem. With some trials, we found VR can be used to promote curriculum effectiveness in an immersive environment so that students can have intuitive sense to understand some abstract knowledge, which is always hard for teachers to describe. We have tried to transfer slides into VR scenes, for the students to learn knowledge in a rather real but totally virtual world. The main contributions were made: (1) VREX build an open and immersion virtual O2O classroom with internet and VR devices so that real classrooms might be used in a different way in the future. (2) VREX provides a distributed mode for students to experience an interactive learning process at anytime, anywhere and any-frequency. (3) VREX can be used to support education in different disciplines, from K-12 to Universities, and we provided some practical cases, like 'Marine Life' to show creatures in deep sea, which provides immersive experience to makes students feel they were there. Finally, the feasibility and advantage of VREX are proved by the actual statistical data in the 3rd season 2017.**

Keywords—Virtual Reality, Immersion, Interaction, Virtual classroom, VR Cloud Platform

I. INTRODUCTION

VR technology was originally developed to train pilots by the military of US in the 1960s. The most significant reason for the application is that people found VR plays an essential and irreplaceable role in reducing danger. But VR device was too expensive until recently, the VR hardware is cheap enough to be applied more widely, which we described as "VR+", such as "VR+ education", to enhance education[1][2].

Integrating VR with education is a giant leap in education and we regard "VR+ education" as MOOC 3.0. To such a new blueprint, it has mainly three challenges: (1) High cost of VR hardware; (2) Seriously shortage of VR resources; (3) Lacking of particular platform to generate VR content. So we build a new project named VREX to realize "VR+ education".

As all knows, it is very difficult to understand some abstract structures (e.g., architectural structure, computer architecture) and complicated process (e.g., how to drive an aircraft, how to perform a heart transplant surgery.) Especially, it is impossible for students to observe and learn all the details via VR. Fortunately, VR could let students have an intuitive understanding of what they learn. VR can not only realize all the traditional education paradigms, which is known as four-dimensional teaching model (listening, speaking, reading and writing) , but also can provide a novel five-dimensional teaching model, they are listening, speaking, reading, writing and touching. Educators continuously work hard to find an effective way to present knowledge better, from blackboard-writing, projector-multimedia courseware to mobile terminals-sharing resources. But all of these teaching tools cannot satisfy the demands on the cultivation of innovative talents. Therefore, it is high time to apply VR to improve the traditional teaching methods.

To make a real and formal study of this topic, we did some surveys and experiments to analysis different factors for VR applications like financial feasibility. The rapid increase in the technological sophistication, diversity, and pervasiveness of 3D virtual learning environments, along with the proliferation of research on their effectiveness in educational settings, necessitates frequent systematic analytical syntheses of their effectiveness. More and more resources in the form of time and money are being devoted to the designing and developing desktop-based VR instruction for teaching K-12 and higher education curriculum. Deploying desktop-based VR instruction in schools and colleges not only involves financial cost but also the efforts to train the teachers to use them effectively. Therefore, it is critical that instructional designers make careful decisions in the design and development of instructional materials utilizing desktop-based VR technologies.

Instead of pens and paper, students are immersed in a VR environment, where they can "touch" the knowledge with 3D goggles, data gloves and space ball. With the aid of VR, teachers can construct a "self-learning" environment and change the traditional "Imparting" way of teaching into the student-oriented "Participating Learning". With the use of VR system, learners can obtain knowledge and skills through full interaction and close connection with the information environment. With the development of VR technology, as well as the cost of hardware equipment goes down, we believe that VR technology, due to its strong advantages and potential for teaching, will gradually get the attention of educators, and

[1] Zhang Jiong is the corresponding author (zhangjiong@buaa.edu.cn).

978-1-5090-5920-1/17/$31.00 ©2017 IEEE

ultimately be widely used and play an important role in education, teaching and training fields.

Furthermore, the combination of VR and education, which is called VR+ education as we have mentioned, has developed a series of valuable curriculum resources. VR+ can be widely used in scientific research, virtual training, virtual simulation campus, classroom teaching, situational testing and other educational scenes. It can not only break the limitations of equipment, venues, funding and other hardware restrictions, but also can effectively avoid all the dangers caused by the physical experiments or operations. With the virtual experiment built by VR technology, students can safely do a variety of dangerous experiments. For example: virtual aircraft driving teaching system can avoid a serious air crash accident caused by the misoperation.

II. Related Works

In fact, VR has been applied to the field of education at different countries and fields. In America, the teachers from St. Joseph Ville School help students to learn the knowledge of the solar system through the VR. [1] Students carry spacecraft to explore every planet of the solar system. And in the middle of the students, it gets a good response. Some students cannot wait to share learning experiences with others, and some students thank they learned a lot and it's very interesting. In US, some universities has set up VR courses to teach students about the design principles of VR. Dr. Shafi Ahmed, a UK-based cancer surgeon, use VR to improve medical training for students. [2][3] Google's Expeditions Pioneer program provides teachers with VR devices that enable students to take adventure of VR trips. [4]

In China, Some of the top colleges and universities also apply VR in education, but they mainly focused on research and exploratory teaching, lacking practical experience.[9-10] There is a highlight case of VR used for education in China, popularization of science by CSTM (Chinese Science Technology Museum), where we setup VR lab foe education.

III. Applications of VR

Based on mass of investigation and study, it finds the core of VR is to make students effectively do VR experiments in a VR lab. VR has mainly four advantages: (1) some complex experiments can be redesigned easily; (2) some dangerous experiments can be implemented safely; (3) some experiments, which cannot be done physically, can be done in a VR environment; (4) some expensive experiments can be repeated in a low-cost way.

Some typical VR applications are as follows:

1. English Teaching: not everyone has the opportunity to communicate with foreigners, not more likely to frequently communicate, which is our deficiencies in English education. Then VR education can take you into a virtual scene, in which students could make real interaction and communication with foreign teachers and students. Further, scenes can be changed according to the topic at any time.

2. Medical Education: Although there are many physical models in the field of medical education, these models are static and dedicated. VR technology can be used to truly reconstruct some 3D solid models, so that students can immerse in and fully interact with the physical model.

3. Engineering Education: The cost of turning a construction drawing into a real building is very high, which needs a significant amount of manpower, material and financial resources. But all of these can be replaced by VR. [2][3][4] In a virtual environment, grand costs can be reduced to very low.

In short, the key characteristics of VR education are immersion, visualization and interaction. And the characteristics of VR technology determine it can be applied in some specific fields in education, which refer to natural science and engineering, language, culture, history, etc. But the concept of the new VR educational thinking has not been put forward yet. More importantly, VR can provide some innovative features at very low costs. Meanwhile, it needs to design more interesting and richer virtual contents to meet the demands.

Developing educational thinking, improving VR technology and enriching VR education content are the three main problems of current VR education which need to be solved for now.

In addition, the current domestic VR education in China has just started, facing the shortage of VR high-end talent [8]. In China, the demand of talent is 18%, but the supply is only 2% of the world. By around 2020, VR will enter a stage of all-around popularization.

IV. VREX PROJECT

A. An VR Education Community and Platform

VREX is the project to enrich VR resources and improve learning experience in the form of both online and offline teaching (at school or at home). VREX provides a richly functional platform to present VR teaching materials and has a special Community to express users' teaching opinions or learning thoughts.

Why do we need such a VREX Platform? At present, in China, a total of more than 450 STMs (Science and Technology Museum) has spread across all the provinces (30), big cities (300+, with over 1 million population) and many counties (200+). Clearly, it is not realistic to provide enough physical devices to all of these STMs. Then, VR is a preferred method. How to promote Science Popularization in a visual and interactive way? We tentatively established 40 large VR games and 260 small ones for all of these STMs.

For this work, we have established a particular VR Lab at CSTM (Chinese National STM) in Beijing, China, whose goal is to draw attention to child's education and explore new and interesting ways to teach, especially in science popularization area by adopting advanced techniques. This VR Lab was installed 4 PCs, each with the either HTC Vive or Oculus Rift DK2 VR headset mounted Leap Motion sensors.

In the past three months, we have verified all the VR games and selected 40 items of them to make distribution to all the

STMs for free. Further, we developed a set of standardized protocols for all of the 40 items since each of them is very different from others and we have to package them into a standard one so that all the 450+ STMs can apply them in a simple way (like selecting Menu), and can download them easily from the cloud. Figure 1 shows the architecture of VREX.

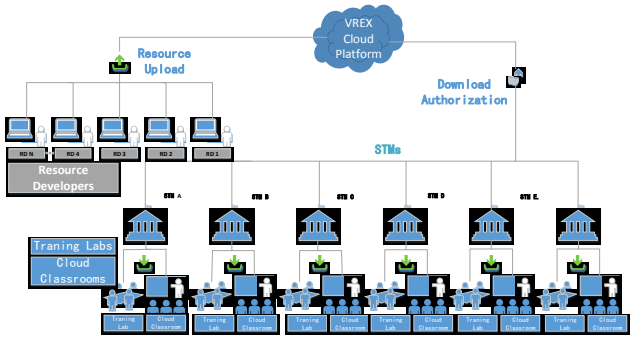

Figure 1 VREX Platform Architecture

Via the VREX Cloud Platform, we have deployed over 300+ VR science popularization games, which covered many fields, e.g., biology, astronomy, mathematics, engineering, etc. People can download the small size of VR games by scanning a two-dimensional-code with on-line identification and view the VR contents on their smart phone by installing a APP. While for those much bigger video games, people can go to their local STM to play the VR games personally. Topics of the VR games mainly focus on the areas as followed in Table 1.

TABLE 1 PART OF THE RESOURCES OF VREX FOR STMS

Biology	Astronomy	Math	Safety	Engineering
Animal Cell	Solar System	Math and Art	Fire Escape	Automobile Producing Pipeline
HIV Virus	Space Shuttle	Math and Music	Earthquake	3D Printing
Blood Cell	Explore the Lunar Surface	Gougu Theorem (Pythagorean theorem)	Emergency First Aid	Sculpture Workshop
DNA Replication	International Space Station	Math and Games	-	Smart Home
Editing Gene	Mars	Fractal	-	Signal Transfer
Nerve Cell	Rectilinear Propagation of Light	Ball's Surface Area	-	-

While, we met much bigger problems when did the same work for university. There are 2200+ colleges (university, college, vocational school) in China and we try to apply the VREX platform, but much bigger, in this area.

In VREX Cloud classrooms, students can take a virtual biology and anatomy course. Donning the VR headset, they're placed in a virtual classroom with some cardiovascular models and interactive devices, like blood vessels and organs. The students are immersed in this scene and can manipulate the models through their physical movements and gestures.

B. *VREX Cloud: A CrowdSoursing platform for VR based Curriculum materials*

We suggest that more and more curriculum materials based on VR should be created and put on the VREX platform, so that students from all over the world can access them easily if only they are armed with proper VR equipment like VR headset or just smart mobile phone and cardboard (a Google VR device). And VREX has also provided many valuable VR contents, like arts, music, history, biology, etc.

VREX platform is mainly designed to provide the most important function of VR education resources, "VREX cloud classroom", which is the terminal solution for VR service.

C. *VR Classroom and Training Lab*

VREX cloud classroom and curriculum courseware cloud aim to deeply support the teaching activities for VR content. In before VR classroom, each student should wear one whole set of VR device, which causes high cost. Meanwhile the students could not learn the same content concurrently. But in our VIVE classroom, multiple students could be imported into the same virtual scene at the same time with only one VR device. Based on a combination of VR technology and education, VREX has created the suitable VR education cloud services for universities and K12.

VREX classroom immersion system: (1) learning progress control, (2) resource play options (3) resource synchronization explicit (4) wonderful VR video resources (5) rich of the teaching application resources.

V. VREX RESOURCE CASES

We brought out four innovations about education models, which are shown in Figure 2, to help traditional teachers who still using blackboard / whiteboard / projector to present lectures:

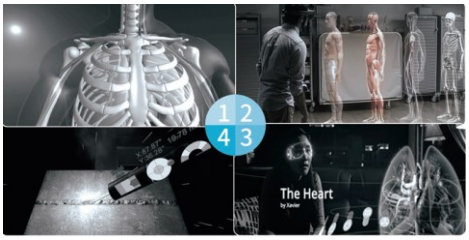

Figure 2 Teacher's perspectives(1,2) vs student's perspectives(3,4)

In order to carry out a form of immersive, practice and interactive learning, teachers need to introduce the VR courseware and guide students to experience the contents of VR curriculum personally.

A. *VR courseware*

1) Artistic Appreciation

This course covers the following topics: (1) the common sense of the artistic appreciation (2) the main factors of an art works (3) the comparison of Chinese and Western art (4) the paint brush stroking (5) VR Art Museum of the world famous painting (6) Tilt Brush (7) tribute to Van Gogh, etc. The

involved famous art works were included such as: "Starry Sky" and “Sunflower” and many others.

2) Basic Medical Courseware

With combination of the modern medical teaching contents and VR technology, VREX’s basic medical courseware can create a full 3D virtual environment, and truly import a complete 3D digital human anatomical structure, which makes students to use the VR in a holistic manner to observe each organ and structure of human body.

3) Clinical Operation Courseware

Before the trainees enter the hospital to learn surgery, they should complete the "theory - demonstration - practice - comment - assessment" by the VR clinical practice courseware. The cost of "simulation operating room" is much reduced compared to the traditional medical education. [10]

4) Automobile Theory Courseware

The courseware includes the contents of automobile, e.g. "Automobile Introduction and Driving Simulation", "virtual 4s demonstration", "car VR", which are taught in the form of VR. The courseware restored the physical practice via VR scenes to realize professional automotive training. Over 15 global mainstream engine models were covered in this courseware. Students could choose the engine model and dismantle it to make comparison so as to master the principles of car structure, especially the engine itself.

5) Marine Life Courseware

This courseware covers a series of VR marine life teaching contents, e.g., "Stanford Ocean Acidification Experience", "The BLU" and etc.. It aims to use VR technology to present the real environment of seawater, the behavior of dissolution, the seabed sediments, so that users can understand the marine environment and marine life in an immersive way.

B. VR based Training Lab

Both VREX cloud training room and professional training cloud are set up to deeply support VR through teaching and training activities. It can greatly reduce the risk, cost, complexity and other practical problems in common training program.

The most valuable characteristic of VR professional training is “restore a sense of reality, but beyond it”.

Restore the reality*:* By accurately modeling the real scenes and capturing the real actions, VR technology can completely restore the real training operation process [5-7], and help students acquire some practical operating experiences by improving the traditional practice training.

Beyond reality: VR is a good solution for hi-danger, hi-risk and hi-cost training program. With VREX, each practical operation process can be recorded in real-time mode for later quantitative assessment and analysis. All the guidance activities can be traced and even be replayed. Besides, it can greatly reduce the training cost.

VREX has setup several training labs based on VR, e.g., Welding Technology Laboratory and Automotive Spraying Laboratory Automotive Engine Laboratory. Through investigation and study, we compared the VREX labs with traditional training methods in Table 2:

TABLE 2 TRADITIONAL METHODS VS. VR METHODS

Features	Traditional	VR
Safety	High risk	Zero risk
Convenience	Complex, requires a lot of preparation	Easy, ready to train
Initial investment	more than 20 million yuan	similar investment
Operating costs	Expensive	Negligible
Maintenance costs	Large, need to be regularly checked for security	Almost zero but online update system
Teachers required	More, each teacher for 5 students, maybe 1:1 for the hi-risk training	Less, dozens of students need only a teacher
Criteria	Teacher subjective scoring only	the system objective quantitative scoring
Help &guidance	Rely on teacher’s experience	Self-improvement aided with training record analysis
Training effect	General, on average need 72.6 hours of training on the machine operation	More efficient, on average only 20 hours of VR training and 8 hours of real welding training

VI. CONCOLUSIONS

Education has evolved from the offline stage, characterized by face2face, to online stage, characterized by screen2screen, and now it is entering the immersion stage with the aid of VR. Compared with the traditional methods, VR education has four features. (1) Efficiency and effect: VR education can overcome the disadvantages of traditional education like abstraction, isolation and interactive-less, which makes students to learn knowledge in a way with interaction and immersion in a real scenario. (2) Instant feedback: in the traditional education model, it is hard for students to learn and understand the abstract knowledge and get its correct answer immediately. But in VR education, students can ask questions freely and get feedback for they feel they are placed in the real scenario. (3) Low cost: virtualized materials reduce the cost and lower the threshold for education. When training, it does not need to provide the raw materials, e.g., real cars and paint for students to learn spray-paint. (4) Operation safety: obviously, VR can cut down most of the dangers and provide a safe teaching environment which is very important in engineering training and practice.

Even though VR based Education still meets many challenges, such as hardware experience defection. But VR bring a revolutionary change to education with different teaching models and methods. We should not miss the opportunity. In fact, we have been trying AR (Augment Reality) and MR (Mixed Reality) to upgrade the VREX platform, which will be discussed very soon.

ACKNOWLEDGMENT

Thanks for (1) Chinese Science and Technology Museum (2) VIVEDU Cooperation.

REFERENCES

[1] Zahira Merchant, Ernest T. Goetz, Lauren Cifuentes, et al. “Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis”. Computers & Education, 2014, Vol. 70, pp. 29–40.

[2] Abdul-Hadi G. Abulrub, Alex N. Attridge, Mark A. Williams. “Virtual reality in engineering education: The future of creative learning”. IEEE Global Engineering Education Conference (EDUCON), Amman, Jordan, 4-6 April, 2011. pp.62-70.

[3] HM Huang, U Rauch, SS Liaw. “Investigating learners' attitudes toward virtual reality learning environments: Based on a constructivist approach”. Computers & Education, 2010, Vol. 55(3), pp. 1171–1182.

[4] RA Earnshaw. “Virtual reality systems”. Academic Press, 2014.

[5] CLF Chan, EKY Ngai, PKH Leung. “Effect of the adapted virtual reality cognitive training program among Chinese older adults with chronic schizophrenia: a pilot study”. International Journal of Geriatric Psychiatry, 2010, Vol. 25(6), pp. 547–655.

[6] L Nl, QI PENG, YU LINA, W JING. “The research and application of products virtual exhibition technology base on unity 3D”. Digital Technology and Application, 2010, Vol. 9, pp. 1213-1217.

[7] JCP Chan, H Leung, JKT Tang. “A virtual reality dance training system using motion capture technology”. IEEE Transactions on Learning Technologies, 2011, Vol. 4(2) Volume: 4, Issue: 2, pp. 187-195.

[8] DWK Man, JCC Chung, GYY Lee. “Evaluation of a virtual reality ‐ based memory training programme for Hong Kong Chinese older adults with questionable dementia: a pilot study”. International Journal of Geriatric Psychiatry, 2012, Vol. 27(5), pp. 439-548.

[9] M Ott, L FREINA. “A literature review on immersive virtual reality in education: state of the art and perspectives”. eLearning and Software for Education, 2015, Vol. 1, pp. 133-141.

[10] K Liu, B Fang, Y Wu, Y Li, J Jin, et al. “Anatomical education and surgical simulation based on the Chinese Visible Human: a three-dimensional virtual model of the larynx region”. Anatomical Science International, 2013, Vol. 88(4), pp. 254–258.