Learning by doing: A Case for Constructivist 3D Virtual Learning Environment

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Abstract

This paper puts forward an idea that 3D virtual learning environment (3DVLE) is an effective way to improve the feasibility of implementing constructivist learning theory in distance education. In this paper, we first give an outline of constructivist learning theory and analyze the relationship between 3DVLE and constructivist learning theory. Then we provide a learning and designing scheme on Web-based system. Finally, we briefly describe our 3DVLE system, present system architecture and some implementation considerations. The main goal of our system is to show the potential of designing constructivist virtual learning environment to enable an active, friendly learner-centered learning.

Categories and Subject Descriptors (according to ACM CCS):   Virtual Reality; Constructivism; Learner-centered; VRML

1. Introduction

Nowadays, an open issue of education reforming is to change teacher-centered behaviorism to learner-centered constructivism. In constructivist view of learning, learners construct knowledge for themselves, and each learner individually (and socially) constructs meaning when he or she learns[1]. Constructivist learning theory puts forward four main factors in a learning process: situated knowledge, collaboration in learning, communication in learning and meaning establishing in human brain. Most of educators agree with constructivist learning theory, for they think that discovering learning, collaborative learning, learning by doing and learning with fun are effective learning methods in practice[2]. Distance education, which is developed rapidly in recent years, takes an important role in implementing constructivist learning theory. It creates a knowledge-based virtual learning world, which provides various learning resources. However, the most common showcase of learning resources in virtual world is in 2D version, which is text-based and using techniques such as HTML, XML. The physical way of doing a learning process is reading the letters one by one presented on paper-like WebPages. Learning in this way does not change the situation of teacher-centered learning theory, for learners cannot do much more except reading. 2D version hypermedia brings new birth to virtual learning world. The showcase of hypermedia-based learning resources varies by embedding multimedia such as sound, flash movie, shockwave and movie.

Virtual Reality (VR), which is also called Artificial Reality, Cyberspace, or Synthetic Reality is the use of computer technology to create the effect of an interactive three- dimensional world in which the objects have a sense of spatial presence[3]. Basically, there are 3 different kinds of VR, desktop VR, semi-immersive VR, fully immersed VR, which are categorized by the quality of the immersion that is being provided. Desktop VR is PC-based desktop system which lacks of immersion but is common and cheap to apply. Semi- immersive VR system attempts to give the users a feeling of being at least slightly immersed by a virtual environment, which is often achieved by different types of so called workbenches and reach-in displays[4]. Fully immersed VR system are expensive but provides full immersion such as CVAE, head mounted visual displays.

The application of VR system in education field is called

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VR-based Education. The main goal of implementing such systems in education is to facilitate learning. In recent years, growing emphasis on VR-based education technology brings forward the potential of developing constructivist 3D virtual learning environment. There is a trend that creating 3D virtual learning environment is a way to improve the feasibility for implementing constructivist learning theory in distance education. The 3D virtual learning mode presented in this paper helps build an easy shared learning environment where learners can learn by doing, by discovering and by exploring.

According to Barney Dalgarno[5], virtual learning environment has been used to encompass any Internet or Web- based learning resources. 3D learning environment refers to one type of virtual learning environment. It is specified by certain learning resource, associated with learning tools that support different types of learning. A back-end knowledge acquiring tool kit supports learning process. It supports:

a) Situated knowledge. Many teaching practices implicitly assume that conceptual knowledge can be abstracted from the situations in which it is learned and used. Thus, knowledge is situated, being in part a product of the activity, context, and culture in which it is developed and used[6]. The situated knowledge in constructivist learning environment helps learners establish knowledge meaning and accelerates the process of grasp abstract concepts.

b) Interaction with and presence of other learners. In the interaction process, tacit knowledge that cannot be codified from textbooks or lectures is transferred among the learners inside the 3D learning environment.

c) Immersive learning. In virtual learning environment, each avatar represents a current learner. By enabling learners to experience, they can develop a deeply experienced understanding of highly complex concept.

d) Communication in learning process. Communication is also regarded as a social interaction. It is an important tool for learners to exchange ideas, share important information. Through communication, each learner's thoughts, experiences, knowledge resource and knowledge result can be shared to the whole learning group. Communication is particularly effective over the net for educational purposes.

e) Collaboration in learning process. Collaboration exists in a whole learning process. In the field of education, collaboration has a very specific meaning. Slavin[7] describes it as a method by which small groups of students incorporate a co-operative task structure, a co-operative incentive structure and a collaborative motive to produce collaborative behavior. Through group discussion or group working, learners can learn not only from the learning environment, but also from each other.

In the following of this paper, in Section 2, we present some typical research and developing works. In Section 3, we provide theoretical analysis of constructivist learning and its relationship with 3D virtual learning environment. In Section 4, we introduce our active 3D virtual learning platform. Section 5 draws a conclusion of our work.

2. Related works

Many researches and developing works have been done in the specified fields discussed above. We will present some typical ones in the following.

COSE[8] is a virtual learning environment developed a bit earlier by Staffordshire University. COSE has been applied in Staffordshire University and used by hundreds of teachers and students. It allows tutors to create learning opportunities which provide "something to do" along with resources (both inside and outside COSE). Tutors also provide media objects, assessments, and references to traditional non-electronic resources. COSE is designed for courses with an output driven approach, where the emphasis is on the learning opportunities provided for learners and the resources needed to enable the learners to carry them out. COSE enables learning to be collaborative, allows content to be reusable and stable, helps Tutors to Manage Learning and makes submission of evidence of learning easy and provides feedback on Learner Activity. In short, COSE is a successful example of constructivism virtual learning environment. However, the showcase of all the learning resources and information in COSE are two-dimensional.

Virtual Campus[9] provides a theoretical analysis of the relationship between constructivist learning theory and virtual learning environments. Its aim is to investigate the extent to which a virtual learning environment facilitates constructivism in higher education. Virtual Campus put forward new ideas of designing courseware incorporating cognitive strategies. The process includes:

- Analyzing the requirements of the learning task.
- Analyzing the learners' ability to complete the task, including the predictable demands on a limitation of memory.
- Selecting or inventing an appropriate strategy [such as a concept map or a flow chart].
- Applying the selected strategy.
- Evaluating the effectiveness of the used strategy.
- Revising as required

On the base of single-purpose education software such as simulations and drills, Virtual Campus analyses ill-structured knowledge domains related with complex problems in an open- ended design space, along with inherent challenges in constructivism and solutions .

CyberMath[10] is an avatar-based shared virtual environment for mathematics education that allows further study of math issues. It is built on top of DIVE, which has the ability to display interactive three-dimensional graphics as well as to distribute live audio between standard desktop PCs. Abstract mathematic concepts are showed in three-dimension,

and they are assembled in an exhibition area like a virtual museum. As CyberMath gives a vivid description of concepts in mathematic region, learners have much of interest to learn in this ŞmuseumŤ.

Virtual Chemistry Laboratory (VCL)[2] is a project carried out by Farrer center in Charles Sturt University in Australia. VCL addresses the theoretical potential of 3D learning environment with a particular focus on their use in tertiary chemistry education at a distance. Through analysis of the relationship between constructivism and chemistry education, VCL claims learners need a direct instruction which is more consistent with the exogenous interpretation of constructivism to help them develop a consistent model of molecular behavior.

WALTZ[11] is a web-based adaptive/interactive learning and teaching zone, which supports dynamic, collaborative, and synchronous/asynchronous learning in 2D/3D virtual environment. WALTZ is based on CIA (Content, Interaction and Adaptivity) learning mode. WALTZ put forward its system architecture. The advantage of WALTZ is that we can access it by Internet and this shows a potential wide implementation in distance education.

In addition, there are also some other works as following:

- NICE[12] A project that applies virtual reality to the creation of a family of educational environments for young users
- ScienceSpace[13] A collection of immersive virtual worlds designed to aid students in mastering challenging concepts in science.
- Virtual Reality for K-12 Education[14] A project assesses televirtuality technology for K-12 education with a focus on pre-college science education.

3. Constructivist learning based on 3D virtual learning environments

3.1. Introduction of Learning Theory: Constructivism

(1) Constructivism
Constructivism is a philosophy of learning founded on the premise that, by reflecting on our experiences, we construct our own understanding of the world we live in. Each of us generates our own "rules" and "mental models," which we use to make sense of our experiences. Learning, therefore, is simply the process of adjusting our mental models to accommodate new experiences[15]. In the constructivism theory the emphasis is placed on the learner or the student rather than the teacher or the instructor. It is the learner who interacts with objects and events and thereby gains an understanding of the features held by such objects or events. The learner, therefore, constructs his/her own conceptualizations and solutions to problems.

(2) Constructivist View of Learning
Behaviorism emphasizes observable, external behaviors and,

as such, avoids reference to meaning, representation and thoughts while constructivism takes a more cognitive approach. Students learn by fitting new information together with what they already know. People learn best when they actively construct their own understanding. In constructivist thinking learning is also affected by the context and the beliefs and attitudes of the learner. Learners are encouraged to invent their own solutions and to try out ideas and hypotheses. They are given the opportunity to build on prior knowledge. Hein[?] puts forward some ideas about constructivist learning:

a. Learning is an active process in which the learner uses sensory input and constructs meaning out of it.
b. People learn to learn as they learn: learning consists both of constructing meaning and constructing systems of meaning.
c. The crucial action of constructing meaning is mental: it happens in the mind. Physical actions, hands-on experience may be necessary for learning, especially for children, but it is not sufficient; we need to provide activities that engage the mind as well as the hands. (Dewey called this reflective activity.)
d. Learning involves language: the language we use influences learning.
e. Learning is a social activity: our learning is intimately associated with our connection with other human beings, our teachers, our peers, our family as well as casual acquaintances, including the people before us or next to us at the exhibit.
f. Learning is contextual: we do not learn isolated facts and theories in some abstract ethereal land of the mind separate from the rest of our lives: we learn in relationship to what else we know, what we believe, our prejudices and our fears.
g. One needs knowledge to learn: it is not possible to assimilate new knowledge without having some structure developed from previous knowledge to build on. The more we know, the more we can learn.
h. It takes time to learn: learning is not instantaneous.
i. Motivation is a key component in learning.

3.2. Integration of 3D virtual learning environments and constructivist learning theory

The relationship of 3D learning environment to constructivist learning theory is that the theory provides a theoretical analysis for designing immersive 3D learning environment[16]. Two aspects can be discussed in detail. One is related with assumptions that constructivism founded, the other is related with three principles of constructivist view learning.

(1) Two assumptions presented by constructivism
Knowledge is constructed through social negotiation and reality is partly subjective (we all experience the same world but interpret it on the basis
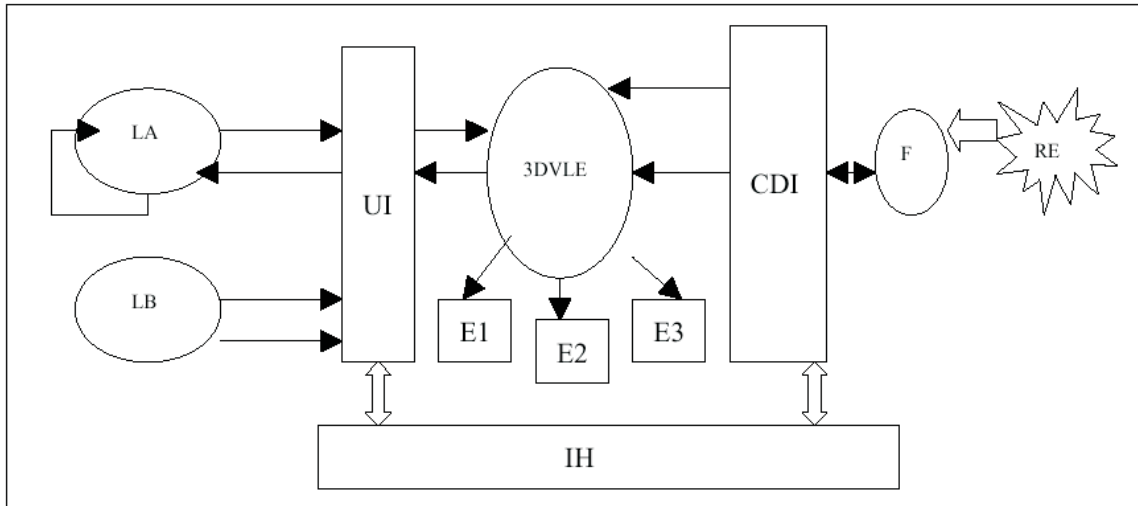
Figure 1: *3DVLE Learning Scheme.*

of our own knowledge and beliefs)[8]. From these two assumptions, we can see constructivism related with 3D virtual learning environment in a fundamental way. The learning that occurs in 3D virtual learning environment is qualitatively experiential and direct. Immersive 3D virtual learning environment allows first person experiences by exploring the learning environment. Assumption aspect shows the key to the compatibility of 3DVLE with constructivism lies in the notion of immersion. Immersive virtual learning environment allows first person experiences by removing the interface between the computer and the user. It also allows the user to learn through interactions with the virtual environment and it is through the interactions that the knowledge is formed[17].

(2) Three principles of constructivist view learning

Three interpretations of constructivism identified by Moshman(1982), namely, endogenous, exogenous and dialectical constructivism were adapted as pedagogical theories.

Endogenous constructivism represents a learning paradigm that begins with the learner's internal cognition, shapes and understanding of the external environment through that mental lens. This view of constructivist learning has many implications for instructional design, methods of delivery, and assessment of learner's accomplishment. Endogenous emphasizes the individual discovery of knowledge through learner's engaging in an active exploration process. Barney Dalgarno[3], figures out two ways of designing endogenous constructivist learning environment. One is 3D simulation in-

cluding simulations of the observable world and simulations of abstract concepts. Another is interface to a complex information space.

Exogenous Constructivism emphasizes individual reconstruct outside reality by building accurate mental representations that reflects "the way things really are" in the external world. In 3D virtual learning environment, we can design a direct instruction to help learner form mental model of the knowledge representation. Instructional resources used in 3D virtual learning environment could be embedded within a tutorial guider (teachers physically instead). The learning tools designed in environment help learners develop an understanding of abstract concepts such as mathematics concepts, micro-chemical concepts, etc.

Dialectical constructivism is an interaction between learners and their environments. This perspective on learning is often associated with contextualism where thought and experience are inextricably intertwined with the contexts or settings where learning occurs (Bruning, Schraw, Ronning, 1999, P.217). Co-operation in 3DVLE provides a learning task in a shared environment to allow learners learn together. Additionally, tutor in 3D environment stands for a group leader to provide support to other learners.

3.3. 3D Virtual Learning Scheme

Based on above constructivist learning theory, we put forward our learning scheme. Figure 1 shows our 3D virtual learning scheme.

LA learner A

LB learner B
UI User Interface
3DVLE 3D Virtual Learning Environment
CDI Courseware Design Interface
CD Courseware Designer
IH Instructional Hint

3DVLE is the core factor of our learning mode. Learning resources in 3DVLE can be divided into several entities.

Realistic entities: Models are created according to the real objects in the world, such as trees, buildings, chemical medicine, machines etc.

Abstract entities: Models are created by peoples' understandings, such as objects in micro-world, objects in cosmic-world, objects that can not be touched.

Artistic entities: Models are created in an artistic ways to reveal the internality of objects, such as vivid mathematic objects in Cybermath.

Simulated entities: Simulated entities include simulation in observable world and simulation of abstract concepts. Simulation entities reveal a realistic context in which learners can explore and experiment, and with these explorations learners can construct their own mental model of the learning resources.

Information entities: Entities such as illumination, courseware instructional information, and personal assessment.

Learning or designing flow can be achieved by following steps:

1. Start to learn interact with UI
2. Request exploring learning resources
3. Get needed learning resources from 3DVLE
4. End learning action online
5. Establish meaning in metal brain
6. Co-operation with other learners
7. Synchronization with other learners
8. Analysis Teaching Target
9. Designing 3DVLE with CDI
10. Upload 3D environment
11. Upload Hint Information
12. Get instruction from IH
13. Get instruction from IH

Learning part in Figure 1 shows 5 steps of completing a learning process. It starts with learners' intension to learn and ends up with establishing meaning in learners' human brain. This learning mode supports co-operative learning mechanism. Several learners organized in a group can use communication tools such as chat, sound, whiteboards etc to explore the shared learning environment in synchronization. Course designing part shows if courseware designer have got a clear teaching target (through a lot of analysis such as what he teaches, where he teaches, whom he teaches, which kind of way he teaches etc), he can design the courseware by himself. That means, the learning mode should provide a common Courseware Designing interface defined by

CDI in Figure 1. According to exogenous constructivism, in a problem-based learning environment, learners rely much on instructional hints to complete their learning process. Instructional hint designed in IH help learners in several ways. Also, agent-based hint system implemented for the needs of learners' individual mental model and learning activity.

4. Implementation of active 3D learning platform

Based on the design consideration discussed above, we have built our prototype system, which is called Collaboration Virtual Learning Environment (CoVLE).

(1) System overview
CoVLE is a web-based system developed to provide an active 3D learning platform. It supports active learning process, text-based communication, white board as a shared space, collaborative mechanism, friendly user interface and learning tools. It was designed to build an online 3D learning database in our college. Students can choose some courses and carry out their leaning processes aided with learning tools which is provided by our platform. Teachers can use the platform to design specified course ware such as some experiments in books like *Data Structure*, *Operating System*, *Computer Graphic*, etc.

(2) System Architecture
HIE-VLE is basically a C/S based 3D virtual learning system. Figure 2 shows the system architecture.

The client side includes: Graphic Show System uses VRML browser plug-in such as (CortonVRML4.0, Blaxxun Contact, Cosmoplayer and so on) or Java applets displaying subsets of VRML97 such as (blaxxun3d, IBM Hypermedia, Cortona Jet, Shoud3D, etc). Java Graphic Interface is a human-machine interface designed according to constructivism learning tool kit, which includes personal Information, upload resource, course maker, course modify, learning course, 3D chat room, shared whiteboard etc. Communication tool support synchronized message delivering. Event Dispatcher dispatches all the request events to server (such as request for login, request for download resource, request for synchronization) or get event from serve (such as get user information, get resource etc). System protocol is a TCP/IP based to support negations between clients and server.

The server side includes application server and resource database. Application server includes System Protocol, Event Dispatcher and Divided Server. SP in server side is consistent to client side. The different function between client ED and server ED is that the former is single thread while the later is multi-thread. Divided server includes Web server responsible for doing HTTP or FTP like event; VRML world server responsible for calling or changing certain 3D virtual learning environment; instructional hint server responsible for helping learners complete the learning process successfully and for giving assessment and collaboration mechanism which supports learners cooperative learn-
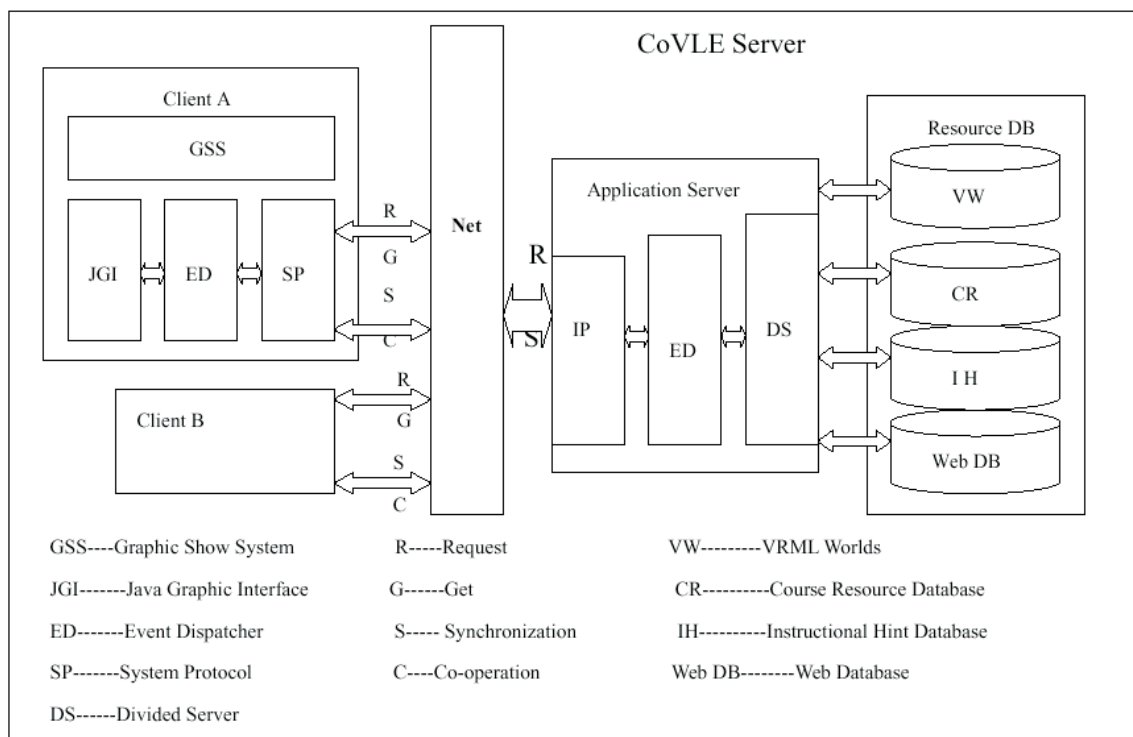
Figure 2: *Architecture of CoVLE.*

ing process, such as doing group meeting, carrying out chemical experiments, etc. Resource Database, divided into four different databases, includes all the resources required in system, such as images, flash movies, sound, etc.

(3) Implementation Considerations
a. Modeling of the virtual learning environment
Two main problems should be considered for modeling the virtual learning environment. One is how to get small size files of VRML. The other is how to simulate realistic learning environment. Combining VRML with 3Dmax modeling tools is an effective way in practice. VRML is a good tool for constructing, distributing, and rendering 3D objects over the Internet. And VRML provides programmers a variety of nodes such as the interaction, animation, and sensor to serve different purpose. With external nodes, we are able to create special objects. 3DMax is used to model complex realistic objects and the models should be optimized before exporting VRML files. Environment construction is based on coordinates since points in 3D models are presented by a group of space coordinates like (x, y, z).

b. Level Of Detail (LOD) for Real-time Walkthrough
In order to accelerate rendering speed in real time walkthrough, we employ LOD to optimize VRML files. LOD is a system feature for optimizing the amount of details rendered in a scene. There are three general rules used in determin-

ing whether LOD should be applied to a graphical object: 1. The object appears to be small in the scene. 2. The object is moving within the scene, or 3. The object is in the observer's peripheral vision. In these types of instances, better use of memory can probably be made through the reduction of object LOD. The goal to optimize VRML files is reducing the number of polygons in each level to simplify models. Four different ways is used to reduce polygon count:

- Remove hidden polygons: This is especially important for interiors of the models, such as the floor and any interior walls.
- Make the model more 2D rather than 3D: As the distance to a model increases, it becomes harder to distinguish depth, so 2Dversions of a feature can stand for 3Dversions.
- Replace complex shapes with simple outlines: Complex polygons or multiple polygons can be replaced with simple polygons.
- Use textures to replace detail: Many modelers use this technique; make the most complex version of the model first, then take screen shots to make an image file. These images can then be used to make lower levels of detail[18].

VRML provides an LOD node, which can be explicitly change different level detail version of model.

```
LOD{
```
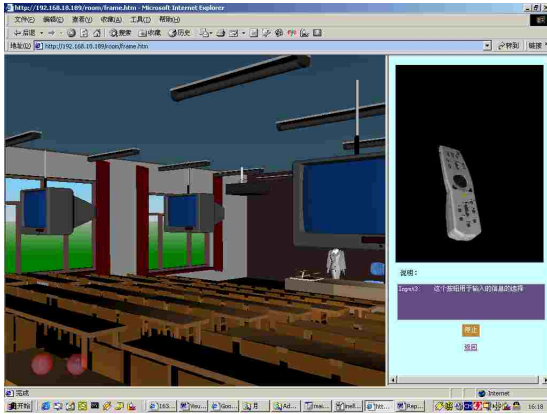
Figure 3: *Virtual Multimedia Room Device Demo.*

Figure 4: *Computer Assemble and Dissemble Training.*

```
   exposedField   MFNode     level{}
   field          SFVec3f    center 0 0 0
   field          MFFloat    range {}
}
```

The value of level specifies a sub-node list in a group. The first sub-node provides the highest level, and the last provides the lowest level. Center domain specifies the coordinates of the LOD model. Range domain specifies the different level distances from user to the model. For example, range 100,200 means that the highest level will be rendered in a distance (d<=100), the medium level will be rendered in a distance (100<d<=200) and the low level in a distance (d>200).

c. User Interface and Dynamic control

User interface supports two kind of learning method, individual learning and cooperative learning. In individual learning, learners first download 3D environment and other basic material, then he/she can browser the learning resource,

Figure 5: *Figure 5 Virtual Device Operation .*

and explore the virtual learning environment with navigation tools. At the same time, learners can interact with the environment, ask some question to or answer the questions from system. In cooperative learning, learners are in groups. They communicate with each other by communication tools to solve the problem. Figure 3 shows an example of device operation show demo. Learners can see the operation flow of projector remote control. Figure 4 is a training course for computer assembling and dissembling. In this course, learners will learn how to assembling and dissembling the different parts in a computer mainbox(such as power, mainboard, RAM, CD-ROM, CPU etc).

Virtual Reality Modeling Language(VRML)[19] provides two external programming language: VRMLScript and JAVA/JAVAScript[20]. The integration of VRML and Java language gives a patterned portable and independent way of console for representing three-dimensional dynamic and interactive scenes for Internet. Java doesn't have a standard library of routines that allow such communication between a Java Application and VRML virtual environment. However, such interaction can be done by an external interface called External Authoring Interface (EAI)[21]. EAI are encapsulated in JAVA classes. EventOutObserver interface encapsulated in JAVA is responsible for sending the EventOut changed event to JAVA applet, and EventInXXX classes are responsible for sending the eventIn to VRML Script node. Through this mode, JAVA applet can communicate with 3D VRML environment. Figure 5 is a subproject in process called Virtual Campus. Students can login into the virtual campus, and

each one will be presented as an avatar. They can talk and do some gestures such as laugh, nod, dance etc. Figure **??** shows a user interface for simulating device operating flow. Both cases use JAVA, EAI and VRML.

d. Communication mechanism

In a C/S mode communication system, the accomplished communication is restricted to communication based in sockets (classes ServerSocket and Socket) and threads. The user, through the browser Web, request connection to a server that is executed in a determined host. A connection confirmation message is sent if the server is running correctly, and then the client applet invokes an event to the server in order to be processed. The event is in a way consistent to system protocol (in terms of eventID). The server receives the eventID and sends it to event dispatcher. Later, the application server responds to the client applet according to the eventID. By the moment the client establishes a connection to the server, a new thread is created to serve such a client and the new client's information is also sent to other clients, such as clientID, user information etc. If other clients receive information, they will update their status.

e. Shared Objects

There are various kinds of interaction among shared objects and participants in learning environment. Sometime, one simple interaction between an avatar and an object may cause very complicate chain-reactions in the world. It is necessary for program at server site to manage each shared object, store their states, and authorize their control rights to clients. In HIE-VLE, we implement lock method based on timestamp. If the status of shared object is locked that means it cannot be operated because other client is operating this shared object. If the status is unlocked, any client has the right to request for operating it. There is also a potential danger to be in the Şdeadlock state. This indicates that shared objects cannot be operated forever. This is because the client who is operating the shared object is thrown by error exception, but the client doesn't give up his or her right. We define a maximum timestamp to hold right to operate shared objects. If the timestamp is over, any client should give up its right. This method can avoid deadlock.

5. Conclusion and Future work

Virtual Reality has brought new concepts and new methods into the world of designing learning approach between users and virtual learning environment. Constructivism as a philosophy of learning, provides a theoretical analysis for designing immersive 3D learning environment. This paper discusses these two main aspects and explored theoretical literature about constructivist learning and its relationship with 3D virtual learning environment. It put forward the idea that 3D virtual learning environment is an effective way to improve the feasibility of implementing constructivist learning theory in distance education. It also provides a learning and designing mode on Web-based system. And we introduce

our 3DVLE system, explain system architecture and some implementation considerations, including object modeling, LOD techniques, man-machine interface, dynamic control, communicate mechanism and shared objects.

In the future, there are some problems we want to resolve. For instance, how to elaborate and refine the system modeling and system design, how to realize systematic framework based on programming, and how to use standard way to analyze constructivist information, etc. At present, we are designing collaboration learning tools to help students explore learning environment together (such as shared 3D computer graphic knowledge museum). At close hand, we will add avatar control to our system, and still we hope we can design a common agent to help students when they are in learning process.

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