Virtual Experiment Environments Design for Science Education

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Abstract

Virtual reality technology is reported that the use of virtual reality(VR) as an educational tool can increase student interests, understanding and creative learning because of encouraging students to learn by exploring and interacting with the information on virtual environments. This paper presents the virtual experiment (VE) environments for science education using virtual reality simulation. We developed the VE environments on the Web designed compatible to the learner levels through level analysis in the learning contents. The students can select the learning level in the exploring step of learning cycle model: regular, advanced and remedial courses according to the degree of their understanding or interest about the learning topic. The VE environments support students to learn scientific phenomena and concepts focusing on: the seismic wave, the earth's crust balance, radiation balance, the movement of ocean, solar system and the control of telescope in the science field of middle school. The responses of learning on VE environments have demonstrated that the VE environments can be used as a useful methodology in science education for middle school students.

1. Introduction

Throughout the 21th century, the science education is to make a transition from an emphasis on delivering content through lectures to getting students "involved in some way in scientific inquiry, not just a hands-on experience." In the science education, inquiry has always been difficult because the phenomena are so far out of reach – students obviously can not visit the Sun. However, the power of the modern day computer to do desktop virtual reality and computational modeling has created a new opportunity for inquiry approaching to learning [1][2] and teaching astronomy [3].

VR is defined as a highly interactive, computer-based multimedia environment in which the user becomes the participant in a computer-generated world. A key feature of VR is real-time interactivity where the computer is able to detect user inputs and instantaneously modify the virtual world in accordance with user interactions.

VR means an fully immersive worlds created by computers but it can be extended to semi-immersive and non-immersive(desktop) VR. In spite of the disadvantage of non-immersive VR system, the non-immersive VR systems are by far the most common in the present because it is not only cost effective but also can be used in the network environments. Furthermore, they give an

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additional benefit. The earth science field which is neither easy to perceive nor to measure in usual experiments can be presented on virtual experiment environments and can be viewed in many different perspectives in a virtual world. This paper presents the VE environments for the internet-based learning of earth science education in middle school and discusses the response of learning in the VE environments.

2. Bring VE environments into science education via the internet

Today there is an increasing number of educators abandoning predominantly didactic, lecture-based modes of instruction and moving towards more learner-centered models in which students are engaged in problem solving and inquiry [4]. Recently, technological advances make possible new types of learning experiences, moving from transmission models where technology functions like textbooks, films, or broadcasts to environments in which the technology functions like studios and laboratories in which students immerse themselves within interactive contexts that challenge and extend their understanding [3][5]. Many such technologies have been discussed in the literature [6][7][8][9].

One interesting technology that has much potential in which to ground learning in rich environments is virtual reality [1][9][10][11][12].

Virtual reality technology may offer strong benefits in science education. It enables students to do things that they cannot do in the physical world (ex. Fly and go to places that do not exist.) These technologies allow students to enact basic scientific concepts (e.g., earth's crust balance, seismic wave etc.) into dynamic, 3-D scale models.

Distance learning has been popularized in recent years because of the fast development of computer systems and the spreading Internet connectivity. One of the major restrictions for distance learning in science and engineering education is the difficulty of experiment activities. One way to overcome these difficulties is to use the VE environments running on a Web browser instead of requiring hands-on experiments. Especially many physical phenomena in the earth science field which are neither easy to perceive nor to measure in usual experiments can be presented in the VE environments and can be viewed in many different perspectives in the virtual world. In addition, dangerous, high cost, and complicated experiments can be realized in a VE environment for distance learners. The VE environments therefore can be used to overcome the physical, safety, and cost constraints that limit schools in the types of environments they can provide for learning-by-doing.

3. VE environments's design

The teaching designers should have the clear idea on the knowledge and function that learners should have. Fig.1 shows a model describing how VE environments is designed.

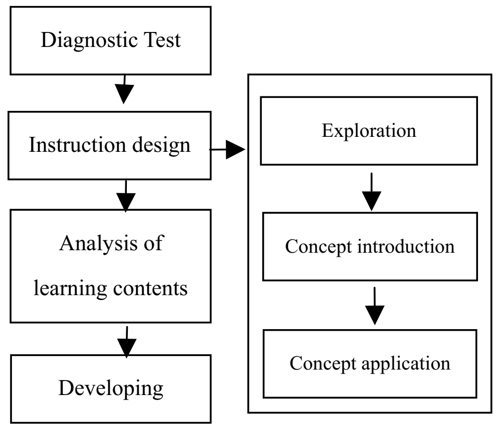

Fig. 1. A designing process for VE environments

First, we conducted the diagnostic test to grasp the intellectual level of what learners have already known. After giving learning topics of earth science field in the multiple choice tests, students make an answer to the questions. The multiple choice tests are commonly used in traditional textbooks and classrooms and need no elaborate explanation.

Second, an instruction design to introduce new knowledge to students is provided. The instruction model basically adopted in this study is similar to the model of learning cycle [13]. The model of learning cycle is the one that was introduced to the SCIS (Science Curriculum Improvement Study) program to facilitate the basic concept of science and to develop the function of thought, and it is composed of mutually related three stages – exploration, concept introduction and concept application.

The stage of exploration is the one that the learners act and solve the problems that they have been curious on their own. In this stage, the learners can get the experimental data while doing the interaction of preparing the experiment equipment on the table in the 3D VE experiments and conducting the experiments. The learners in this stage solve their curiosity and intellectual conflict to some degree. The concept introduction stage is the one that the teachers arrange the concepts including what the learners have not solved and is the stage to solve the intellectual conflict. The concept application stage is the one to make sure what has been learned and is the stage to apply it to the different situations of nature or the actual life.

Third, the learning contents have been organized with three levels according to the degree of difficulty and been devised to put the learning subjects in a hierarchical structure.

The learning contents in the learner level-based learning structure for learner-centered learning have been devised with analysis methods of the inquiry level [14] and the concept level for science education of middle school provided by the Department of Education [15]. The subjects of learning is also to put in a hierarchical structure in order to identify which concepts are prior to the others, and conceptual pyramids can be built. We followed the results of an official announcement by the Department of Education to analyze a hierarchical structure.

After analyzing both inquiry level and concept level about the contents of learning, the levels of learning contents can be built to regular course(RGL-C), advanced course(ADV-C) and remedial course(RMD-C). Specially, the selection

Table 1.

A level analysis of the earth structure(High:**H**, Average:**A**, Low:**L**)

Unit	Sub-Unit	Subject	Learning -Type	Level						RMD-C	ADV-C	Remarks
				Inquiry			Concept					
				H	**A**	**L**	**H**	**A**	**L**			
Earth Structure	Atmosphere	Constitution of atmosphere	Concept						♣		♣	ADV-C(**iconic**): the density variance of vapor and dust
			Inquiry		♣					♣		RMD-C(**symbolic**):the test of oxygen mass in the air
		Perpendicular Structure of atmosphere	Concept					♣			♣	ADV-C(**enactive**): radiation balance
			Inquiry		♣						♣	ADV-C(**symbolic**): the analysis of measured data in high level layer of the air
	Earth interior	Seismic wave	Concept				♣			♣		RMD-C(**enactive**): an electromagnetic wave
			Inquiry	♣							♣	ADV-C(**enactive**): A draw of a cross-sectional of the Earth.
		Earth's interior	Concept					♣		♣		RMD-C(**iconic**): the damage of earthquake
			Inquiry		♣					♣		RMD-C(**symbolic**): the inference of structure in the Earth interior

of educational content using virtual reality was considered by mainly enactive representation among the learning types(enactive representation, iconic representation, and symbolic representation) of Bruner [16] and experimental attributes. Table 1 shows an example of learning contents was analyzed with both inquiry level and concept level.

Finally, VE environments have been developed to open at our homepage for the free access of anyone including middle school students on the Web.

This study used Superscape 3D Wed master software from VRT for development of the virtual experiment environments, which is a multifunctional tool to create, manipulate, texture, and animate shapes, group and ungroup objects, create various view points from which to view VR worlds among other features. This software is the virtual reality modeling language(VRML) editing tool. VRML is the WWW standard for VR and is a language similar to HTML in that it establishes a common standard for making VR easily distributed over the Internet. The worlds created from this software can be displayed on the web as fully interactive environments, or embedded in 2D HTML pages on a PC. It also has the advantage of being able to minimize the load of communication because the size of files is small. VE environments developed are now briefly introduced.

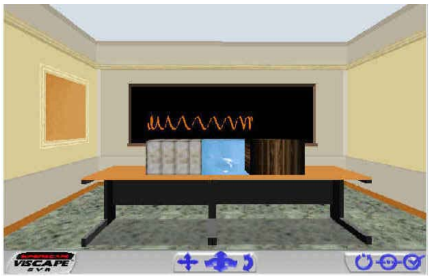

Fig. 2. VE environment of the seismic wave

VE environment of the seismic wave

Fig.2 that shows a virtual experiment environment of the seismic wave (P-wave, S-wave) of the internal earth. The waves and a value of velocity have been selected from the learners, then they can explore features of each wave selected in the 3D. The learners can understand the features of P-wave, S-wave and visually conduct the simulated experiment on how each wave proceeds.

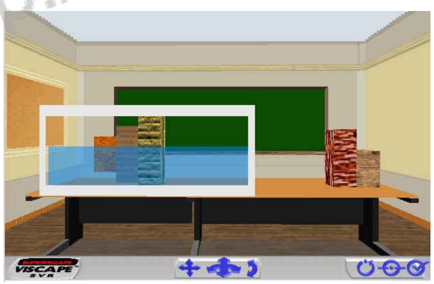

Fig. 3. VE environment of the earth's crust balance

VE environment of the earth's crust balance

Fig.3 is a virtual experiment environment for the earth's crust balance. This VE environment was designed to explore the earth's crust floating on the mantle. The learners can drop by dragging optional blocks in a water tank with a mouse button and observe the length of blocks in the water tank according to the scale and density of blocks on the 3D. This VE environment designed a visual symbol as blocks of tree floating in a water tank in order to create concrete metaphor of the earth's crust structure floating on the mantle.

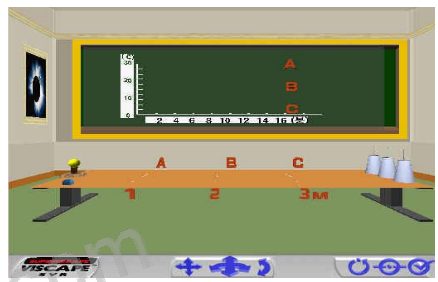

Fig. 4. VE environment of the radiation balance

VE environment of the radiation balance

Fig.4 is a virtual experiment that measures the change of internal temperature and the equilibrium temperature of each cup that is differently away from the light source. When the learner moves the cups with the thermometer to certain places by using the mouse and turn on the switch, the temperature of each cup will rise. Of course, the rise of the temperature varies with the distance respectively the colors of three cups into different colors, if the learner put the cups the same distance away and warm them with the same energy, the learner can also see the absorption degree of radiation energy according to the color on which cup's temperature rise most.

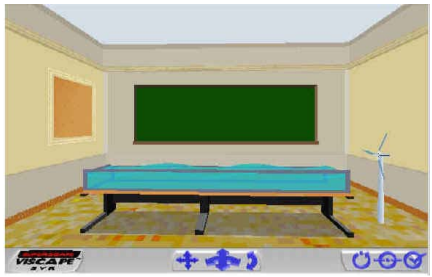

Fig. 5. VE environment of the ocean's movement

VE environment of the ocean's movement

Fig. 5 is a virtual experiment for the movement of ocean. The learners can observe the size of the wave in the water tank according to the strength of the wind. The strength of the wind can be adjusted to 1m/sec, 5m/sec, 10m/sec, and 20m/sec etc., and it is a virtual experiment necessary to understand the height of the wave and the wind velocity that actually look in the sea.

Beside, we have developed VE environments of the solar system and telescope control system .

4. Results of student responses

The VE environments developed have been evaluated to the reactions of learners on a Web targeting 701 middle school students for 6 months. The survey was conducted to find out the quality level and the possibility of use in the classes of the developed VE environments. The questions are composed of 3-phase Likert technique. The result of the learner responses is shown as in Table 2.

About 70% of the learners who used this VE environment answered that this VE environment expresses the real world well. Such result seems to come from the fact that we tried to get the maximum similar environment to the real world by inputting the physical values such as the gravity value and mass value etc. of each object in a concrete manner and conducting the design.

Table 2. The Result of student responses (Agree:**A**, Common:**C**, Disagree:**D**)

No.	Questions	Response(%)		
		A	C	D
1	Is the learning situation similar to the real situation?	70.2	19.4	10.4
2	Is it composed to understand the learning contents well?	74.4	13.2	12.4
3	Can the learners selectively study according to their level?	55.1	27.5	17.4
4	Is it possible for the learners to actively participate in the inquiry experimental environment?	72.3	17.0	10.7
5	Is it composed so that you can effectively achieve the inquiry objective?	76.1	19.4	4.5
6	Is the sense of immersion provided by this virtual experiment environment helpful in giving the learners interest and motivation?	82.1	14.9	3.0
7	Is the interaction of the learner on this virtual experiment environment easy?	74.6	20.9	4.5

We had those who had effectively reached the learning objective conduct the advanced learning and for those who had not reached the learning objective, we provided the arrangement of what they had studied before once again and had them do the supplementary learning so that they could do the complete learning.

In the responses related to this, they said they could easily understand the learning contents

(74.4%), but the third question was not complete (55.1%). It seems that this result comes from the fact that the learning contents by level provided in this study was composed of the contents of remedial level and advanced level for the representative learning contents only related to the inquiry and experiment contents. Therefore, it is judged that we should design it by including the remedial and advanced learning contents for the various contents related to the inquiry and experiment contents in the future.

As for the responses of the learners for the inquiry, 72.3% were positive for the degree of participation possibility, and 76.1% were positive for the achievement degree of the inquiry experimental objectives, which means the responses were relatively positive. what we should pay attention to the responses related to the inquiry experimental learning is that in case it is difficult to conduct the field experiments as in astronomy or geology, or it is costly or dangerous to do experiments, it has the effect of replacement for the actual situational learning when we provide the learning situations to the 3D VR space of the computer.

The very positive responses of this questionnaire are the sense of immersion and interest inducement (82.1%). It seems that such result comes from the fact that while the existing learning programs were mostly 2D, this program was 3D so they could study while moving in 3D space as if they were doing 3D simulation games. The effect of the interaction is one of the fundamental functions to the 3D virtual experiment environments. The learners responded that the interaction effect was well considered in VE environments (74.6%).

5. Conclusions

This paper presented virtual experiment environments considered learner levels in science education for middle school students. The learners who used the VE environments developed showed the positive responses totally. Such result indicates that for the inquiry learning tasks that need the interaction in the 3D space, it is possible to achieve the learning objective if using this method. In case of geology or geophysics where it is difficult to conduct the experiment and to obtain the inquiry experiment results, the VE environments can be the indirect situational learning.

In order for the VE environment to be embodied as the program learning close to the real world, it should be designed and embodied so that it can get various experiment results in various experiment conditions. For this aspect, it is necessary to do sophisticated design and development reflecting the various situations related to the learning contents. I expect that the use of VE environment on the web-based will play the role of catalyst in establishing the realistic school education environment on the remote education.

6. Acknowledgement

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