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ABSTRACT

This document contains the full text of the following full and short papers on virtual reality in education from ICCE/ICCAI 2000 (International Conference on Computers in Education/International Conference on Computer-Assisted Instruction): (1) "A CAL System for Appreciation of 3D Shapes by Surface Development (C3D-SD)" (Stephen C. F. Chan, Andy Wai, Jean Chow, and Vincent T. Y. Ng); (2) "A Case Study of Creating Geochemistry Lab of Virtual Reality in Education" (Fung-Chun Li, Jer-Yann Lin, Shyhh-Jiung Liu, Shih-Hua Hsu, Chau-Rong Tarng, Chan-Fu Yieng, and Tzong-Yiing Wu); (3) "A Virtual Reality Application for Middle School Geometry Class" (Ki-Sang Song, ByungRae Han, and Woo Yul Lee); (4) "Constructing a Real-Time CAD Learning System Based on OpenGL in Web-Based Environment" (Wen-Chai Song, Shih-Ching Ou, and Song-Rong Shiau); (5) "Designing Extensible Simulation-Oriented Collaborative Virtual Learning Environments" (Yam San Chee and Yong Bing Khoo); (6) "The Effect of Virtual Reality Learning Transfer with Different Cognitive Style" (Jia-Rong Wen and Li-Ling Hsu); (7) "Using Virtual Environments for Studying Water Phases and Phase Transitions" (Jorge F. Tindade and Carlos Fiolhais); (8) "Using Virtual Reality Courseware To Enhance Secondary School Student Learning in Geosciences" (Hsiao-Shen Wang and Jyr-Ching Hu); (9) "WALTZ: A Web-Based Adaptive/Interactive Learning and Teaching Zone" (Long-Chyr Chang, Heien-Kun Chiang, and Pi-Shin Wey); and (10) "Web-Based Subject-Oriented Learning Program on Geophysics for Senior High School" (Rong-Kuan Yang, Yi-Ben Tsai, and Shi-Jen Lin). Abstracts of the following papers are also included: "Strange Creatures in Virtual Inhabited 3D Worlds" (Jens F. Jensen) and "Virtual Inhabited 3D Worlds and Internet Based Learning Environments" (Jens F. Jensen). (MES)

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A CAL System for Appreciation of 3D Shapes by Surface Development (C3D-SD)

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A web-based Computer-aided learning system for 3D - Surface Development Module (C3D-SD) has been developed for teaching the appreciation of 3D geometric shapes by unfolding the surface boundary of a solid object into a planar 2D pattern. The problem is similar to the problem of surface development in technical drawing and highly related to the reverse problem of folding a 2D shape into a 3D object, with practical applications in sheet metal work, pattern making, and packaging design. C3D-SD makes extensive use of animation, interactive control by the student, and quizzes to present the material and to engage the students. It makes use of the solid modeling library SML to create 3D solid shapes by Boolean combinations (union, intersection and difference) of primitive shapes, and Java3D for rendering and animation. It includes a Packaging Design Module which builds on the Surface Development module by automatically adding flippers and minimizing the rectangle enclosing the unfolded pattern. This system is the second installment of a series of CAL systems for Three-dimensional Geometry that the authors have been developing.

Keywords: **3D geometry, surface development, animation**

1 Introduction

Surface development is an important technique in design. Generally it involves unrolling a curved surface into a planar 2D pattern. Theoretically speaking only certain classes of surfaces are "developable" [Carmo 1976]. If, however (as is the case in many computer graphics systems), curved surfaces are approximated by sets of planar facets, then all curved surfaces can be unfolded into 2D planar shapes, although they may appear to be "unnatural" or "ugly". A related problem is the unfolding of the planar faces bounding a facetted solid object into a planar 2D shape. The inverse of the problem is folding a planar 2D shape into a 3D object, e.g., folded the card-board boxes for hamburgers in fast-food restaurants. These techniques have practical applications in sheet metal work, pattern making, packaging and package design, etc. [Giesecke et al 1997] This paper describes the development of a Web-based computer-aided learning system for teaching the appreciation of surface development/unfolding based on a polygonal representation of solid objects. It is a part of a series of Web-based tools for teaching 3D geometry that our group has been developing. A previous project focussed on sectioning and interactions between some primitive solid shapes was reported in [Chan et al 1999].

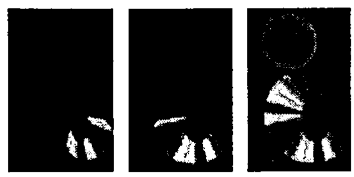
Traditional teaching materials on these topics were mainly text based. Better materials have graphics or charts in addition to plain texts. In presenting descriptive topics, this approach is adequate. However, in teaching three-dimension geometry, the two-dimensional and static presentation style is obviously not enough. The use of videos can be effective to some extend but it is still one-way communication and not interactive. A more effective alternative is to use real solid objects to help students visualize 3D shapes. But some objects are difficult to be made, and it is impossible for teachers and students to change the size, scale, shape or appearance of the object quickly.

In contrast to the limitation of 2D materials, videos and real 3D objects, a virtual environment can be a better approach in presenting certain 3D geometry problems. A virtual environment is a computer-generated environment in which 3D or even the forth dimension (time) can be presented through animation. Within the virtual environment, one can change the size, scale, shape or appearance of the virtual object interactively. To have a clearer look, one can zoom into the object. To see the inner structure, one can set part of the object

to be transparent. And geometry can be animated by transforming the object over time. And of course, an interactive teaching approach is much better than one way communication in enhancing student understanding. Finally, for purposes of accessibility and distribution, the Web is the ideal environment. These considerations drove the development of this project.

2 Overview of C3D-SD

The main problem tackled by C3D-SD is surface development, as illustrated below in Figure 1. In (a) is shown a solid cone shaped object with the top cut off at an oblique angle. In (b) the surface of the cone is in the middle of being unfolded. In (c) the unfolding is complete. Note that we had tried to keep the unfolded 2D shape connected. As a result, the curved conical surface itself became disconnected (actually connected through a single vertex). It is not difficult to see that it is possible to unfold the surface while keeping the curved conical surface connected.



(a) (b) (c)
Figure 1. Surface development in action.

C3D-SD is organized into three types of activities:

1. Tutorials - Students are guided through demonstrations, including: matching 3D solids to unfolded shapes, animations of unfolding (e.g., of the conical object in Figure 1), animations of folding 2D patterns into 3D solids, adding flippers to unfolded 2D patterns for fastening, reducing the size of the rectangle bounding the unfolded pattern, etc.
2. Free-form exercises - Students are allowed to explore the teaching material on their own. They are provided with numerous opportunities to interact with the teaching material, e.g., creating complex 3D solids by combining primitive shapes, selecting view points, putting different textures on objects, controlling the animation process, etc. The problems are similar to those presented in tutorials. But many more shapes are available for students to experiment with, for self-guided exploration and exercise.
3. Tests - Students can test their understanding of the material through multiple-choice tests. They are asked, e.g., to match an unfolded 2D shape with the solid object, such as illustrated below in Figure 2. If so desired, they can turn to the free-form exercises to explore the test shapes that they have problems with.

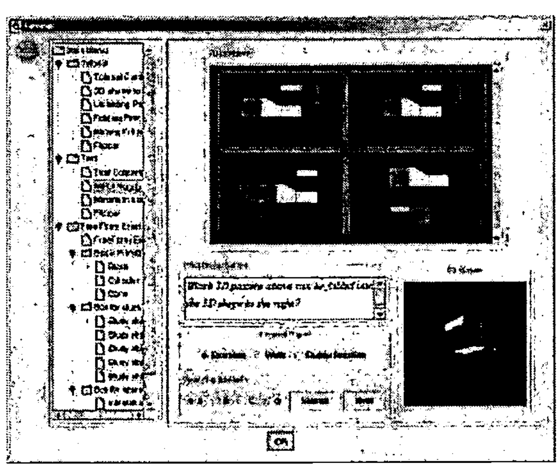


Figure 2. Sample multiple choice question.

The three types of activities are chosen for the following reasons. The tutorials provide core contents to be imparted to the students. The free form exercises allow the students to explore the subject on their own.

Different students with different backgrounds and learning styles benefit from different learning activities, hence both guided and sef-guided types of activities are provided. Finally, tests are developed to gauge the students' grasp of the material. It is expected that C3D-SD can be integrated with an intelligent tutoring system to provide a learning experience more tailored-made for the individual students.
C3D-SD focuses on five types of problems:

1. Matching 3D solid shapes with the corresponding unfolded 2D patterns.
2. Unfolding the surface boundary of a facetted solid and developing curved surfaces.
3. Folding 2D patterns into 3D solid shapes.
4. Simple packaging design: Adding flippers to the unfolded 2D pattern for fastening.
5. Simple packaging design: minimizing the rectangle bounding the unfolded 2D pattern.

3 The 3D Solid Design Module

Java was chosen to develop this system as it is a web-oriented development language and only a Java-enabled Web browser (e.g. Netscape, Microsoft Internet Explorer) is needed to access the Web pages without installing other plug-ins. However, it is difficult to build 3D applications using only the core Java classes. A Java-based high-level programming library, Solid Modeling Library (SML) [Chan et al 1998] is used in C3D-SD for designing 3D solid objects. SML supports the building of 3D solid objects through a set of atomic functions called Euler operators. These functions allow the incremental manipulation of Boundary Representation (B-rep) models, while processing the underlying well-formed data structure. It also supports the creation of solid primitives (block, cylinder, cone, sphere, torus) and Boolean operations (union, intersection, and difference) on solids and transformations (translation, rotation) of solid objects for easy creation of complex 3D solid shapes. For example, a hollow pipe can be created by the differencing (subtracting) a smaller cylinder from a larger cylinder. SML uses a hierarchical half-edge data structure that stores rich information about a solid model [Mantyla 1988], including solid-to-face, face-to-face, face-to-edge, edge-to-edge, edge-to-vertex, and vertex-to-vertex information. The data structure used in SML to represent the surface boundary of solid objects is illustrated in Figure 3.

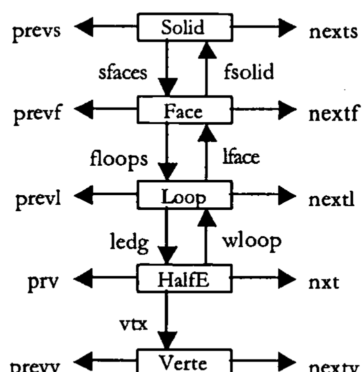


Figure 3. Hierarchical half-edge data structure of SML.

4 Surface Development

The process of surface development or unfolding is illustrated in Figure 4 using a cube as an example. Each face of the cube is coloured differently for easy identification. One might imagine that the unfolding starts by holding the bottom (red) face of the cube fixed to the horizontal plane, and rotating the rest of the cube about the edge linking the red face with the green face until the green face is in the same plane as the red face. This is followed by the blue face, then the yellow, then the light blue, .., and finally the purple, until all faces lie in the horizontal plane.

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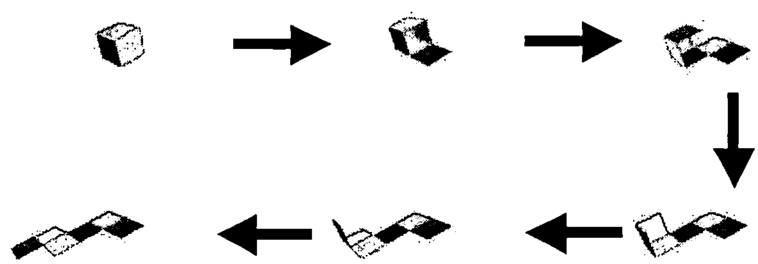


Figure 4. Unfolding a cube.

Sun Microsystems provides the Java3D application programming interface (API) which can be used to develop three-dimensional graphics applications and applets. It gives developers high-level constructs for creating and manipulating polygon-based 3D geometry and for constructing the structures used in rendering that geometry [Sowizral et al 1998, Sun 2000, Brown & Peterson 1999]. It is an object-oriented API, which can be used to construct individual graphics elements as separate objects and connect them together into a tree-like structure called the scene graph. It contains a complete description of the entire scene including the geometric data, attribute information and viewing information needed to render the scene from a particular point of view. Java3D provides a simple and flexible mechanism for representing and rendering scenes with lighting effect but it does not provide high-level construct for creating complicated solid object models. Hence SML was used to create the 3D solids which are subsequently converted into Java3D for rendering and animation.

4.1 Conversion from Solid (in SML) to Surface (in Java3D)

Each face object in SML is converted into a Java3D geometry object by using the information on the vertices of the face. As a result a SML solid object is converted into a group of Java3D geometry objects, each representing a face as illustrated in Figure 5. However, the data structures used to represent objects in Java3D and SML are different, and a conversion process is required to integrate the two systems to take advantage of their respective strengths to produce a more complete solution.

The displayable object in Java 3D is implemented by the Shape3D class. The Geometry and Appearance objects make up a Shape3D object. The Appearance objects controls the outlook of an object, e.g. color, material, etc. The Geometry object contains the vertexes information. We choose triangle as the basic shape in forming a geometry object because it contains the minimum number of vertexes that can form a plane. So that any face shape can be formed by the combination of triangles.

The conversion of an object represented in SML to one represented in Java3D involves 4 steps. Recall that each face in a SML Solid is converted into a Geometry object in Java3D.

1. Find the number of faces in the SML Solid object.
2. For each face, find the number of vertexes and the coordinates of each vertex.
3. Group three vertexes into a triangular strip.
4. Combine all triangular strips to form a Geometry object in Java3D.
5. Each Geometry object will result in a Shape3D object.
6. Group all Shape3D objects to form the representation of the solid in Java3D.

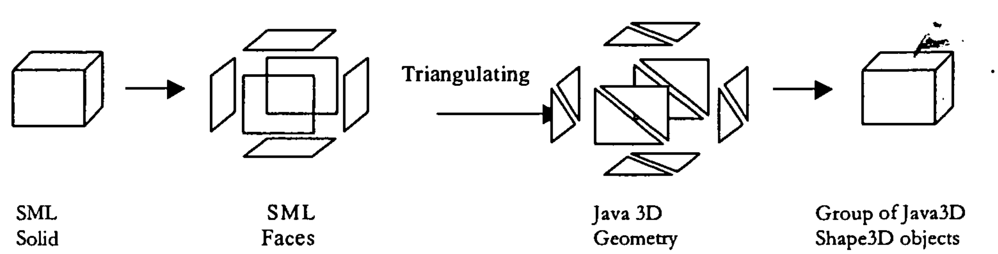


Figure 5. Converting an object from SML into Java3D.

4.2 Unfolding Path

In order to "develop" a surface approximated by a set of polygons, or to unfold the boundary of a solid, one needs to determine a connected path traversing all the faces one at a time. The path for unfolding can be

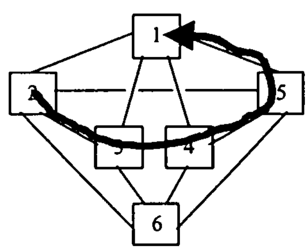
1. specified manually by the student,
2. pre-set in CAL-SD manually by the teacher, or
3. determined automatically by CAD-SD.

Automatic determination of the path for unfolding involves two steps:

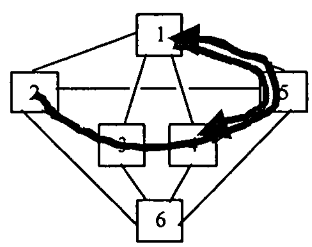
- Determine the connectivity between the faces, e.g., in the form of a **graph** whose nodes are the faces, and an edge links a pair of neighbouring faces, and
- Traverse the graph to find the desired connected **path**(s) that visits each face one at a time and each face only once.

As the data structure of SML stores rich information of the complete solid, the connectivity relationships between faces can be easily derived. To derive the path(s) of traversing all faces one and only one at a time is a version of the traveling salesperson problem [Johnsonbaugh 1996]. It is a problem that is known to be hard (computationally expensive) for arbitrary graphs. In our system prototype, we chose to use exhaustive search because of its simple implementation. In future versions we may try to find a more efficient algorithm. In the default version of the algorithm, we simply try to find a solution (any solution) using the well-known **backtrack** algorithm. Firstly, pick up a face arbitrarily. Then, traverse to one of its neighbors. Repeat this process until all the faces have been visited. When a dead-end occurs, it will back track one or more steps to find another possible way (Figure 6). Dead-end means arriving at a face with no un-visited neighbours, while there are still un-visited faces remaining in the graph.

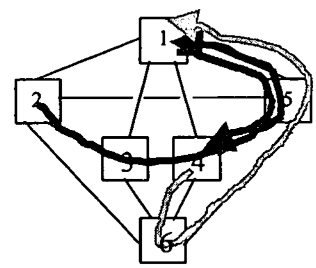
The algorithms implemented in C3D-SD so far traverse the faces of an object in a linear sequence, i.e., the unfolded faces form a linear chain of planar polygons. There are other alternatives, e.g., unfolding in two directions at the same time, resulting a Y shaped chain of polygons, etc. In future versions of the system, we will implement other unfolding algorithms.



(a) Dead-end occurs when traversing 2 ⇨ 3 ⇨ 4 ⇨ 5 ⇨ 1



(b) Backtracking from dead-end to face 4 to find another possible path



(c) Path 2 ⇨ 3 ⇨ 4 ⇨ 6 ⇨ 5 ⇨ 1 is one of the possible paths traversing all the faces one and only one time

Figure 6. Finding a possible path for unfolding the faces of a solid.

4.3 Heuristics for Developing Smooth Surfaces

In SML and in Java3D, as in many computer graphics systems, a curved surface (e.g. conical, cylindrical, etc.) is approximated by a set of planar polygons. If we choose a face's neighbor in an arbitrary way, a solid may be unfolded into an "ugly" or "unnatural" shape because the set of polygons used to approximate a smooth surface my or may not be unfolded (smoothly) in an appropriate sequence. The left side of Figure 7 shows a cylinder approximated by a total of 22 plane faces (20 for the curved surface and 2 for the top and bottom faces). If we unfold the cylinder arbitrarily, for example, following the path 1-2-3-...-21-22, may result in the patter in the middle. One of the polygons in the set used to approximate the curved cylindrical surface is disconnected from the other polygons in the set.

We observe, however, that in the set of polygons approximating a smooth curved surface, each polygon shares at least one edge with another polygon in the set, and the included angle between the two polygons is very close to, but just slightly less than, 180 degrees. Taking account of the Smooth Surface Heuristics discussed above, we can try to select the neighbor making the largest angle with the current face, instead of selecting an arbitrary one. Applying this heuristic to the unfolding of the cylindrical solid will result in the developed surface to the right.

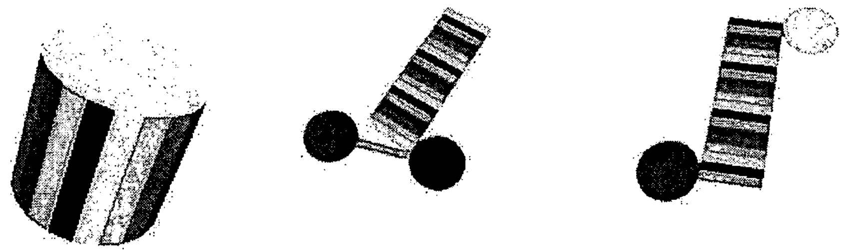


Figure 7. Arbitrarily unfolding the cylinder to the left may result in the pattern in the middle, and applying smooth surface heuristics will result in the pattern to the right.

5 Partially Automated Packaging Design

The design of packaging such as the rectangular boxes used to hold hamburgers at fast food restaurants involves the design of the 2D patterns that can be folded into such boxes. Similar problems exist in sheet metal work and other areas. The surface development/unfolding algorithm discussed above can be used to partially automate such designs.

5.1 Addition of "Flippers"

In addition, one also need to add "flippers" to some of the faces. Flippers are extended faces for putting glue or stickers in order to fasten two faces together when folding the planar 2D shape into a 3D solid shape. We have developed a simple algorithm to determine which edges of the faces of a solid model need to have flippers added. As flippers are used in connecting neighbouring faces, basically, all edges around a face need flippers except:

1. Edges that have been used as axes of rotation during the process of unfolding, i.e., edges between consecutive faces in the connected path for unfolding (in Figure 8)
2. Edges for which flippers have already created on the opposite face (in Figure 8)

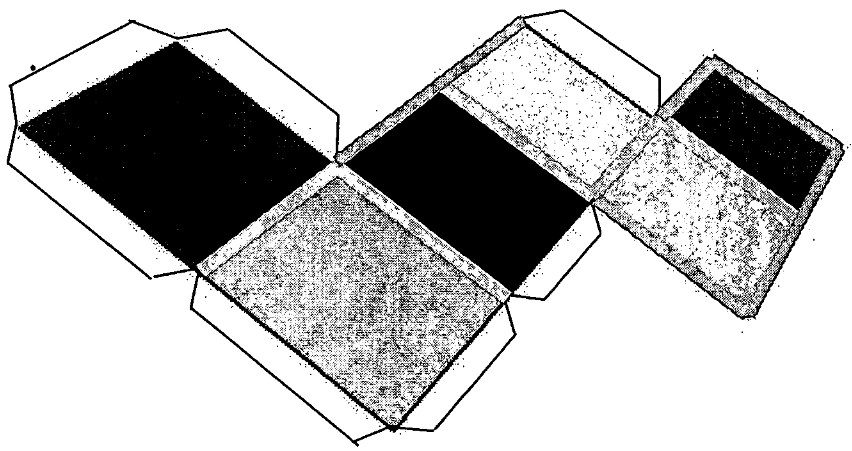


Figure 8. Creation of "flippers" in partially-automated design of packaging.

5.2 Minimizing Bounding Rectangle

The unfolding of 3D shapes are often constrained by certain requirements. For example, in the design of

packaging or sheet metal work, the unfolded shape may be the pattern to be cut out of a rectangular sheet, to be folded into the solid shape. In such cases it is desirable to reduce the amount of wastage by making the rectangular sheet required as small as possible. This translates into a requirement to minimize the area of the smallest rectangle enclosing the unfolded planar shape, as illustrated in Figure 9. Smallest rectangle enclosing the unfolded 2D shape. Such constraints may not be easy to satisfy absolutely. However, it is often enough to find a reasonable but not necessarily the perfect solution. In the case of determining a minimum bounding rectangle, it may be sufficient to find a local but not the absolute minimum. A local minimum can be determined by backtracking a few steps from the solution found to determine the set of related solutions and choose the one with the smallest bounding rectangle.

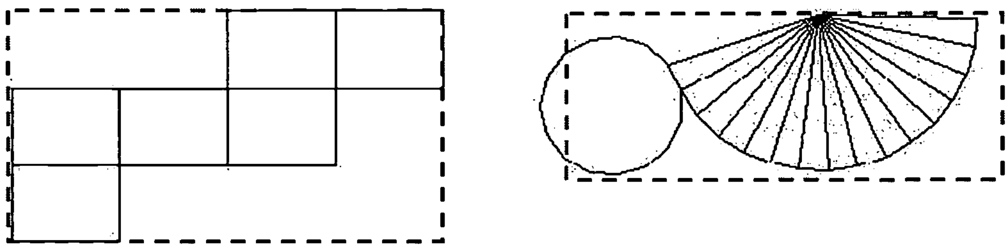


Figure 9. Smallest rectangle enclosing the unfolded 2D shape.

5.3 Some Examples Used in CAD-SD

Many examples of realistic solid shapes have been built into CAD-SD for illustrating and teaching surface development. Figure 10, Figure 11, and Figure 12 show the results of unfolding some common solid shapes, with "flippers" added automatically. For simple solid shapes it is fairly easy to deduce from the unfolded 2D patterns what the original 3D solid shapes are. Some of these are given to the students as exercises.

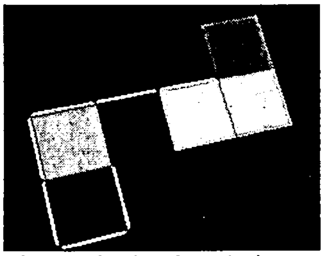


Figure 10. The 2D shape that results from unfolding the cube in a sequence different from that shown in Figure 8. Creation of "flippers" in partially-automated design of packaging., also with flippers added.

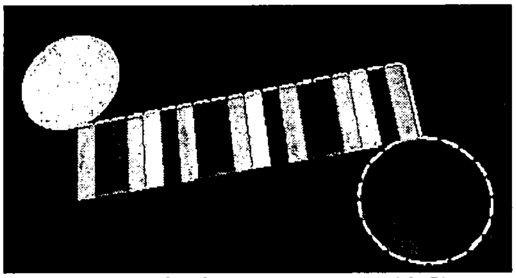


Figure 11. The result of unfolding a cylinder, with flippers added.

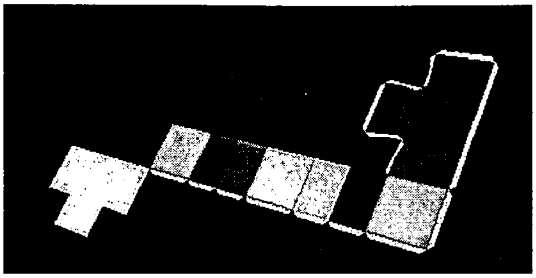


Figure 12. The result of unfolding a T-shaped box, with "flippers" added.

6 Conslusion

Using the SML solid modeling system and Java3D surface modeling and rendering system, we have successfully developed the basic structures of a CAL system that makes use of 3D modeling, animation, and interactivity to teach the appreciation of certain class of 3D shapes through surface development and unfolding. We have also shown how the unfolding algorithm can be used to partially automate the design of the 2D patterns used in certain sheet metal work and packaging design problems, by also automating the addition of flippers for attaching neighbouring faces, and reducing the rectangular sheet from which the planar (unfolded) patterns are to be cut out. Based on these basic functions, a comprehensive set of teaching materials can be developed to greatly enhance the degree and interactivity and effectiveness in the teaching of the appreciation of 3D geometry.

Acknowledgement

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References

[Brown & Peterson 1999] Brown, Kirk & Peterson, Daniel. *Ready-to-Run Java 3D*, Wiley, 1999.

[Carmo 1976] M P do Carmo. *Differential Geometry of Curves and Surfaces*. Prentice-Hall, 1976.

[Chan et al 1998] Chan, S., Ng, V., and Au, A.. "A Solid Modeling Library for the World-Wide Web", *Computer Networks and ISDN Systems*, Vol. 30, Issue 20-21, Nov. 1998, pp. 1853 – 1863.

[Chan et al 1999] Chan, Stephen, Lui, Kin Ming, Ng, Vincent & Chui, Raymond. "A Java-based Computer-Aided Learning System for 3D Geometry", *Proceedings, The 7th International Conference on Computers in Education*, Volume 1, November 4 – 7, 1999, Chiba, Japan, pp. 1010 - 1017.

[Giesecke et al 1997] Frederick E. Giesecke, Alva Mitchell / Henry Cecil Spencer, Ivan Leroy Hill / John Thomas Dygdon /James E. Novak with Shawna Lockhart. Technical Drawing, Tenth edition (p.626 - 640): Prentice Hall 1997.

[Johnsonbaugh 1996] Richard Johnsonbaugh. Discrete Mathematics, fourth edition (p.304 – 309, p.331 – 336): Prentice Hall

[Mantyla 1988] Martti Mantyla. An Introduction to Solid Modeling (p.161 – 174): Computer Science Press 1988

[Sowizral et al 1998] Henry Sowizral, Kevin Rushforth & Michael Deering. The *Java 3D API Specification*, Addison Wesley, 1998.

[Sun 2000] Sun Microsystems, Inc. *Java 3D 1.1 API Specification*, http://java.sun.com/products/java-media/3D/index.html, 14 April, 2000.

A Case Study of Creating Geochemistry Lab of Virtual Reality in Education

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Thanks to the financial supports of "Ministry of Education, Taiwan" and "National Science Council, Taiwan", we are building a preliminary geochemistry lab in education of virtual reality (VR). The mission of the Geochemistry Lab is to analyze and interpret the erosion history of upper Stream from the key elements (^{10}Be and ^{36}Cl) in the environment of Taiwan. Our lab's primary service is to the students of National Tainan Teachers College (NTTC). The lab is dedicated to the development of VR techniques for education. This study has tried to integrate the different domains of earth science, geochemistry, scientific education and information education. We have succeeded to make an integrated study in our Virtual Laboratory of Natural Science Education, NTTC, Tainan, R.O.C. We have made field investigations and collected 30 samples of rock from upper Tseng-wen Chi last summer. J-Y Lin, Liu S-J, Wu P-C and Chen H-P made Laboratory experiments. Li F-C, Yieng C-F, Wu H-T, and Tarng C-R created the lab of virtual reality in education. Yieng Chau-Fu has created six dynamic modules by himself for the VR experiments. Those modules of wrl files have simulated VR experiments and use AMS techniques to estimate the Beryllium-10 and Chlorine-26 in upper Tseng-wen Chi of Taiwan. This case study worked very well by means of virtual lab, experiment design, pretest and posttest. Let us understand that geochemistry lab of VR in education may assist students to learning with greater devotion and efficiency.

Keywords: **Virtual Reality, Virtual lab, geochemistry laboratory, Virtual Reality in Education, Accelerator Mass Spectrometry(AMS)**

1 Introduction and questions

Today, it is very popular and very important to reform education in Taiwan. It is a thousand pities that many education reformers neglect tools of learning and VR technology of teaching. All the earth-science professors of National Teachers College in Taiwan have the similar challenges that they must face every day. Problem is, they're facing them without adequate tools. We cannot talk about Taiwan Education Reforms (TEF) without talking about tools and technology. That's exactly what we're here to talk about in this special issue of virtual reality (VR): how VR technology will and can help us to reach our some goal of TER. Tools and technology in and of themselves are not a solution to TER. Although VR technology is only a tools and only a very small part of the TER. It's still a very interesting, very impressing and very efficient in future.

2 Plans and reasons for using virtual reality

We try to develop short, two-week, single unit courses on VR geochemistry lab. The VR sub-subject is called "Cosmogenic Nuclides Tell Erosion History of upper Stream in Taiwan". This strategy will introduce teachers and students to VR technology, allow them to get used to the VR equipment, begin to develop a feel for what works and what doesn't, and make both teachers and students aware of the limitation of VR. Let them understand that geochemistry lab of VR is very interesting.

Our long-range plan is to utilize the geochemistry lab of VR to provide enrichment and advanced courses to the students of NTTC, Taiwan.

What' s so special about Virtual reality (VR) in education? It' s their interactivity: You do something and the VR does something back (Thomas C.O' Brien 1994). Can VR play an increasing role in school? Can different students react to it in different ways? If there are different ways and reactions then understand the diverse reaction can help teachers tailor the instruction to individual students (Kathryn A.A lvestad 1994). We suspected that differences in student' s attitudes toward VR geochemistry experiment learning might underlie their different responses to using VR – and that their performance in the lab would be strongly influenced by the different learning ways each student approaches different learning tasks.

Is a Geochemistry Lab. of VR in Education a special kind of learning environment? Students work individually and intensively over a long period, doing the best they can with little or no assistance from teachers.

3 Main Tools of VR

VR equipment including World UP for Windows NT, VR Expert800 (Pentium • •••••• • •• •• • ••••MB DRAM, Graphic accelerator (64MB Texture Memory, 3000 MFLOPS Geometry Accelerator), PCI Bus System, Support OpenGL• HEDIA• Direct 3D Direct Draw), head mounted displays (HMDs), positional 3D trackers, data gloves, eyeglasses and VR software toolkits (home PC virtual reality software). Yieng Chau-Fu has created six dynamic modules.

•

4 Experiment in education (K.E.Chang, S.F.Chen, and T.C.Sung 1999)

Six dynamic modules have been created for the virtual lab. The virtual lab concept reflects an approach to designing educational activities. This experiment design allows learners to choose a particular module that interests them, and then provides links and makes a test or learning.

To test our hypotheses, we worked with 60 students who were randomly selected and had taken part in the geochemistry program of VR for at least two seminars.

- Subjects "Cosmogenic Nuclides Tell Erosion History of upper Stream in Taiwan "
- Experiment design: Our experiment employed a pretest-posttest control group design. Each class of earth science in NTTC was randomly assigned to one of the "VR" groups or "paper-and-pencil" group. Since subjects of the three groups might have different prerequisite abilities, their earth science achievement scores of last semester were used as covariates. The posttest scores were collected after the experiment and submitted to an analysis of covariance (ANCOVA).
- Materials and Techniques: 30 samples of rock was randomly collected by LI Fung-Chun, Tarng Chau-Rong and assistants from the upper stream of Tseng-Wen Chi. The Experimental Techniques of Laboratory can be divided 3 steps (unfinished). Step1, Chemical separation. Step2, Solid source mass spectrometry. Step3, Isochronal regression line fitting.
- Procedures:
  1. Use two methods of simple random sampling and stratified sampling to collect 30 samples of rock from the upper stream of Tseng-wen Chi.
  2. Make analyses in chemical laboratory.
  3. Create this geochemistry experiment of VR.
- Formal experiment: The next day after the subjects finished their formal earth science lessons, they worked individually with geochemistry laboratory of VR or with paper-and-pencil to construct the earth science concept about "Cosmogenic Nuclides Tell Erosion History of upper Stream in Taiwan", one dynamic module each time. Approximately an hour are needed to complete each experiment of module. Since there were six modules in the experiment materials, the formal experiment phase lasted for one week.
- Posttest: Immediately after the last formal experiment completed, the subjects were administered to take the earth science achievement test and answer the questionnaires for the posttest.

5 Result

Pretest scores were used as covariates to understand the potential differences of students' knowledge. The test of homogeneity of regression showed that the homogeneity of regression of the two groups were not different (F=0.01, P>.05). The posttest scores of one experimental group (geochemistry experiment of VR) and one control group (paper-and-pencil group without VR) were significantly different (F=4.01, P<. 05). The posttest scores of two groups were different. Why so? We think that the geochemistry experiment of VR can see visions of 3D and can revolutionize our approach to the central aspect of education: student's learning. Some of our students clearly were more comfortable in the geochemistry lab of VR than others. From this study, we understand that VR in education may assist students become more self-reliant and more willing to accept challenging material and work out of curiosity and interest. Using VR to bring out these qualities will go a long way toward fostering a new generation of students who are very interesting to learn.

Thanks to those supports of "Ministry of Education, Taiwan" and "National Science Council (NSC), Taiwan", this case study is very expensive. Ministry of Education gives us all the financial supports of software and hardware. NSC gives also us financial support and six assistants for those studies from 1997 to 2002 (NSC 86-2511-S-024-003-CL, NSC 87-2511-S-024-009, NSC 88-2520-S-024-002, NSC 89-2511-S-024-008, NSC 89-2515-S-024-002, NSC 90-2520-S-024-001 & NSC 90-2520-S-024-001). Their supports let this work with greater devotion and efficiency. Thanks a lot.

Reference

[1] • • • • • • • • • • • • •(1999) ASP • •ACP •103 • •SIM655 • • • • • • •

[2] K.E.Chang, S.F.Chen, and T.C.Sung (1999) Concept Mapping System with Scaffolding and Guided Learning, Computer-Assisted Learning Forum '99

[3] LI Yuan-Hui. (1976). Denudation of Taiwan Island since the Pliocene Epoch: Geology. 4, number 2, p.105-107.

[4] Steven A. Ackerman. (2000). University of Wisconsin, "Developing a Virtual Lab Using the World Wide Web" --http://www.geo.nsf.gov/ear/ehr_test/GEOEDU_Awards.html

A Virtual Reality Application for Middle School Geometry Class

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The traditional mathematics teaching method which mainly depends on verbal explanation with pen and paper sketches has severe limitations teaching abstract concepts of formal and axiomatic geometry concepts such as points, lines, planes, and solids. In communicating information regarding geometric figures, one drawing may be worth many hundreds of words, and therefore visualization aids for complicated three-dimensional (3-D) solid objects are greatly helpful for both teacher and students. In this paper, we describe the utilization of Virtual Reality Markup Language (VRML) to visualize 3-D objects in middle school geometric class via WWW in a networked environment and show its usefulness for both teacher and students. In class, teacher uses VRML objects and students have been allowed to explore these objects with the teacher's explanation using their computer. The test results between a class with VRML based teaching and a class that solely depends on verbal explanation show that the application of VRML based 3-D objects has a positive effect on students' learning.

Keywords: **Virtual Reality; VRML; Mathematics; Geometry; WWW**

1 Introduction

Among Euclidean geometry subjects, Euclidean plane geometry is the study of properties of various figures, and the relationship between the figures in a plane irrespective of the location of the figures [1]. In Korea, the middle school mathematics curriculum includes definitions of plane, identifying plane and solid figures, and learning about some of their properties. In geometry class, teachers present these subjects mainly depending upon pen and pencil through verbal explanations. However, most teachers experience difficulties to describe or illustrate some solid figures that lie in three-dimensional (3-D) space. Sometimes teachers try to use notes, books and anything that may be helpful for visualizing abstract concepts of plane, intersections, etc. This kind of approach may work in some cases, but, most of the time they experience the limitations to illustrate these concepts and thus, they appeal better class aid materials.

In communicating information regarding geometrical figures, one drawing may be worth several hundred words. And thus, if real objects or figures such as polyhedra and polygons are provided, and students are allowed to explore them in class, the physical reality of geometry figures may be greatly helpful for students to grasp the 3-D geometric concepts in detail. Unfortunately, providing objects with physical reality is not easy due to the difficulties in making such complex objects. Therefore, it is necessary to devise alternatives to provide these materials, and we believe that the computer and information technology can be used for this purpose.

As the document from the National Council for Educational Technology [2] suggests, information technology can be a very helpful means [3] of providing 'observing patterns' and 'working with dynamic images' [2]. To provide interactive and dynamic figures as a thinking aid for students [4], we need networked computing facilities and appropriately designed class materials.

With these in mind, we have applied the World Wide Web and the VRML based 3-D illustration technique to provide 'virtual reality figures and solids' for geometric subjects. In this paper, we use VRML as a document authoring language and computer networks as a tool for providing distribution of multimedia to the classroom environment to allow students to explore these figures using their computer connected with a

working server equipped with class materials.

2 VRML and its implication to mathematics learning

2.1 VRML and its characteristics

The Virtual Reality Modeling Language (VRML) is the file format standard for 3-D multimedia [5] and shared virtual worlds on the Internet [6, 7]. Just as HyperText Markup Language (HTML) led to a population explosion on the Internet by implementing a graphical interface, VRML adds the next level of interaction, structured graphics, and extra dimensions (z and time) to the online experience.

The applications of VRML are broad, ranging from prosaic business graphics to entertaining web page graphics, to manufacturing, scientific, entertainment, and educational applications, and, of course, to 3-D shared virtual worlds and communities. Also, the VRML can be used for textual description of a 3-D world in its basic form. A VRML world can be simple or complex, and it may range from a single object, such as a cube or sphere, to a large environment of many objects representing a city or even a solar system. Once loaded into a VRML viewer, users have the ability to interactively navigate or fly through this 3-D world and view it from any perspective with a few clicks of a mouse.

VRML models are easy to create, and just as one can import a table of numbers into a spreadsheet application to perform calculations or create graphics, the same can be done with a series of 3-D coordinates that can be converted into a 3-D environment with VRML. Therefore, some middle school geometry subjects such as plane, polyhedra, etc., can be modeled in VRML and can be browsed on popular Web browsers with plug-in software.

We need to use a plug-in for the Web browser to navigate the VRML documents. In this paper, we use the Cosmo Player that is a high-performance, cross-platform VRML 2.0 client designed for fast and efficient viewing of virtual worlds. With this plug-in, a student is able to navigate and manipulate 3-D scenes of class material and bring experience to ' real objects' with virtual objects. Since Cosmo Player is a viewing client for VRML with support for the latest standards, if the teacher provides this software in a server, students download and install it in their computer.

2.2 VRML and its implication to geometry class

The aforementioned VRML characteristics can be applied to geometry classes by implementing solids, and figures that do not lie in one plane, in cyberspace of computer. In this paper, the *figure* means a picture or drawing that represents a geometric figure. Most geometry texts use plenty of figures to explain geometric figures; those drawings are described in 2-dimensional space. That means the teacher needs to prepare some materials that can be easily shown in 3-D space. Also, students cannot explore 2-D texts or drawings in a manner of flipping the figures or looking inside of an object.

Fortunately, if figures or objects are modeled and implemented with the VRML format, these drawbacks can be easily overcome. For instance, the VRML allows the document to be linked with any type of multimedia such as text, sound, movie and graphic images (in static or dynamic state) in 3-D space. After figures or objects are authored in VRML format, users are able to access easily to these objects using VRML browsers. If drawings in texts are integrated into Web courseware using VRML, the student is able to access specific figures and is able to observe that figure in many ways. For example, if a class learns about the concept of perpendicular, students can observe the figure at the point of under, top, and in front of the figure by simply controlling the browser control boxes.

Thus, they can vividly observe and "feel" figures taught in class as if these figures are real objects. Even though the VRML figures may not provide "object in reality, " but it can show the "object in virtual reality." Therefore, we are sure that the application of virtual reality based class aids is a challenging approach to improve the learning effectiveness in geometry class.

3 Modeling geometry figures into VRML format

When one designs courseware or computer assistant class aids, it is necessary to analyze not only learners, but also teaching subjects [8, 9]. It is hard to say that a specific method is the only unique way to teach a certain subject, and thus, the teacher needs thoughtful consideration for his/her class. With this in mind, we have designed geometric figures by fully utilizing VRML characteristics and interesting human computer interaction capability.

One example is as follows. To show "*a point is not sufficient to define a plane*," we used the VRML animation capability as shown in Figure 1. Fig. 1(a) shows a point in a Web browser. If a student clicks the point with the mouse, several planes appear and cross that point as shown in Fig. 1(b). Teacher then explains that "when any plane crosses a point in any directions, it is not sufficient to compose a plane with a point."

Since cross planes appear when the student touches the point with the mouse, the dynamic images allow the student to participate actively in the class. Also, teacher can show these figures as an example to deliver axiomatic ideas with dynamic visual aids, in which case the class can be changed into a more vivid learning environment.

Modeling geometric figures and drawings with the VRML needs several steps. First, basic drawing is described with the VRML code. Then, shape transformation is done for complicated object drawing. This step is required for various solids that are not possible using only basic drawings. Finally, covering a figure with certain colors and patterns finishes texture mapping.

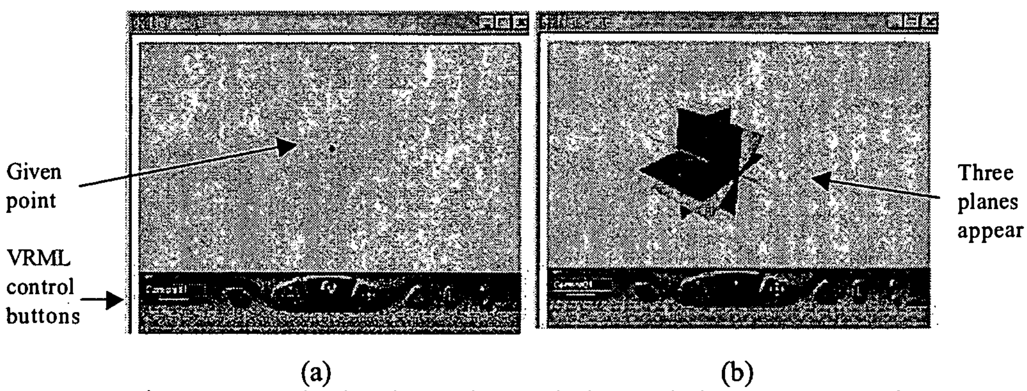


Figure 1. VRML drawings for showing "a point is not sufficient to make a plane"

We chose solid subjects in middle school mathematics class and, some of the examples of the courseware contents were "relationship between lines," "planes in 3-D space," "polyhedral objects," and "bodies of rotations." We drew these objects in VRML format and students explore these objects using several functions of VRML control buttons such as zooming, turning, and searching capabilities.

We used VRML drawings to describe these subjects as virtual reality including several polyhedra. It is known that the best way to learn to visualize 3-D is to make objects that demonstrate the spatial concepts [10]. Students can observe and use many spatial relationships while they construct polyhedra. Attractive visual aids also stimulate creative thinking. We are sure that objects displayed by the virtual reality technique are helpful for students. Current VRML technology allows students to navigate these objects as if they were handling real objects.

It is not easy to make polyhedron objects that have more than 8 faces. But, if we use VRML, it is quite easy to make such polyhedrons. Figure 2 shows a polyhedron that has 20 faces. If students observe these objects at several different angles using browser controller, they may easily grasp the principles of polyhedrons.

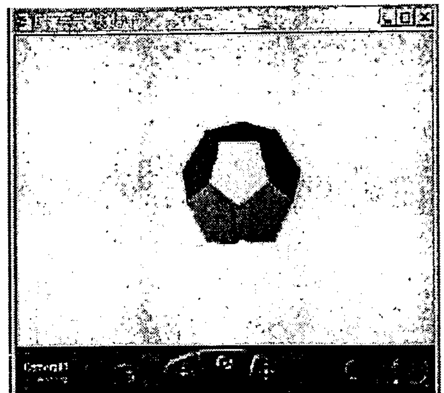


Figure 2. A polyhedron of 20 faces

4 Evaluation of a VRML based geometry class

The VRML based class materials were designed as a support for both teacher and students aids for the teaching and learning process of abstract concepts with physical reality. The designed materials are basically based on textbook contents that are drawn in 2-D.

4. 1 Method

To evaluate the effectiveness of VRML based geometry class, we designed two groups of classes; one applying networked VRML materials, and the other taught in conventional approach. Each class had 34 students and they did not show significant difference in their average score in the 1st semester of school.

For the VRML based class, the teacher used VRML materials in class and the students were encouraged to explorer these materials using their computer. The class was equipped with multimedia computers hooked into the network. The other class was taught in verbal explanations as in conventional classes. One teacher taught two groups at different times. The class schedules for each group were as follows.

Table 1. Class schedule for each group

Class	VRML group (classroom/ subject)	Non-VRML group (classroom/ subject)
1st class	Audio-visual class The relationship of line and plane	Blackboard classroom The relationship of line and plane
2nd class	Audio-visual class (Multimedia equipments are used) Polyhedra and rotational objects	Blackboard classroom Polyhedra and rotational objects
3rd class	Computer room Self exploration with VMRL materials	Blackboard classroom Problem practice
4th class	Test	Test

As Table 1 shows, we scheduled 4 classes and evaluation test was taken at the last class. Selected teaching subjects were included in the first year middle school mathematics class in Korea. The VRML group classroom was equipped with computers and audio-visual facilities. The teacher utilized VRML for his teaching and students were allowed to explore VRML objects with their computers. On the other hand, the blackboard classroom students did problem solving in the 3rd class.

After tutoring the subjects, both groups were tested with the same questions. The chosen method was student knowledge of taught geometry subjects. We designed 25 questions, and half of them required visual imaginations to answer correctly. We showed the characteristics of each question as relevant to visual imagination critical with symbol 'v' in Table 2, and each group's right answer rate. Examples of the given questions are shown in the appendix. Using a 5% level of significance that indicates the risk of incorrectly

chosen two groups were not equal, a t-test analysis [11] was conducted assuming equal variances and a null hypothesis of equal means.

Table 2. Test questions and relevant to visual imagination

Questions	Relevance	Correct answer rate (%)	
		VRML group	Traditional group
1	V	97.2	89.2
2	V	88.9	67.6
3		55.6	56.8
4		69.4	83.8
5		16.7	10.8
6	V	52.8	35.1
7	V	61.1	27.0
8	V	83.3	45.9
9	V	58.3	48.6
10		27.8	27.0
11	V	52.8	40.5
12		91.7	89.2
13		63.9	64.9
14		41.7	54.1
15		72.2	83.8
16		58.3	54.1
17	V	83.3	78.4
18		47.2	45.9
19		50.0	59.5
20	V	80.6	62.2
21	V	75.0	64.9
22	V	47.2	37.8
23	V	80.6	59.5
24	V	38.9	27.0
25	V	72.2	64.9

As shown in Table 3, the calculated t-statistics of –0.32 was less than the t-critical value of 1.99, indicating that the expected interval of plausible values of the average score of the spring semester could be constructed. That plausible interval values could be constructed implied that there was no difference in the two groups. Also, a P-value of 0.748 was calculated to indicate the level of significance in the breaking point of rejecting or accepting the null hypothesis. We used a 5% level of significance, and the null hypothesis of equal means must be accepted since it is less than the P-value of 74.8%.

Table 3. Two groups' average exam scores in Spring 1998

	Average	SD	t-Statistics	t-Critical	P-Value
VRML group	62.33	400.22	-0.32	1.99	0.74
Traditional class	63.83	382.65			

Table 4. Test results of visualization aid critical and non-critical questions

Questions		Average	SD	*t*-Statistics	*t*-Critical	*P*-Value
Visualization critical	VRML class	69.44	307.37	2.36	2.05	0.02
	Traditional class	53.47	380.38			
Visualization non-critical	VRML class	54.04	439.00	-0.33	2.08	0.74
	Traditional class	57.26	571.57			

Using the same method as used for the null hypothesis of two selected groups, we analyzed the effectiveness of the VRML based class by applying statistical differences of correcting answer rates for given questions between two groups. The test problem set was organized as 14 problems that were critical for visual experience and 11 questions that were normal questions that may be not dependent on visual aids.

The analysis of test data revealed that there is a statistical difference between the VRML based class and the traditional method class. Students of the VRML based class showed a 29.7% more correct answer rate to these questions than those in the traditional classroom in overall. To show the statistical meaning of this result, we applied the null hypothesis that "applying VRML based materials do not affect the two groups in statistical significance difference." As shown in Table 4, for visual experience critical problems, the *t*-statistics value is 2.36 and *t*-critical value is 2.05 and this means this hypothesis should be rejected. Also, the P-Value is 0.02 and we used the significance level of 5% and this result shows that applying VRML based materials affects the two groups' answering rate for given questions. Therefore, we can emphasize that the VRML based teaching is a very effective way for the geometry class.

Also, the hypothesis that "VRML based materials may not affect the two groups for non-visual critical questions" was analyzed in statistical significance difference. To decide to accept or reject this hypothesis, we used the same aforementioned method. As shown in Table 4, for visualization non-critical questions answer rates of between two groups, the *t*-statistics value is –0.33 and *t*-critical value is 2.08. This result shows that this hypothesis should be accepted. Furthermore, the P-value of 74% is much greater than the level of significance of 5% showing that this hypothesis is true. Therefore, we may conclude that VRML based teaching and conventional teaching method does not show significant differences in students' understanding for visualization non-critical questions. This implies that VRML drawings may not be quite as useful for a geometry class where visual aids are not so crucial.

5 Conclusions

Learning abstract geometric concepts in middle school class needs visualization of figures in 3-D space. The relationship between lines, planes, and figures cannot be easily described simply by using the verbal explanation approach. To visualize geometric objects for middle school class, we have designed and implemented VRML drawings for visual aids and the test results show that the VRML based visual aids are very effective in the geometry class.

The advantages of the VRML based geometry class can be summarized as follows. First, it provides a virtual reality of figures and objects that cannot be easily described verbally. Secondly, the WWW application of VRML materials can be effectively used for teaching or learning purposes in class. Finally, any shape of geometry figure can be easily modeled into VRML drawings; thus, it is a good visual aid tool for the geometry class. Therefore, we are recommending using VRML based visualization techniques as a visual aid tool for not only mathematics class, but also any class that requires detailed description of physical reality beyond the verbal approach.

References

[1] Bell, F. H., "Teaching Elementary School Mathematics: Methods and Content for Grades K-8", Wm. C. Brown Company Publishers, (1980).

[2] NCET, "Mathematics and IT – a Pupil's Entitlement", NCET, Coventry, NY, (1995).

[3] Masks, W. J., "How to use the spreadsheet as a tool in the secondary school mathematics classroom", National Council of Teachers of Mathematics, (1990).

[4] Abidin, A. and Hartley, J. R., "Developing mathematical problem solving skills", Journal of Computer Assisted Learning, Vol **14**, 278-291, (1998).
[5] Matsuba, S. N. and Roehl, B., "Special Edition Using VRML", (1997).
[6] Adnanes, M., and Ronning, W, M., "Computer-networks in education - a better way to learn?", Journal of Computer Assisted Learning, Vol **14**, 148-157, (1998).
[7] Antechev, K. et al., "A WWW Learning Environment for Mathematics", http://www.w3.org/Conferences/WWW4/papers/89, (accessed on December 1999).
[8] Kahn, B.H., "Web-Based Instruction", (1997).
[9] Heinle, N., "Designing Dynamic Web Pages with JavaScript", (1998).
[10] Pohl, V., "Visualizing Three Dimensions by Constructing Polyhedra", in 1987 Year Book of National Council of Teachers of Mathematics, Learning and Teaching Geometry, K-12, (1987).
[11] Cryler, J. and Miller, R., "Data Analysis and Modeling", Duxbury Press, California, (1994).

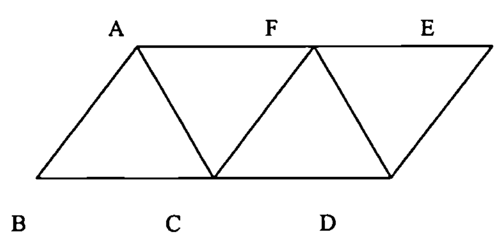
Appendix

Some of the test questions used for evaluating the effectiveness of the VRML based class are as follows.

Q1. Which one does not define a plane:
(1) Two lines in crossed position (2) Two lines that meet (3) Two parallel lines (4) A line and a point outside of the line (5) Three points out of a line

Q2. Choose which shows the condition for perpendicularity between line and plane:
(1) The line and plane are in parallel (2) The plane contains the line (3) The plane and line meet at same point and the line is perpendicular to a line which lies in the plane (4) The plane and line are in twisted position

Q3. If we want to make a regular tetrahedron with following development figure, which edge is in twisted position with edge AB?



(1) Edge BC (2) Edge CD (3) Edge AF (4) Edge DF (5) Edge ED

Constructing a Real-Time CAD Learning System Based on OpenGL in Web-Based Environment

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The purpose of this paper is to apply network technology to make the design of Web-based learning graphics systems for user. Several issues will be addressed in this paper such as the development of an Integrated Interactive Graphics System (IIGS) for a better design environment. In this paper, we attempted to develop a web-based graphics learning system by Bézier, B-spline and NURBS algorithms. The purpose of the research was to increase the effect of Computer-Aided Design (CAD) in network .The other advantages is that network browser is the common platform in internet and intranet, the graphics system can be portable cross different operating system, as like windows 98,linux..etc. In fact, the graphics learning system have attempted to be shared the resource each other.

Keyword: **OpenGL, VRML, NURBS, CAD/CAM, CAI, Curves, Surfaces**

1 Introduction

As the Internet has improved in the last ten years, web-based graphics learning has become very important in Internet. In recent year, the distance learning by Internet has been established and developed in Computer-Assisted Instruction (CAI) system. In this paper, the user can design and learning sculpture curves and surfaces on a personal computer by the interactive way. The graphics system has friendly interface in operating process.

OpenGL is a software interface that allows the programmer to create 2D and 3D graphics images. OpenGL are both a standard API and the implementation of API. In other words, OpenGL is a set of functions which have the same syntax and which act the same way on every platform, even though different vendors have written the actual subroutines, which implemented the API standard.

Graphics programming concepts underlie the function of OpenGL. These concepts are easy for ~~the~~ average application programmer to understand and use. OpenGL is independent of the hardware, operating, and windowing systems in use. Using OpenGL to make a program is easier than using API to do. API is integrated into a windowing system, since learning how to program a windowing system is often quite complicated.

2 Curve Modeling

Curve methods are usually included in different courses such as geometric modeling, CAD/CAM, computer-aided geometric design (CAGD), computer graphics, etc. In teaching this material, it is essential that students have an access to computer graphics facilities. Practical experiences help them to understand the dry theory. There are many books concerning curve and surface modeling and each of them considers

this subject in a different way (with some modifications). Users are confused, especially beginners. The next weakness of method representations is in lack of comparative means. Learning can be more effective if different methods are studied simultaneously on the same data by changing control parameters.

This field is developing very quickly and therefore researchers need also an effective comparative tool for their new improved approaches or methods. For these reasons, a program package for modeling and analysis of parametric curve methods called CM ("Curves Modeling") has been constructed. It is written in OpenGL. Not only 2D but also 3D curves are considered. Three various methods are incorporated in CM in the first menu level. Including all menu levels, there are ten methods or their modifications. In the interpolation methods, a curve passes through all control points, in the approximation methods, however, a curve passes only near to control points.

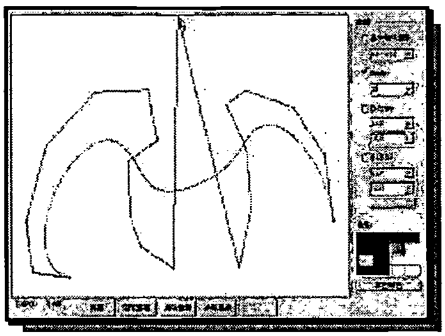

Figure 1. The Curve modeling interface

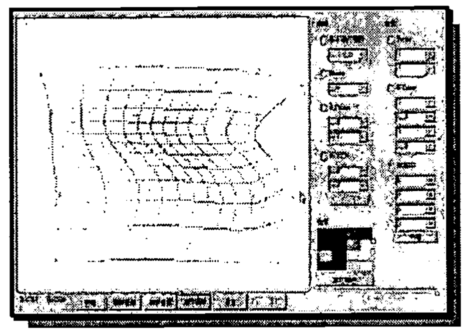

Figure 2. The Surface-modeling interface

A curve is compounded of small curves called curve segments and is determined by an equation in parametrical form (parameter u). In the knot vector for u (Uknot), there are parameter values for segment boundaries.

3 The Bézier, B-spline and NURBS Curves Algorithms.(extract)

NURBS curves:

A pth-degree NURBS curve is defined by

$$C(u) = \frac{\sum_{i=0}^{n} N_{i,p}(u) w_i P_i}{\sum_{i=0}^{n} N_{i,p}(u) w_i} \quad a \leq u \leq b \tag{12}$$

Where the {Pi} are the control points (forming a control polygon), the {Wi} are the weights, and the {Ni,p(u)}are the pth-degree B-spline basis functions defined on the non-periodic (and non-uniform) knot vector.

$$U = \left\{ \underbrace{a, \ldots, a}_{p+1}, u_{p+1}, \ldots, u_{m-p-1}, \underbrace{b, \ldots, b}_{p+1} \right\} \tag{13}$$

4 Surfaces Modeling

In the computer graphics, a surface is usually generated by a surface representation method on a control net (linked control points in a 3D space). Methods for surface representation are divided in two major groups: approximation and interpolation methods. At the interpolation methods, a surface passes through all control points, at the approximation methods , however, a surface passes only near to control points. A surface is compounded of small surfaces, called patches, presented by two families of isoparametric curves.

A program package for modeling and analysis of parametric surface methods called SM ("Surfaces

Modeling") has been constructed .A surface is determined by an equation in parametrical form (parameters u and v). We speak about u and v directions (parametrical view) or about direction X and direction Y respectively (2D screen view). In the knot vectors for u and v (Uknot, Vknot), there are parameter values u and v for patch boundaries.

5 The Bézier, B-spline and NURBS Surfaces Algorithms.(extract)

NURBS surfaces:

A NURBS surface of degree p in the u direction and degree q in the v direction is a bivariate vector-valued piecewise rational function of the form

$$S(u,v)=\frac{\sum_{i=0}^{n}\sum_{j=0}^{m}N_{i,p}(u)N_{j,q}(v)w_{i,j}P_{i,j}}{\sum_{i=0}^{n}\sum_{j=0}^{m}N_{i,p}(u)N_{j,q}(v)w_{i,j}} \quad 0\le u,v\le 1 \tag{14}$$

The $\{P_{i,j}\}$ from a bi-directional control net ,the $\{W_{i,j}\}$ are the weights ,and the $\{N_{i,p}(u)\}$ and $\{N_{j,q}(v)\}$ are the non-rational B-spline basis functions defined on the knot vectors

6 The structure of the graphics learning system:

(1)System operating process and interface:
(2) Graphics algorithms:

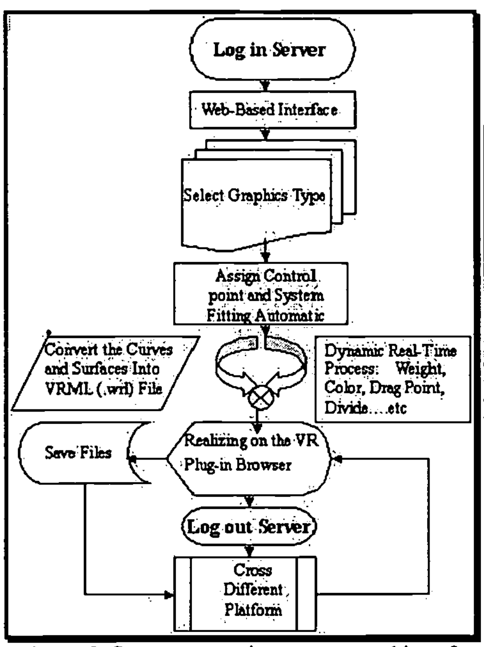

Figure 3. System operating process and interface.

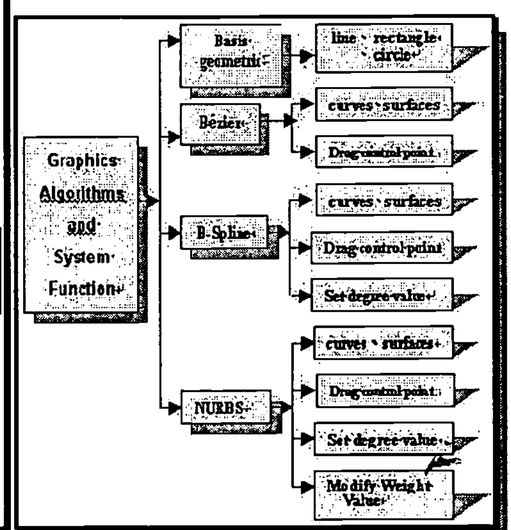

Figure 4. System graphics algorithms.

7 Brief Overview of OpenGL

OpenGL is the premier environment for developing portable, interactive 2D and 3D graphics applications. OpenGL have the following obvious benefits:

(1) Reliable and portable

(2) Scalable

(3) Easy to use

VR as a Training Tool

Virtual Reality training can dramatically reduce the cost of delivering training by decreasing learning time for student and instructors.

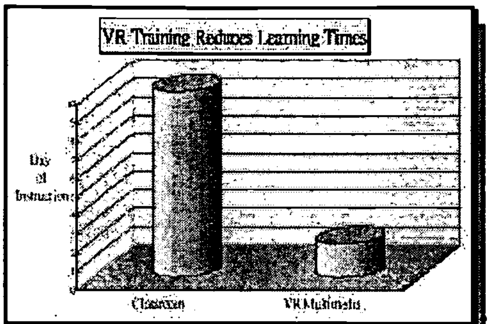

Figure 5. VR as a training tool as opposed to Classroom techniques (RTI)

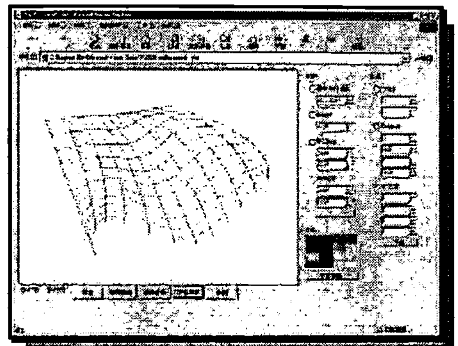

Figure 6 WebDeGrator System

8 Implementation and Example:

(1)The Integrated graphics Learning real-time system:
(2)Drawing NURBS curves and Covert Curves into VRML 3D Type:

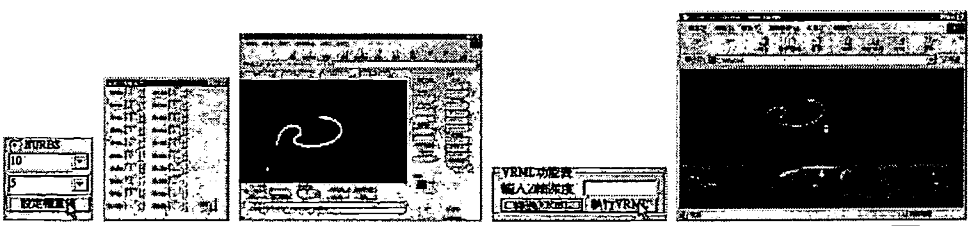

Figure 7 Drawing and Covert NURBS Curves

Covert VRML Type

9 Experiment results:

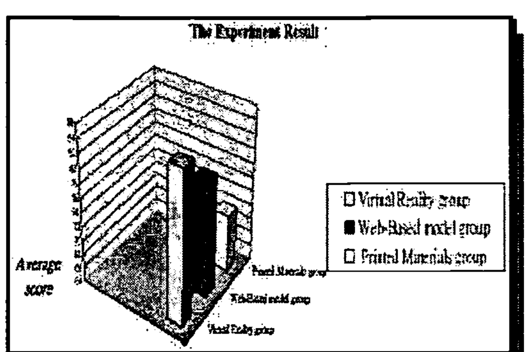

Figure 8 The experiment result

While the differences between the groups were significantly different, the virtual reality group performed is best; the Web-based model group is better than the printed materials group.

10 Conclusion:

The paper describes a new technology that we have established a VR-Based real-time graphics system. In summary, the system offers the following contributions:

1. To accomplish an Integrated Graphics Learning Real-time System
2. To share the resources in network.
3. To establish a computer network assisted learning system.
4. To explore and compare these algorithms of the sculpture curves and surfaces.
5. To integrate VRML with web–based learning system and realize 3D graphics on VR environment

11 Acknowledgments:

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12 References:

[1] Ainge D. J., "Upper primary students constructing and exploring three dimensional shapes: a comparison of virtual reality with card nets", J. Educational Computing Research, 14(4), pp 45-369.1996.

[2] Bricken, M. A, "Description of the Human Interface Technology Laboratoryí s Virtual Worlds". Technical Report, Human Interface Technology Laboratory, U. of Washington, Seattle: 1990

[3] Christine Youngblut.."Educational Uses of Virtual Reality Technology". Institute for Defense Analyses. 1998

[4] Clark, R.E. "Reconsidering Research on Learning from Media". Review of Educational Research, winter, Vol. 53, No. 4, pp. 445-459, 1983

[5] Flanagan, D.: "Java in Nutshell, A desktop quick reference - Java 1.1", Second edition, O'Reilly, 1997.

[6] GERALD, "NURBS from Projective Geometry to Practical Use". FARIN,1999.

[7] Les Piegl. & Wayne Tiller." The NURBS Book". .Springer, 1997

[8] Manetta and R. Blade in "Glossary of Virtual Reality Terminology" in the International Journal of Virtual, 1998

Designing Extensible Simulation-Oriented Collaborative Virtual Learning Environments

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Theoretical understanding that learners acquire is concretized through exploration and collaboration with other learners as they articulate their understanding and knowledge of the learning domain. Recognizing that knowledge building is a dynamic process that requires learners' active participation, there has been a shift from traditional teacher-centered instruction towards interactive, peer tutoring, as well as simulation-oriented collaborative group learning. Systems that allow users to engage in such activities are increasingly interesting to scientific communities and learning organizations.This paper shows how our system's design leverages off the Model-View-Controller (MVC) architecture to allow developers to share the behaviors and interactions of virtual objects. We also present our approach to partitioning different parts of our system's virtual environment as well as storing and synchronizing virtual worlds such that our system can support unlimited interactivity with virtual objects and encourage user interactions in quasi-immersive online learning communities.

Keywords: **Collaborative learning, virtual reality in education, simulation, experiential learning**

1 Introduction

Constructivist theory, based in part on the results of Piaget's research, is the most widely accepted pedagogical standpoint adopted among teachers today. Constructivism emphasizes the careful study of the learning processes and leverages learners' active participation in problem solving as well as in learning activities that promote creative and critical thinking. Rather than memorizing concepts through iterative rote learning, learners internalize new concepts through exploratory learning and develop their own understanding by integrating newly acquired knowledge with prior knowledge and experience. Peer tutoring among learners and interactions with experts facilitate such learning processes where "knowledge [is] directly experienced, constructed, acted upon, tested, or revised by the learner" [10].

The pedagogical consequence is that learning environments should support and stimulate further growth and development of learners' minds while encouraging learners' autonomy and initiative. This constructivist orientation requires a fresh perspective on the roles of technology in learning. Instead of viewing computers solely as a knowledge presentation device, we can also view them as tools for supporting a pedagogical focus on communications in collaborative learning ventures [4]. Suppose we are able to bring a group of people together to interact in a model of a real environment, then we also have a tool for constructivist learning. Imagine students steering ancient battleships and firing cannon balls at one another in order to explore the concepts of relative velocities and projectile paths. Or perhaps a chemistry class where students can mix and test chemical reactions in the safety of a virtual chemistry laboratory.

A successful Constructivist Learning Design (CLD) should provide familiar environments that reflect the

thinking processes of the participants; in such environments there must be trust and public sharing of knowledge in this environment [14]. Moreover, the Across-Schools Pedagogy Issues group [4] endorses the "necessity of large-area networks for particular contexts, instructional goals, and learner characteristics." Injecting constructivism into the educational system culminates in a revolution, from planning for teaching to designing for learning [14] and the "key to reinventing our educational system . . . lies in what our teachers believe about the nature of knowing" [1].

Increasing interest in virtual environments coupled with a recognition of their potential benefits from the use of simulation, experientially-grounded learning, and socialized learning have led to the development of many virtual reality (VR) systems. Working within the constructivist paradigm, we have developed a system that creates virtual collaborative learning environments. Our system supports user interactions that facilitate mutual tutoring and knowledge sharing. The system can be used by academic institutions that offer courses through distance learning, or it may be used as a complementary form of on-line collaborative learning. In particular, these institutions can conduct laboratory classes with visual demonstrations, simulations, and presentations. The system can also be used to create virtual towns where users can interact with one another and coordinate online meetings.

In subsequent sections of this paper, we critically evaluate related applications, present our research focus, and describe one of the virtual worlds in our system to demonstrate how users collaborate and interact in virtual environments. After the virtual world description, we discuss our approach to system design such that it is easily extensible by future developers. Next, we present the basic mechanisms used to implement our virtual environment system. The discussion on system architecture is followed by the conclusion and intended further work for our system.

2 Critique of Related Applications

There have been several attempts to create similar VR environments. *VR for Learning* [6] is based on Couch's multi-user virtual reality system. It is limited in that it does not store its data in a database. Moreover, avatars in the virtual environments are static. They do not adhere to any common structure, and they *float* in the virtual worlds rather than *walk*.

Active Worlds is a proprietary-standard virtual world browser that provides game-like 3D rendering of the world with user-selectable (first-person or third-person) views. In addition to the browser window, *Active Worlds* also comes with a chat window that supports user communications. Mouse- and keyboard-based navigation through virtual worlds is remarkably smooth. However, the joints of *Active Worlds* avatars have far fewer degrees of freedom than that possessed by humans. Hence, the avatars are capable of a smaller repertoire of actions compared to avatars that model humans more accurately.

Community Place, developed by Sony Corporation, is designed to be scalable and to support many "geographically dispersed users, interconnected through low bandwidth, high latency communication links" [5]. However, the chat and whiteboard windows are separated from the navigation window. This increases the semantic distance between the different components of the system.

blaxxun, by blaxxun interactive, has the advantage of using Humanoid Animation 1.0 (HANIM) [13] compliant avatars. However, *blaxxun* lets avatars float instead of walk. Avatars move very quickly, but realism is compromised.

3 Research Focus

In order for our system to benefit as many users as possible, our work is implemented using non-proprietary technology. We developed the system's virtual world browser using Java3D and implemented the other components in Java. Hence, our system is portable to hardware platforms that support Java3D and Java Virtual Machine (JVM). Moreover, the system is designed to support a large number of users while maintaining reasonable performance.

Considerable effort was devoted to designing an engaging interface so that the system is pleasurable to use. This is pertinent because the objective of our system is to help users actively participate in learning

environments and not in learning how to use the system. This will encourage users to engage in experiential learning and increase their familiarity with the learning context.

In order to support collaborative learning and to enhance learning experiences, interactions between users and virtual world objects must be supported. Moreover, each object should have unique behaviors and properties, or they should be able to share behaviors and properties with other similar objects in an Object Oriented (OO) fashion. In our system, virtual object states are modified by manipulating components of these virtual models directly. The system processes new object states and updates virtual worlds as well as a database of virtual world states. By storing virtual world states, users can collaborate in discussions that span several login sessions. Similar to most virtual environments, avatars are pertinent for promoting user interactions because they allow users to establish their presence in virtual worlds by creating sensations of "being there."

4 BattleShips World Description

One of the virtual worlds in our system is the *BattleShips* world (Figure 1). This world allows users to explore three physics concepts:

- the time taken for free-falling objects to reach level ground is independent of the objects' masses
- the relative velocity between two moving objects creates the illusion that the objects are moving at different individual speeds
- the trajectories of projectiles are parabolic

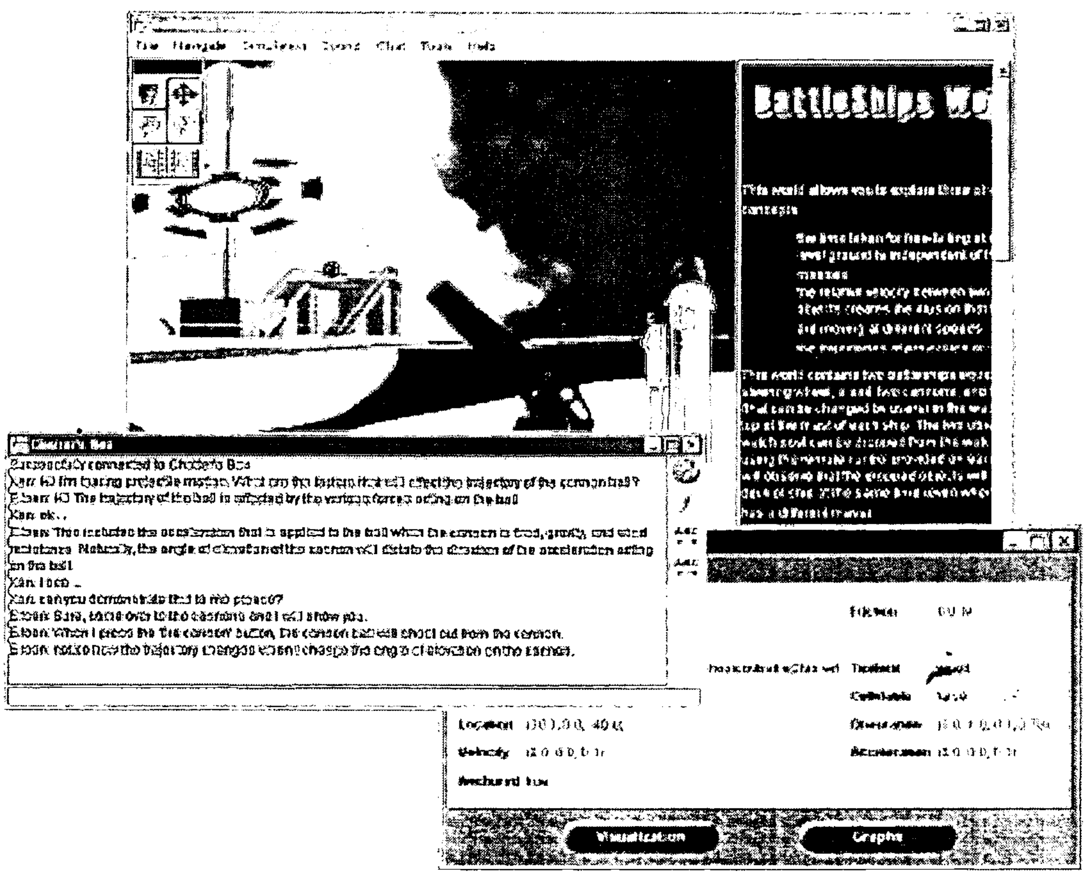

Figure 1 A screen capture of the *BattleShips World* with two cannon balls of different masses falling down towards the cannons

This world contains two battleships equipped with cannons on both sides of each ship. By default, cannon balls from each cannon have different mass. Users can change the mass of a ball by selecting the *Examine*

mode on the floating toolbar palette followed by the ball of interest. The system will pop up an *Inspector* window (where users can enter a new mass for the ball) at the position of the mouse click.

One of the battleships has two user-selectable objects in the crow's nest on top of the mast. When users activate the trapdoor at the bottom of the crow's nest by clicking on the remote control button provided, the selected objects will start to fall to the deck of the ship. Users are asked to find the object that will reach the ground in the shortest time given that each object has a different mass. (The heaviest object will reach the ground fastest due to air resistance. This is contrasted with the *VacuumChamber* virtual world where the time taken to reach the ground is independent of the mass of free-falling objects due to the absence of air resistance.)

Users can collaborate in controlling a ship. For example, one user may be navigating the ship to place it in a more strategic firing position (with respect to the other ship) while trying to stay out of the other ship's line of fire. Another user (on the same ship) may control the firing of cannons and the angles of elevation of the cannons. Users can engage in mutual tutoring and knowledge construction by communicating with one another using our system's text-chat facility.

Because both ships are moving, it is necessary to consider the relative velocity between the two ships when navigating and firing the cannons. In addition, trajectories of cannon balls in this virtual world illustrate that projectiles trace a parabolic path in contrast to the early intuitive (but mistaken) belief held by many novices that cannon balls drop vertically near the end of trajectories [7].

5 System Design

Our system is designed to be easily extensible by developers so that virtual worlds supporting new learning activities can be created more efficiently through reuse of existing implementation. Its design adheres to the MVC architecture, hence providing minimally coupled yet cohesive subsystems. In this section, we describe the Model, View, and Controller portions of the system. Following that, we discuss how we use a database to store virtual world states persistently and how events are propagated to other clients in order to maintain virtual world consistency (across different clients).

5.1 Model

In our system, the Model is represented by the *vtalk* package. *vtalk* models virtual objects (*VObject*), virtual worlds (*VWorld*), and laws that can be applied to each *VObject* and *VWorld*.

5.2 Virtual Object

Every virtual object (*VObject*) in our system is modeled as an OO class. This design allows virtual objects to inherit and share properties as well as behaviors easily. In this manner, objects can be placed in new virtual worlds and behave according to the conditions of the new worlds. For example, consider a virtual world where users are placed on a planet with lower gravity (compared to the Earth). Users can choose to insert a cannon into the virtual world (even though there are initially no cannons in this virtual world) and fire the cannon to observe the trajectory of the cannon ball. The main challenge, however, is to classify a potentially infinite number of objects into an extensible taxonomy. Our approach to the taxonomy is to categorize objects into *Living* and *NonLiving* things. The taxonomy for *Living* things is well defined by Parker [8].

On the other hand, the taxonomy for *NonLiving* things depends on the context in which the objects are placed. As such, *NonLiving* objects are classified according to generic behaviors (such as moving when a force is applied to it) and properties. For example, billiard balls, golf balls, bowling balls are placed as subclasses of the *Ball* class. This classification of *NonLiving* things is developed in the context of the scope of our intended experiments and is not meant to encompass all possible scenarios.

In order to minimize coupling, the Model communicates with the other parts of the system via messages encapsulated into events. Consequently, behaviors of each object generate events (such as velocity changed) that are propagated to the virtual world that contains the object and other Views (typically represented by a virtual world browser) rendering the object.

Virtual worlds (*VWorld*) are managers of *VObjects*. A virtual world delegates events generated by objects that the world contains, responds to events using implemented laws (such as Newton's Laws of Motion), and routes events to affected *VObjects* as well as the network component of the system. Each *VWorld* presents a rich set of cohesive simulations where users can modify attributes of virtual objects and observe the effects. For example, when users change the texture of a billiard table, a billiard ball on the table will be observed to roll at a different speed (compared to the speed before the change) when the users hit the ball with a cue stick.

5.3 Laws

Laws are implemented separately from *VObjects* and *VWorlds* because different laws are applicable to *VObjects* depending on the learning objectives (determined by *VWorld*). The consequence of incorporating laws in virtual worlds is that laws cannot be shared across virtual worlds. On the other hand, embedding laws within *VObjects* may result in ambiguity of applicable laws as well as prohibit sharing of laws. Hence, the separation of laws from *VObjects* and *VWorlds* allows *VWorlds* to determine applicable laws and the priority of laws to resolve conflicts.

5.4 View

A View denotes the portion of the system that listens for events. This approach allows the system to present different representations of the same model, for example a 3D virtual environment and a 2D plan view of the 3D environment. Currently, our system has one View component, *VBrowser*. Consider a cannon ball fired from a cannon, the ball will generate high-level events that inform *VBrowser* that its velocity and acceleration have changed. Subsequently, the view will apply Newton's Laws of Linear Motion at every uniform interval to compute the new location, velocity, and acceleration of the ball. The laws can be applied independently of the world containing the virtual objects.

Collision detection is necessary for most virtual environments especially in simulation-oriented systems. Ideally, collision detection should be implemented in the Model. However, only *VBrowser* has access to geometric data of all virtual objects necessary to compute collision accurately. For these reasons, our system detects collisions by leveraging off collision detection mechanisms available through the graphics engine of *VBrowser* [12]. When *VBrowser* detects collisions, it generates events of the collisions and routes them to the virtual world where the collisions occurred. Virtual worlds would then handle the collisions according to the implemented laws of each world.

5.5 Controller

Users generally interact with the Model using a Controller. Because users interact with virtual objects through direct manipulations, the Controller's interface is part of *VBrowser*'s interface. For example, users navigate through virtual environments by dragging the mouse across *VBrowser* (representing the View). However, the engine that handles the mouse movements is part of the Controller. In this case, the Controller updates the Model, and the Model, in turn, generates events that are received by *VBrowser*. *VBrowser* would then update the View presented to users.

Our system supports direct manipulation of objects such that users interact with the objects they see in virtual worlds directly. Because the types of possible (and logical) object interactions depend on the virtual world containing the object, introducing the allowed interaction types into the Controller or View would couple these two components undesirably to the Model.

In view of this, Controllers convey user intentions of manipulating objects to the Model which then decides the appropriate interaction types and pops up a toolbar containing valid actions that can be taken next to the object of interest. Users can then select the desired action (from the toolbar) to perform.

5.6 Network

The network component of our system propagates events from virtual worlds in order to synchronize worlds on different clients and to update the database storing virtual world states. However, if all virtual world events are propagated to other clients, the events will be "bounced" from client to client indefinitely. For example, when client A sends an event denoting that the location of object 1 is changed, this event will be

sent to client B. Client B updates its copy of object 1, thus triggering off another location changed event. This event would then be propagated back to client A, and so on.

Although this event looping situation can be circumvented by tagging every event with the originating client, a better design is to send only high-level events that result directly from user interaction. For example, a user moves a stick to strike a ball. The location changes of the stick (as the user manipulates it) are sent to all clients in the same world. However, events of collision between the stick and ball as well as subsequent location changes of the ball due to this collision are *not* propagated. It is not necessary to propagate such events because every client is able to detect the collision and handle the subsequent ball movements locally. This is similar to the dead-reckoning technique. As a result, bandwidth requirements are reduced because "update packets can be transmitted at lower-than-frame-rate frequencies" [9].

5.7 Database

The relational database in our system is used to store virtual world states and other data necessary to facilitate restoration of virtual worlds. Using the Java Reflection API and object serialization [11], we designed the database to handle objects of new virtual object classes without requiring any modification in the database code. As a result, other developers can create new virtual objects, by extending available virtual objects, without implementing ways to store the new objects.

In interactive collaborative virtual environments, two or more users may attempt to grab the same virtual object at the same time. By leveraging off concurrency control mechanisms of the relational database, our system prevents concurrent attempts by multiple users to grab the same virtual object through the use of "ownership" data in every virtual object's database tuple. A user who holds an object is considered to be the "owner" of the object until the user releases the object [9].

On the other hand, a user may attempt to grab an object that is already held (virtually) by another user. However, this scenario is unlikely to occur with the exception of virtual worlds where such actions are appropriate because socially acceptable norms discourage users from "snatching" other users' objects.

5.8 Flow of Events

Figure 2 illustrates a typical scenario representing the flow of control and events when the system is running.

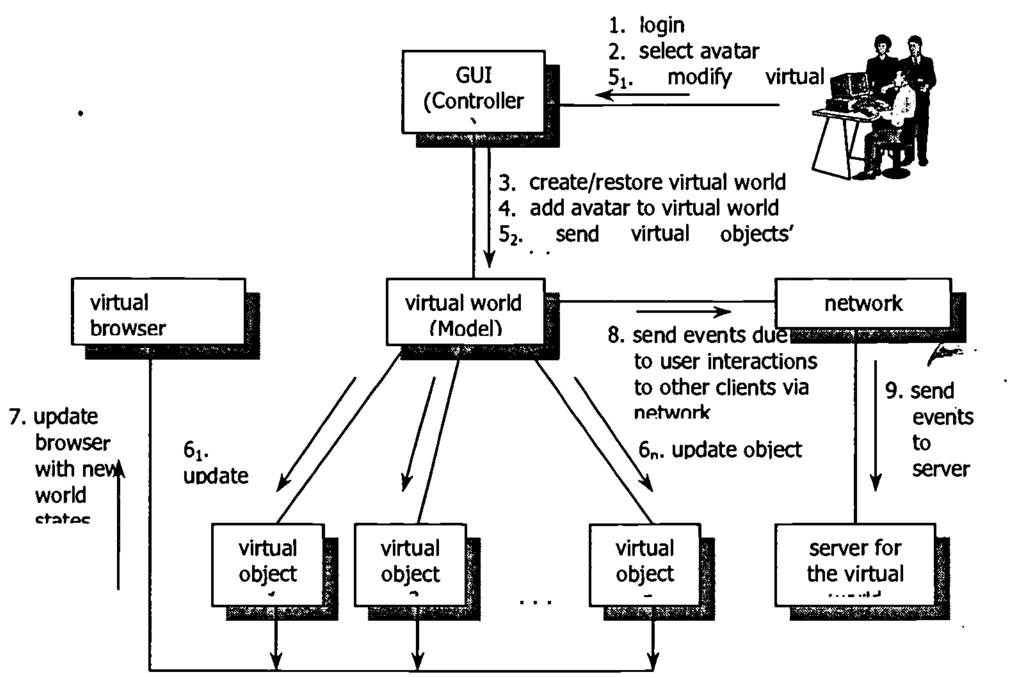

Figure 2 Flow of control and events in a typical scenario

When users interact with the objects in virtual worlds (Model), the Controller sends events to notify the associated virtual world of attribute changes. At the same time, the Controller also sends these events to other client machines via the network in order to synchronize virtual worlds on all clients. Every event is tagged with the time that the event occurred so that the order of events is preserved and consistent across all client machines. Because each client may have a different local time (such as in the case of client machines in different time zones), our system synchronizes the time of an event with the server's time.

The virtual world on every client machine will propagate the events encapsulating the changes to the virtual objects concerned. Upon receiving such events, the virtual objects will process these events representing the necessary updates and route the events to event listeners; that is objects that indicate interest in receiving virtual object events.

Finally, the View will interpret the events it receives from the Model and render the necessary changes by updating the geometric representations of all affected virtual objects.

6 System Architecture

In this section, we describe the basic mechanisms that we used to implement our system. We adopt a client-server architecture where there are multiple servers, with each server catering to several client machines (Figure 3). Although the system's server programs currently execute on one Sun workstation only, these programs can potentially reside on different physical workstations to support scaling beyond the processing power of one workstation.

Our system architecture is similar to the RING system [2]. Unlike the RING system, however, the servers in our system do not communicate directly with one another (although they share the same repository for virtual world states) because each server in our system handles only events from client machines in the same virtual world. Moreover, server programs may be hosted on different machines to distribute workload. When a user logs on to the system, the Controller retrieves the current states of the virtual world where the user is located from the database using JDBC. Using these states, the Controller instantiates the Model to represent the virtual world and all objects within the world. The Model then generates events to the listeners. One instance of a listener is the View (or *VBrowser*) that renders the virtual world as an interactive 3D environment on the monitor.

If the current states of the virtual world into which a user has entered are not available either due to a disconnected network or the fact that the world is newly created, then the virtual world is built locally according to the default layout of the world. If the world is new, then the Model will update the database with the default states of the virtual world. On the other hand, if the network is unavailable, the system is still functional because *vtalk* package's virtual network (*VNetwork*) is able to simulate the existence of a network connection. Hence, users can still engage in learning activities in virtual worlds in single-user mode. Changes made to objects in this mode are, however, not saved.

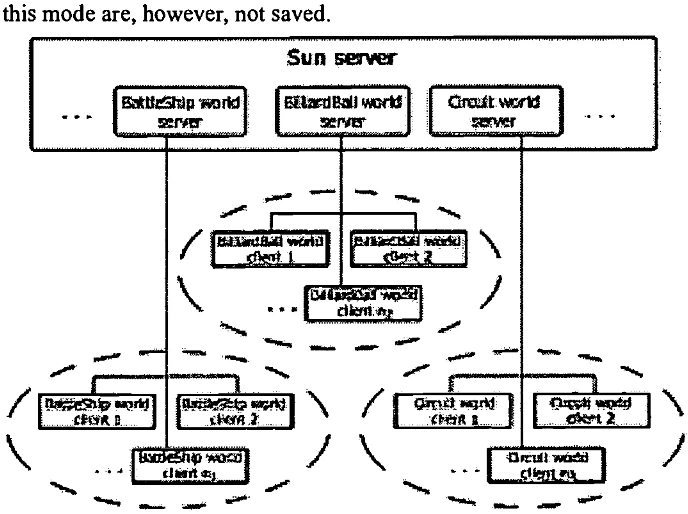

Figure 3 System architecture showing connections between virtual world servers and clients

The View of our system's virtual environment is generated using Java3D while the interfaces are created using Java Swing. The View is driven by events that are generated by virtual worlds and objects. Typically, these events are generic attribute changes (such as change in velocity) that affect the rendered view directly.

A possible event generation implementation is to use the Java Observer/Observable classes. Although these classes resemble the example code written by Gamma et al. [3], the Observer/Observable approach has the following disadvantages [15]:

- In order for event listeners to make use of the Observer/Observable classes, the classes modeling the event listeners have to be subclasses of the Observable class. However, it is usually difficult to meet this requirement because Java does not support multiple inheritance and the listeners may be subclasses of other classes already.
- Programmers need to understand details of how the update handler methods work.

Hence, the event generation mechanism of our system is based on the MVC architecture instead. Using this mechanism, each object that generates events stores its own list of event listeners [15]. When the attribute of an object changes, the object generates an event and routes it to every event listener in its list of listeners. Event listeners can be added and removed dynamically at run-time. As such, our system can create multiple views of the same model simultaneously. For example, it is useful to represent virtual worlds as 3D environments and also as a 2D plan view to aid navigation through large virtual worlds.

7 Conclusions

In this paper, we have explained the design of our simulation-oriented collaborative virtual environment based on the MVC architecture. We presented a description of our system's *BattleShips* virtual world where learners can explore physics-related concepts in an engaging and immersive fashion through interaction with objects in the world. Moreover, learners can participate in constructive online discussions as part of a learning community using our text-based chat facility. We further showed how different behaviors and laws can be shared and extended among virtual worlds and objects in an OO fashion. We also explained how our system is designed to support the addition of new virtual objects with minimal changes to the network and database. Finally, we presented the underlying system architecture of our current system to support collaborative learning distributed over geographic locations.

Our future work will include letting users see the actions and gestures of other users so that less time and effort is spent on prefatory remarks in online discussion (using text-chat). We will explore network topologies that afford greater scalability. We also intend to implement automatic distribution of load among several workstations and conduct formative and summative user evaluations.

References

[1] Fosnot, C., "Constructivism: Theory, Perspectives, and Practice", New York: Teachers College Press (1996).

[2] Funkhouser, T. A., "RING: A Client-Server System for Multi-user Virtual Environments", Proceedings of the 1995 SIGGRAPH Symposium on Interactive 3D Graphics. Monterey, CA: ACM SIGGRAPH, pp. 85-92, (1995).

[3] Gamma, E., Helm, R., Johnson, R., & Vlissides, J., "Design Patterns: Elements of reusable object-oriented software", MA, Addison-Wesley, (1994).

[4] Koschmann, T., Newman, D., Woodruff, E., Pea, R., & Rowley, P., "Technology and Pedagogy for Collaborative Problem Solving as a Context for Learning: Report on a CSCW '92 Workshop", ACM SIGCHI Bulletin, Vol 25, No. 4, October 1993, pp. 57-60, (1993).

[5] Lea, R., Honda Y., & Matsuda K., "Virtual Society: Collaboration in 3D Spaces on the Internet", Computer Supported Cooperative Work: The Journal of Collaborative Computing, Vol 6, pp. 227-250, (1997).

[6] Lim, K. P. E., "VR for Learning", National University of Singapore, Department of Information Systems and Computer Science, (1997).

[7] McCloskey, M., "Intuitive Physics", Scientific American, Vol 248, No. 4, pp. 122-130, (1983).

[8] Parker, S. P. (ed.), Synopsis and classification of living organisms, NY: McGraw-Hill, (1982).

[9] Singhal, S. & Zyda, M., "Networked Virtual Environments", ACM Press, pp. 119 & 142, (1999).

[10] Thompson, J.G. & Jorgensen, S., "How Interactive is Instructional Technology? Alternative Models for Looking at Interactions between Learners and Media", Educational Technology, Vol 24, (1989).
[11] Build an object database, http://www.javaworld.com/javaworld/jw-01-2000/jw-01-step.html (accessed on July 26, 2000).
[12] Extended Collision Detection for Java 3D, http://www.burrows.u-net.com/collisiondetectionJ3D.html (accessed on July 26, 2000).
[13] Specification for a Standard VRML Humanoid Version 1.0, http://ece.uwaterloo.ca:80/~h-anim/spec.html (accessed on July 26, 2000).
[14] Teachers' Perspectives on a Constructivist Learning Design, http://www.prainbow.com/cld/clds.html (accessed on July 26, 2000).
[15] The 'event generator' idiom,
http://www.javaworld.com/javaworld/jw-09-1998/jw-09-techniques_p.html (accessed on July 26, 2000).

Strange Creatures in Virtual Inhabited 3D Worlds

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This paper discusses the strange creatures that currently populate 3D cyberspace and3D Internet. First, the concept of Virtual Inhabited 3D worlds are discussed and defined. Next, some of the key elements or basic entities that can be found within the horizon of Virtual, Inhabited 3D Worlds are identified and denned. Among these basic elements are objects and agents, differentiated by whether or not their primary function is to carry out an action. Agents (denned as entities, which primary function is to carry out actions) have two main forms, which have been described as relatively sharply differentiable polar opposites. This is done based on questions such as: who is controlling the agents? ' who is doing the driving?' On the one hand there are agents that react independently of the user, but which are controlled by software or AL, the so-called ' autonomous agents' or ' bots' . On the other hand, there are agents, which directly represent and are controlled by users, the so-called ' avatars. Although there is then, in principle, a differentiation, in terms of definition, between bots and avatars, the paper argues that both concepts cover a relatively wide spectrum of very different types of phenomena with differing degrees of control. There also seems to be a tendency toward the appearance of more and more hybrids- in the present context termed ' cyber-hybrids' - combining avatars and bots. Furthermore, these hybrid forms are in many ways the most interesting and most promising in the virtual worlds at the moment. Rather than considering avatars and bots as polar opposites, it may therefore be more productive to consider them as the outer points along a continuum, between which can be found all sorts of combinations or hybrids. Following this line of argument, the paper outlines a new typology of hybrid creatures, which currently populate the continuum between (objects) bots and avatars in Virtual worlds.

*The paper was not available by the date of printing.

The Effect of Virtual Reality Learning Transfer with Different Cognitive Style

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The virtual reality has great potential capacity in distance learning. There are three characteristics of virtual reality learning, simulation, interaction, and involvement of multiple users. The purpose of this study is to discuss the effect of virtual reality learning transfer with different cognitive style, and recognize the relationship between cognitive style and relatively different form. Cluster sampling was used in this study. Two schools, Kwan Hwa Junior High school and Youth Junior High school, were selected for sampling. Two classes of each school were recruited. Four research instruments such as "Cognitive Style Profile", "The Need for Cognitive Scale", "Computer Attitude Profile" and "The learning classroom of virtual reality" were used for evaluation. The main finding after analyzing the score statistically are as followed:(1).The cognitive style of students is generally good and above medium level, however, it seems not very good at discrimination skill.(2).The verbal spatial preference skill of students leans toward the spatial learning.(3).The computer attitude of students is good generally and has positive attitude.(4).The social position and owning computer have a remarkable influence on the VR learning transfer; yet sex, learning computer experience and family education mode do not have a distinguished influence on learning.(5).Increasing the opportunity for students to use computers helps VR learning transfer by computers.(6).The VR learning transfer differed by the difference of cognitive need.(7).The number of computer attitude will influence VR learning transfer, that one having positive (computer) attitude is much more efficient than the negative.(8).Discrimination skill and spatial skill will influence the VR learning transfer.(9).The number of different personal factor have a remarkable influence on cognitive style, cognitive need and computer attitude; yet family education mode does not have a distinguished influence on them.(10).The discrimination skill, spatial skill, cognitive need and computer attitude have a remarkable positive correlation with the VR learning transfer.(11).By means of predictive analysis, attitudes in computer, cognitive need and cognitive style have distinguished prediction.

Keyword: **cognitive style, virtual reality, learning transfer**

1 Introduction

A highly concerned subject to educators is how to enhance the outcome of education. In nearly a century, the researchers of educational technology are trying to find out the best educational media to assist their teaching. Educators expect the learner can learn effectively in short time. Because of individual difference, several factors could affect final achievement, including physiology, psychology, cognition, the attitude of educator, and the learning environment. As a result, the relationship between educational technology and the learning effect always being questioned.

Under the trend of "global life-time learning", distance learning has become a new learning model. It is excited that the technology shorten the distance between teaching and learning. Moreover, the interaction among virtual reality makes the communication possible between the real world. The researchers are aware of the potential of virtual reality. They believe the functions of simulation, interaction, and involvement of multi user leads the virtual space towards the model of virtual community. However, the reality and the virtual world have to coexist. The problems in real world have to be solved. It is important to consider how to make good use of the characteristics of virtual reality learning while trying to set up a virtual learning environment. We can not put every learner under virtual learning world(Chu,1998). Lin(1997) believed a

well-designed hypermedia helps learning. Furthermore, it has positive impact on the attitude of the learner using hypermedia.

The characteristics of the learning media and the learning attitude of the media are both variables of the cognitive style used to predict learning effects. Therefore, the objective of this study was to assist junior high school student study drawing in living technology education by using virtual reality. In addition, the impacts of the different cognitive styles on the learning using virtual reality are investigated. Student's adaptation of cognitive styles to the new media was discussed.

2 purpose

The purpose of this study is to discuss the transition of virtual reality learning transfer with different personal variable, cognitive need, cognitive style, and computer attitude. To summarize, the purpose of this study is follow: (1). To inquiry the influence compared with different personal variable, cognitive need, cognitive style, computer attitude and VR learning transition. (2) To explore the influence between personal variable and cognitive style. (3). Beside on the result and finding , to provide the concrete suggestions for teachers and people who design the environment of web virtual reality .

3 Method

3.1 Subject

Cluster sampling was used in this study. Two schools, Kwan Hwa Junior High school and Youth Junior High school, were selected for sampling. After the rejection the invalid samples 133 students are analyzed.

3.2 Materials

3.2.1 Cognitive Style Profile

To explore whether student with different cognitive styles react differently to the same material, this research adapted the Cognitive Style Profile that was developed by Keefe and Monk (1979) and translated by Liu (1992). The result of this profile is to investigate students' cognitive style in several dimensions. Scales between poor to excellent were measured to separate students into several groups. Factors as sequential processing skill (SQP); discrimination skill (DS); categorization skill (CS); analytic skill (AS); spatial skill (SS); memory skill (MM); and verbal spatial preference skill (VSP) are discussed.

3.2.2 The Need for Cognitive Scale, NCS

The NCS scale developed by Cacippo and Petty(1984) and translated by Cheng-Ren Zhan (1997) was used here. Research showed NCS had high positive correlation with IQ and low positive correlation with cognitive style.

3.2.3 Computer Attitude Profile

Ming-Long Wu (1997) developed the "Computer Attitude Profile" to investigate the computer attitude tendency of students. This profile includes four dimensions: computer affection, computer application, confidence attitude, and gender differences.

3.2.4 The learning classroom of virtual reality

This study adapted the " The learning classroom of virtual reality " which designed by Jia-Rong Wen (1999) (NSC 88-2520-s-017-001). Contents cover "Technology education--show visions". "The learning classroom of virtual reality" is divided into four areas: direction, disappeared-point, three visions and heap. The relationship between teaching materials and cognitive style is as the right side.

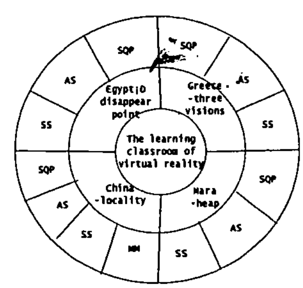

Figure 1 The relationship between teaching materials and cognitive style

3.3 Experimental design and procedures

The learning process of virtual reality in this research was divided into five steps: (1) The input of basic personal data; (2) Profiles Test; (3) pretest; (4) Virtual reality learning; (5)Posttest.

About the path of this framework , describe as follow:

A. To explore the relationship between personal various and VR learning transfer.
B. To inquiry the relationship between cognitive need and VR learning transfer.
C. To investigate the relationship between computer attitude and VR learning transfer.
D. To study the correlation between cognitive style and VR learning transfer.
E. To understand the effect of between personal various and cognitive need, computer attitude, and cognitive style.
F. To investigate the distinguished predictive force with cognitive style, cognitive need and computer attitude toward VR learning transfer.

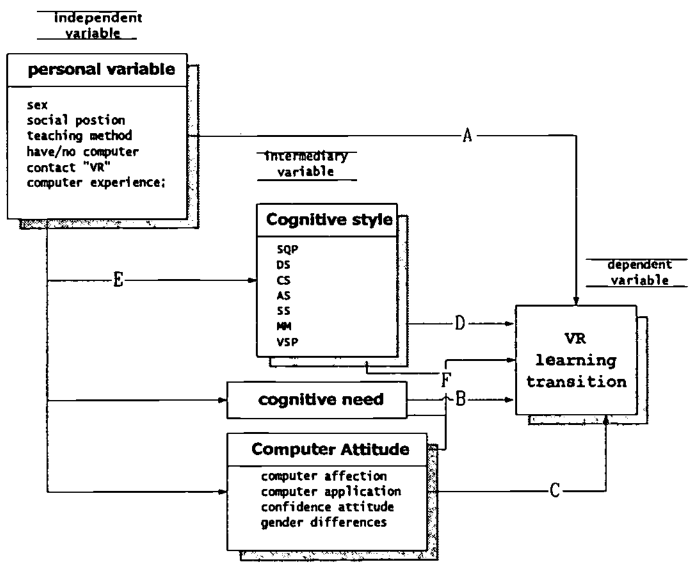

Figure 2 The framework of research

4 Results and Discussion

After the test, the collected data was analyzed in statistical methods such as T-test, one-way ANOVA, correlation, MANOVA,regression and the Scheffe test; the report, based on the results and discussion, is as follow.

4.1 descriptive illustration

4.1.1 The present situation description of cognitive style

Table 1. The present situation description of cognitive style

Cognitive Style	Mean	SD	TSTANDARD SCORE RANGES				
			weak	Lower than mean	mean	High than mean	strong
SQP	52.12	8.28	12	13	27	81	0
DS	44.72	12.24	33	22	30	40	8
CS	59.7	7.67	0	11	8	50	64
AS	51.28	9.71	30	35	0	24	44
SS	53.15	9.26	21	33	0	31	48
MM	53.98	10.29	10	29	17	36	41
			Space	Neutrality toward space	neutra lity	Neutrality toward language	language
VSP	45.39	7.29	21	68	30	10	4

As the Table 1, show the situation of junior high school students about cognitive style. Students have excellent skills in SQP, CS and MM. Students are short of DS skill. The mean of DS skill is lower than 50 and the SD is higher score, to display students have large different in DS skill. Both AS and SS have twin-peak distribution patters. VSP indicates the habit and perference of personal learning styles. From Table 1, the result shows that most of the subjects are used to or prefer spatial skill rather than verbal skill.

4.1.2 The present situation description of computer attitude

Table 2. The abstract description of computer attitude

	mean	SD	number	Mean of number
Computer affection	31.06	6.06	8	3.88
Computer application	54.71	8.61	13	4.21
Gender differences	23.86	4.78	8	2.98
Confidence attitude	19.05	5.86	7	2.72

According to Table 2. ,the mean of number approximate 3 to confirm the information spreading effect in these years. "Computer application" is higher and "confidence attitude" is lower than others. Study displays Junior High School students have bad confidence toward computer attitude.

4.2 The relationship of VR learning transfer with personal variable, cognitive need, and cognitive style

4.2.1 Test of significance of different personal variable for VR learning transfer

Table 3. The abstract of T-test of significance about personal variable in VR learning

Basic personal variable	classification				T_test	Scheffe
	Mean	SD	Mean	SD		
sex	male (67)		female (66)			
	6.57	11.05	6.36	11.32	0.105	
Have computer at home	have(86)		no(47)			
	9.07	10.42	1.70	10.95	3.829***	have > no
Have contact with 3D VR	have(45 □)		no(88 □)			
	7.78	10.47	5.8	11.47	0.807	

*P<.05 **p<.01 ***P<.001

Table 4. The abstract of ANOVA of significance about personal variable in VR learning

	Mean	SD	Mean	SD	Mean	SD	Mean	SD	F	Scheffe
Socio-economic level	2(33)		3(42)		4(58)				4.017*	2 > 4
	10.30	9.27	7.26	11.80	3.71	11.06				
train	authority(3)		freedom(3)		assistance(3)		Other(4)		2.382	
	1.76	11.58	8.29	10.56	6.25	11.37	0.00	11.40		
Computer experience	Less 1 year(1)		1-1.9 year(2)		2-2.9 year(3)		More 3 year(4)		1.318	
	5.17	11.77	8.52	9.49	6.68	12.52	10.83	7.93		

Ps: 2:high socio-economic level ; 2:middle socioeconomic level; 4:low socio-economic level

According to Table 3 and Table 4, to show the basic personal variable influence VR learning transfer. "Have computer at home" and "socio-economic level" influence VR learning transfer directly. Those students whose families are at higher social or economic levels perform better in VR learning transfer. Their parents usually pay more attention to their environment of education and afford computers in their own homes.

4.2.2 Test of significance of different personal variable to cognitive style and computer attitude

Table 5. are the results of MANOVA comparing with different socio-economic level and computer experience. It shows that higher socio-economic level students get high score on DS.

In Cognitive Style Profile, students from families of different social or economic levels have significant difference (p<0.05) in DS. Moreover, after having applied Scheffe Mathod, those who are from higher social or economic levels ahve better DS than those who are from middle levels.

Table 5. The abstract of significance of MANOVA about socio-economic level

socio-economic level	1 (38)		2 (75)		3 (10)		Wilk's	F	Post compare
	Mean	SD	Mean	SD	Mean	SD			
SQP	3.36	0.86	3.29	1.02	3.34	1.04		0.068	
DS	3.03	1.29	2.31	1.24	2.93	1.25		3.992*	2>3
CD	4.36	0.90	4.21	0.95	4.22	0.88		0.313	
AS	2.88	1.73	3.50	1.57	3.00	1.61	0.845	1.665	
SS	3.73	1.57	3.52	1.49	3.10	1.57		1.941	
MM	3.70	1.24	3.50	1.31	3.43	1.40		0.423	
VSP	2.48	0.97	2.40	0.91	2.14	0.91		1.813	
								1.556	
computer affection	32.06	5.23	32.14	6.31	29.71	6.13	0.896	2.633	
computer application	55.73	7.35	55.81	9.54	53.33	8.52		1.326	
gender differences	16.36	5.81	19.48	5.77	20.28	5.55		5.150* *	4>2
confidence attitude	24.33	3.93	24.45	5.63	23.17	4.54		10.84	
								1.786	

In Computer Attitude Profile, students from families of different social and economic levels also ahve different profermance in the dimension of "gender differences".On the Contrary, those who are from lower social or economic levels have greater differeces between genders.This suggests that the male from lower social or economic levels have stronger stereotype about "computers are particularly for the male".

4.3 The relationship between cognitive style, cognitive need, computer attitude and learning translation

Table 6. The abstract of significance of ANOVA about cognitive need and computer attitude toward learning translation

	Mean	SD	Mean	SD	Mean	SD	F	Scheffe test
Cognitive need	1--lower(37)		2--middle(62)		3--higher(34)		3.247*	3>1
	3.78	10.50	5.97	12.51	10.29	7.97		
Computer attitude(3 in 1)	1--lower(31)		2--middle(72)		3--higher(30)		6.759*	3>2;3>1
	2.58	10.64	5.69	10.82	12.33	10.40		
computer affection	1--lower(40)		2--middle(54)		3--higher(39)		2.542	
	3.25	11.80	7.41	9.94	8.46	11.59		
computer application	1--lower(34)		2--middle(60)		3--higher(39)		3.535*	3>1
	2.79	9.86	6.5	11.80	9.62	10.41		
confidence attitude	1--lower(34)		2--middle(63)		3--higher(36)		2.049	
	3.68	10.89	6.51	10.42	9.03	12.24		
gender differences	1--lower(34)		2--middle(53)		3--higher(46)		0.449	
	7.35	13.10	6.98	10.02	5.22	10.95		

Table 6 shows that personal cognitive need affects VR learning transfer ($F=3.247$; $p<0.05$).After having applied with Scheffe, those with more cognition need have better VR learning transfer than those with less Need(3>1).

Table 7 shows the effect upon several dimensions in cognitive style toward VR learning transfer. From the result, those with "Strong" and "Higher Than Mean" DS have better in VR learning transfer than those with "Lower Than Mean" DS. In other words, DS and VR learning transfer are somehow associated. SS and learning transfer are also associated since they show significant differences. After having applied with Scheffe, those with "Strong" SS ahve better in learning transfer than those with "weak" SS.

Table 7. The abstract of significance of ANOVA about cognitive style toward learning translation

level	1 Weak		2 lower than mean		3 Mean		4 higher than mean		5 Strong		F	Post compare
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
SQP	6.67	10.30	1.15	11.02	8.33	11.27	6.67	11.18			1.255	
DS	4.24	12.26	-0.45	11.84	8.00	9.79	9.25	8.44	15.0	11.34	4.91***	5>2;4>2
CS			10.0	14.49	8.13	8.43	4.50	12.34	7.19	9.71	1.037	
AS	5.50	10.28	8.14	10.99			6.04	13.02	6.02	10.97	0.369	
SS	0.95	11.69	6.67	11.57	7.67	12.13	7.22	10.31	5.24	12.04	2.804*	5>1
MM	7.50	5.89	6.21	12.08	7.65	12.13	7.22	10.31	5.24	12.04	0.232	
VSP	4.76	12.60	7.21	10.01	5.33	11.37	8.50	15.47	6.25	11.81	0.352	

Table 8. The relationship of cognitive style, cognitive need, computer attitude with VR learning translation

	SQP	DS	CS	AS	SS	MM	VSP	Cognitive
Learning transfer	.056	.226*	.073	-.024	.221*	.009	.068	.051
	Cognitive need	computer affection	computer application	confidence attitude	gender differences	Computer attitude(3 in 1)		
Learning transfer	.245**	.188*	.186*	-.058	.218*	.244**		

In Cognitive Style Profile, DS and SS are highly associated with VR learning transfer ($p<0.05$). The correlation coefficient are 0.226 and 0.221 respectively. In the VR learning transfer of the subjects, the variances accounted by DS and SS are 0.5 and 0.48 respectively.

The Need for Cognitive Scale and VR learning transfer are significantly associated ($r=0.245, p<0.01$) with a variance at 0.06.This indicates that those with higher Cognitive Need tend to perform better in VR learning transfer. In the Computer Attitude Profile, only the dimension "gender differences" is staticstically independent from VR learning transfer. The rest dimensions of the profile are significantly positively associated with VR learning transfer.

This shows that it is easier for those with positive attitide toward computers to have more VR learning transfer.

4.4 Stepwise Multiple Regression

In the analysis of Distinguished Predictive Force of variables, Stepwise Multiple Regression was used with VR learning transfer as the dependent variable. And the independent variables included seven dimensions of Cognitive Style Profile (which are SQP, DS, CS, AS, SS, MM, and VSP), four dimensions of Computer Attitude Profile and NCS. The result shows on table 9.

Table 9. The Stepwise Multiple Regression table

order	R	R^2	ΔR^2	β	F
1.cognitive need	.245	.060	.060	.110	8.386**
2.DS	.328	.108	.048	.267	7.842***
3. Computer attitude(3 in 1)	.387	.150	.042	.219	7.569***
4.SS	.430	.185	.035	.198	7.247***

Within the thirteen independent variables, four of them show significance in Distinguished Predictive Force. They are NCS, DS, CA, and SS. They altogether can explain 18.5% variance in VR LEARNING TRANSFER. When only one single independent variable is effective, the distinguished predictive force of NCS is the best, which reaches 6%; DS accounts 4.8%; Computer attitude(3 in 1) predicts 4.2%; and SS only score 3.5%.

4.5 Synthetic analysis about VR learning transfer

After analysis,table 10 shows the result of comparison. As follow:

Table 10. The synthetic analysis about VR learning transfer

	Cognitive need	Computer attitude				
		Computer attitude(3 in 1)	computer affection	computer application	confidence attitude	gender differences
VR learning transfer	3 > 1	3 > 2 3 > 1		3 > 1		

	Cognitive Style						
	SQP	DS	CS	AS	SS	MM	VSP
VR learning transfer		5 > 2 4 >2			5 > 1		

Table 10 shows the facts which effect VR learning transfer. Those are "cognitive need"□" Computer attitude(3 in 1)"□" computer application" and cognitive style (DS and SS).

5 Conclusion and Suggestions

5.1 Conclusion

Distance education offers a new chance applying to review learning conviction and learning tactic for developing learning environment. Virtual Reality is an important style for distance education. In this study, the relationship of learning translation with cognitive style, cognitive need and computer attitude is concerned. The main results of this study are as follow :

(1).The cognitive style of students is generally good and above medium level, however, it seems not very good at discrimination skill.

(2).The verbal spatial preference skill of students leans toward the spatial learning.

(3).The computer attitude of students is good generally and has positive attitude.

(4).The social position and owning computer have a remarkable influence on the VR learning transfer; yet sex, learning computer experience and family education mode do not have a distinguished influence on learning.

(5).Increasing the opportunity for students to use computers helps VR learning transfer by computers.

(6).The VR learning transfer differed by the difference of cognitive need.

(7).The number of computer attitude will influence VR learning transfer, that one having positive (computer) attitude is.much more efficient than the negative.

(8).Discrimination skill and spatial skill will influence the VR learning transfer.

(9).The number of different personal factor have a remarkable influence on cognitive style, cognitive need and computer attitude; yet family education mode does not have a distinguished influence on them.

(10).The discrimination skill, spatial skill, cognitive need and computer attitude have a remarkable positive correlation with the VR learning transfer.

(11).By means of predictive analysis, attitudes in computer, cognitive need and cognitive style have distinguished prediction.

5.2 Suggestions

According to the result of the research, we request the following suggestions to the related authorities in educating long distance of virtual reality reference:

(1) Among the seven items of Cognitive Style, students in domestic have better skills in sequential processing, categorization and memory; while in discrimination skill, the average is lower, and there are more differences inside. According to the explanation of the scale which evaluates the students whether they can focus on some level. The ones will high grades have better special quality on the focusing in cognitive styles, sharply watch the proper details and grasp the key points at work. The grades of students become lower is possibly due to fewer focusing on learning.

(2) The combinded resources of communities and schools can contribute to the education of the students from families of lower social or economic levels. In addition, the bond between the communities and the schools can provide various opportunities for students to operate computers.

(3) To increase students' oppertunities of active observation and to enhance their abilities in science and technology.
(4) To progress students' DS and SS, to benefit their VR learning transfer.
(5) To promote students' confidence in operating computers, to develop positive attitude toward computers, to enhance learning, to increase VR learning transfer the stereotype of gender differences should prevented
(6) To accommodate Spatial Learning, to escalate VR learning transfer.
(7) To let students establish the positive cognitive demand is more helpful to VR learning transfer.
(8) The computer attitude is also the important factor of VR learning trandfer. Students with positive confidence in believing computer is a kind of assit-tool have better learning effect.

References

[1]Cartwight,G.F.(1994).Virtual or Real?The mind in cyberspace. The futurist,18(2),22-26.
[2]Hong Jon-Chao (1994). A Study of Discovery Learning with Different Learning Styles in a CAI Environment, National Science Council, Vol. 4(2) 70-80.
[3]Keffe, I. W.(1979). Learning style: An overview .In O. B. Kierman (ed),Student Learning Styles. Virginin: NASSP Reston.
[4]Keefe,J.W.(1987).Learning style theory & practice. Reston,Virginia: National Association of Secondary School Principals.
[5]Liu Xin-Xiong (1992). A study of relationship of primary students between cognitive style, learning method, and achievements.
[6]MacNal, W. et al. (1991). Cognitive style and analytic ability and their relationship to competence in the biological science. Journal of Biological Education, 25(2),135-140.
[7]Messick, S. (1994) . The matter of style:Manifestations of personality in cognition, learning, and teaching. Educational Psychologist, 29 (3), 121-136.
[8]Moore, J. L., Lin X., Schwartz, D. T., Campbell, O., Hmelo, C., & Cognitive and Technology Group at Vanderbilt (1994). The relationship between situated cognition and anchored instruction: A response to Tripp. Educational Technology, 34(10), 28-32.
[9]Qiu gui-fa (1998). The learning of network: belief and development. Educational Research & Information. Vol. 6(1) 20-27.
[10]Rollins, H. A. & Genser, L. (1977). Role of cognitive style in a cognitive task: A case favoring the impulsive approach to problem solving . Journal of Educational Psychology, 69(3),81-287.
[11]Woodrow, J. The development of computer-related attitudes of secondary students. Journal of Educational Computing Research, 11(4), 307 – 338
[12]Wu Ming-long (1998). A Study of The Relationship Between Math Learning Behavior of Primary Students and Their Anxiety, Attitude toward Computer. The thesis of National Kaohsiung Normal University, not published.

Using Virtual Environments for Studying Water Phases and Phase Transitions

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In recent years, many studies have dealt with students' reasoning in science. Those studies suggested that pupils, in different degrees, have difficulties in understanding matter phases and phase transitions. To increase pupils understanding of phases and phase transitions, we are developing the "Virtual Water" project, a virtual environment centered on the learning of the structure and properties of water in its different phases. Within this environment, the molecular dynamics in the solid, liquid and gaseous phases of water and the corresponding phase transitions take place in three-dimensional space, with the possibility of haptic interaction with the molecules.

Keywords: **Virtual reality, virtual environment, water, phases and phase transitions**

1 Introduction

All substances undergo dramatic changes in their qualitative properties when certain parameters pass through particular values. Matter phases and phase transitions have received considerable attention in the framework of research on children's understandings in different ages and development stages [1-4], [10], [15].

Ice melting is an everyday example of a phase transition. When the temperature increases, keeping the pressure constant, the molecular vibrations become gradually more violent and thermal expansion occurs. Since this increase of vibration amplitude is gradual, one might expect that the macroscopic properties of water would also undergo a smooth change. While this is true for most temperatures, there is a well-defined temperature for which something dramatic happens: a sudden change in the properties of the substance and the appearance of a liquid. The liquid, in its turn and at a higher temperature, undergoes another phase transition going into a gas.

Few pupils use the corpuscular theoretical model taught in school to explain these processes. Indeed, their knowledge and understanding of the corpuscular theory of matter is sometimes very fragmentary. They apply it in some situations but not in others. For example, they may apply the corpuscular theory to explain gases but not to explain solids and liquids. There are also cases where pupils say that the shape and size of molecules changes when the state of matter changes: the shape of molecules depends on the shape of the vessel, molecules of solids are the biggest while gas molecules are the smallest for Portuguese children (13-15 years) [9], etc.

Other studies of students' conceptualization of phase transition from liquid or solid to gas have indicated that some children have difficulties conceiving gas as a substance [6] [12]. As students do not develop the general idea of gas prior to formal learning, the perceptual clues for detecting and identifying gases are weaker than for liquids and solids. Although pupils know some properties of air, they do not compare air with other gases, claiming that other gases do not have the same properties as air. A frequent explanation is that air is a big bulk system [11]. Gases are frequently linked by some invisible entity, something immaterial, for example energy in various forms. Kircher [5] also reports that high school pupils understand gases as a

continuous substance with no empty space between particles.

Since the use of images is a powerful tool for understanding complex and/or abstract information and since immersion in virtual environments is a recent technique which needs to be explored and evaluated, a virtual environment for studying phases and phases transitions is being developed by the Physics and Mathematics Departments of the University of Coimbra, Portugal, the Exploratory "Henry the Navigator", in Coimbra, and the High School for Technology and Management of the Polytechnic Institute of Guarda. We have named it "Virtual Water".

2 Overview of the Molecular Dynamics Virtual Environment

"Virtual Water" (VW) is a set of virtual environments designed to help in the instruction of high school students of Physics and Chemistry (it might also be useful for freshman university students). The main goals of this virtual reality application are:

a) To provide an educational environment for students to explore some microscopic concepts which they are taught in class.

b) To develop a practical knowledge concerning the application of virtual reality techniques to education, contributing with data on the usefulness of virtual reality [13-14].

The molecular dynamics component of VW is devoted to understanding some water properties and studying its phases and phase transitions by computer simulation. These simulations are based on the corpuscular theory of matter and use the equations of Newtonian Mechanics. We assume that the dynamics can be treated classically because more realistic simulations (incorporating quantum effects) are cumbersome and more computationally demanding. We also assume that the force between any pair of molecules depends only on the distance between them.

The interactions using *dataglove* allow the user to act and change the environment in order to distinguish the properties of solids, liquids and gases. The *cybertouch* system associated to the dataglove enables the user to experience some molecular behaviors that are impossible to feel in real world. For example, in the solid phase the user may fly through the ice structure and learn about it (Figure 1). Using the *dataglove* the user is able to break the ice and with the *cybertouch* system he can feel the increase of molecular vibrations with the temperature. While breaking ice may be a common macroscopic experience, watching the network of hydrogen bond and feeling molecular vibrations, for example, are quite uncommon experiences. On the other hand, in the liquid and gas phases, it is possible see and try to grab a molecule, understanding by direct experience that its speed is bigger than in the solid phase.

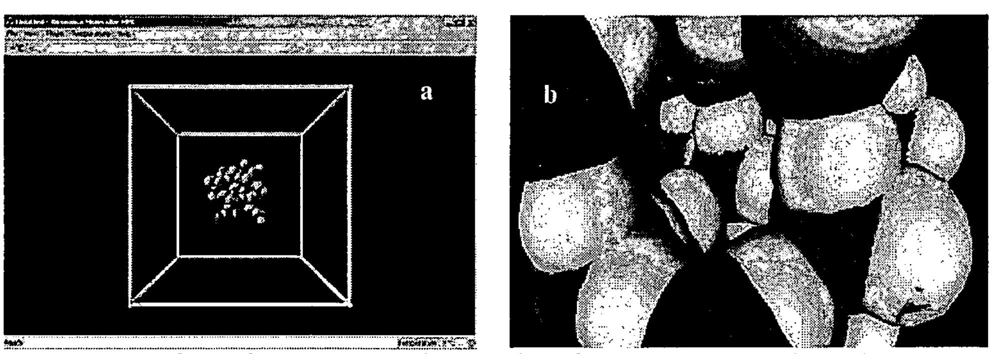

Figure 1: Two frames from the water solid phase (ice) of our molecular dynamics environment: a) balls model of a group of molecules; b) flying through the ice structure.

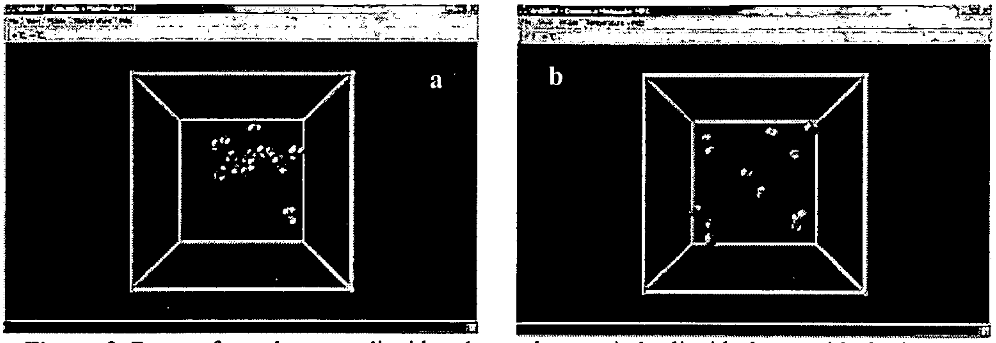

Figure 2: Frames from the water liquid and gas phases: a) the liquid phase, with the balls model of twelve molecules; b) The gas phase, showing the same molecules. These pictures, as well as those of Figure 1, were created with *PC Gamess*, *Molden*, *3D Studio Max*, being the dynamics implemented in *Visual* C^{++}on *WorldToolkit.*

Using balls models of water molecules the user may interiorize the corpuscular theory of matter. Since the molecular dynamics simulation takes place in a box (closed system) it is easy to understand that the molecules are the same in solid, liquid or gas phases. It is clear from our virtual environment that, in any phase of water, empty intermolecular spaces are present, these being smaller in the solid and liquid phases than in the gas phase (Figure 2). The density is different in the three phases.

For designing the VW models we used the free software *PC Gamess* [8], that performs the calculations on the water molecule, and *Molden* [7], for the molecular representations. For model development and optimization we used commercial software packages (*Mathcad* and *3D Studio Max*) and *Visual* C^{++} for implementing the molecular dynamics algorithm. Concerning the definition and creation of the virtual scenarios we used *WorldToolkit* (from Sense8). For navigating in the virtual environment and interacting with our models we use a *dataglove* with *cybertouch* system (for haptic information) from Virtual Technologies.

3 Conclusions

Important strategies in teaching Physics and Chemistry are based on central the idea that matter consists of particles but the fact that these are invisible hinders sometimes the development by students of the right scientific concepts. However, the analysis and comparison of various results in the pedagogic literature show that some incorrect concepts and their relationships are simply transferred from the macroworld to the micro world. In fact, there is a firm link between the concepts on matter structure and empirical knowledge of macroscopic phenomena.

If students accept the corpuscular theory mainly for gases and not for solids and liquids, it is advisable to confront them with this contradiction and to treat specifically the processes of phase changes from gas to liquid, and *vice versa,* in terms of identity of substance, identity of particles and conservation of the number of particles. Similar procedure applies to students who accept better the corpuscular theory for solids.

The use of immersive virtual environments and haptic information, although recent, seems to be a powerful means for visualizing and understanding complex and/or abstract information. Actions like grabbing a molecule, breaking hydrogen bonds networks, feeling molecular vibrations, flying through channels in ice and through the empty spaces of molecules in liquid and gas phases (as in George Gamow's book "Adventures of Mr. Tompkins"), etc. are impossible in real world but possible in computer simulations.

"Virtual Water", our virtual environment for studying phases and phase transitions based on corpuscular theory of matter is promising to make progresses along the indicated directions. We are acquiring new means in learning and teaching the Physics and Chemistry of water and building knowledge on virtual reality techniques and tools, which can later be applied to other problems. In particular, our experiment with virtual reality should point out what are the most effective educational benefits and also to indicate the weaknesses of this new technology in an educational setting.

Feedback from pupils is being collected and analyzed in order to quantify the pedagogical usefulness of our

virtual environment. Of course, if these techniques prove to be successful, teacher's strategies should incorporate them. We hope that, with tools like the one we are developing, intangible experiments become more and more concrete and that this fact may facilitate the development of scientific models among science students.

Acknowledgements

The authors thank Prof. Dr. Victor Gil, from the Chemistry Department of the University of Coimbra, for his precious suggestions, and Prof. Dr. José Carlos Teixeira, from the Computer Graphics Center of the same University, for his technical advice. We also wish to acknowledge the assistance of the students Nuno Pereira and Eduardo Coutinho, who have developed the molecular dynamics component of "Virtual Water". This research was supported in part by the Portuguese Foundation for Science and Technology (project PRAXIS/FIS/14188/1998).

References

[1] Andersson, *B.*, "Pupils' conceptions of matter and its transformations (age 12-16)", Studies in Science Education, *18*, pp. 53-85 (1990).

[2] Driver, R. Squires, A., Rushworth, P. & Wood-Robinson, V., "Making Sense of Secondary Science - Research into Children's Ideas" (London: Routledge) (1994).

[3] Driver, R., Goesne, E. & Tiberghien, A. (ed.), "Children's Ideas in Science" (Milton Keynes: Open Universitv Press) (1985).

[4] Garnett, P., & Hackling, M., "Student' s alternative conceptions in chemistry: a review of research and implications for teaching and learning", Studies in Science Education, 25, pp. 69-95 (1995).

[5] Kircher, E., "Research in the classroom about the particle nature of matter" in W. Jung, H. Pfundt and C. Rhoneck (ed.), in *Proceedings of the International Workshop on Problems Concerning Students' Representation of Physics and Chemistry Knowledge* (Ludwigsburg: Pedagogische Hochschule), 342-359 (1981).

[6] Lee, O., Eichinger, D. C., Andersson, C. W., Berkheimer, G. D. & Blakresle, T. D., "Changing middle school students' conceptions of matter and molecules", Journal of Research in Science Teaching, 30 (3), pp.249-270 (1993).

[7] Molden, a package for displaying MOLecular DENsity, written by G. Schaftenaar, CAOS/CAM Center Nijmegen, Toernooiveld, Nijmegen, The Netherlands.

[8] PC Gamess, a program for ab initio quantum chemistry, written by Alex. A. Granovski, Moscow State University.

[9] Pereira, M. P. & Pestana, M. E., "Pupils' representations of models of water", International Journal of Science Education, 13(3), pp.313-319 (1991).

[10] Pfundt, H. & Duit, R., "Bibliography: Student' s Alternative Frameworks and Science Education", 4th ed. (Keil, Germany: Institute for Science Education) (1984).

[11] Sere, M. G., "Children' s conceptions of the gaseous state prior to teaching", European Journal of Science Education, 8(4), pp.413-425 (1988).

[12] Stavy, R., "Children' s conceptions of gases", International Journal of Science Education, 10(5), pp.553-560 (1988).

[13] Trindade, J., Fiolhais, C. & Gil, V., "Virtual Water, an application of virtual environments as an education tool for physics and chemistry". In *Advanced Research in Computers and Communication in Education*, Proceedings of ICCE' 99 – 7th International Conference on Computers in Education, Chiba, Japan, ed. G. Cumming, T. Okamoto, and L. Gomez, vol. 2, pg. 655-658, (IOS Press, Amsterdam) (1999).

[14] Trindade, J., Fiolhais, C., Gil, V. & Teixeira, J. C., "Virtual environment of water molecules for learning and teaching science", Computer Graphics Topics, 5 (11), pp.12-15 (1999).

[15] Wandersee, J. H., Mintzes, J. J. & Novak, J. D., "Research on alternative conceptions in science". In D. Gabel (ed.), *Handbook of Research on Science Teaching and Learning* (New York: Macmillan), pp.177-210 (1994).

Using virtual reality courseware to enhance secondary school student learning in geosciences

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Based on the rapid development of the technology of virtual reality, the project was to integrate the contents of the geosciences with virtual reality courseware (VRGeo) to enhance student learning in secondary level. Three subject-oriented course themes were included in the VRGeo. The first theme is Active Faulting in Chihshang. In this theme, a 3-D topography around Chihshang area was designed to demonstrate the surface faulting along the Longitudinal Valley. The 3-D demonstration enhances the comprehension of basic geologic information in studied area. The second theme focuses on the arc-continent collision process, which was divided to five consecutive scenarios from late Miocene to present day. The mountain building process in Taiwan was demonstrated clearly the growth of mountain in Taiwan and the relationship of the collision process due to arc-continent collision. Finally, the third theme shows the mechanism of the foehn due to geographic effects. In a pilot study, eighty percent of 120 in-service teachers agreed that the use of the courseware facilitated secondary school student learning in Geosciences. The VRGeo is now on-line to be used through the Internet (http://www.isst.edu.tw) and will be collected the experiment data for the future research.

Keywords: **Virtual reality courseware, CAL, CAI, Geoscience,**

1 Introduction

Wang (1999) indicated that when teaching courses in secondary level, it was important to identify student learning difficulties and to adopt the suitable teaching and learning strategies in subjects for the best learning effect. Based on the discussion with teachers in geoscience (ISST, 1997), it is found that secondary school students had the difficulties to understand the process of geographic effects for climate, aseismic surface faulting and orogenic process in Taiwan through traditional instruction. Traditional instruction usually used textbooks, maps, and videotapes in geoscience and had the learning effect in static geology concept but not dynamic processes. Thus, the purpose of the project focused upon how to provide a learning environment to enhance secondary school student learning in the dynamic processes of geographic effects.

2 General background

The Taiwan orogeny is young and presently very active (Tsai, 1986).. It provides an excellent environment for studying ongoing orogenic processes, especially since the region is monitored intensively with dense seismologic and geodetic networks for natural hazards. The Longitudinal Valley Fault zone of eastern Taiwan is the present-day plate boundary between the Philippine Sea plate and Eurasia. Repeated surveys of active deformation were carried out along its most active segment, the Chihshang Fault (Angelier et al., 2000). Creep on the Chihshang Fault started after of the "Taitung Earthquake sequence" in November 1951. Annual records of displacement from 1990 to 1998 revealed concentration of shear on a single fault. However, large earthquakes occurred in the past. Continuous motion took place in the absence of large

earthquakes for several tens of years along the Chihshang Fault. Along the Longitudinal Valley, earthquakes with magnitudes larger than 5 occurred in 1951 (Meilun magnitude Ms=7.1; Yuli, Ms=5.3), in 1972 (Juisui, Ms=6.9) and 1986 (Hualien, Ms=6.4 and 7.8).

The problem of a better description of the historical seismicity is still crucial in considering the need to better define the so-called earthquake cycle: the destructive Chichi earthquake (September 21th, 1999) highlights this importance (Ma et al., 1999). Thus a dynamic learning environment is needed to help student to construct the geographic concept in geoscience. Several 3D simulation and virtual reality applications had the learning effects in different subjects, such as special education, chemistry, music, Electrical Engineering, Computer, etc (DE SOUZA, et al. 1999; Cass & Roblyer, 1998; ALLPORT et al., 1998; Cox, L.1998). Based on the rapid development of cybernetic and virtual reality technologies, the learning environment would be developed by virtual reality technology in cyberspace.

3 Lessons learned from the development of VRGeo

Our work in the study first focused upon identifying the student learning difficulties in the process of geographic effects for climate, aseismic surface faulting and orogenic process in Taiwan. The next was to create the virtual reality courseware (VRGeo) to emphasize the dynamic processes of geographic effects, the natural hazards and earthquake risk mitigation along the Chihshang Fault. Finally, we expect to learn new and better ways to integrate the VRGeo in a classroom activities in order to enhance student learning.

Three subject-oriented course themes were developed in the VRGeo. The first theme is Active Faulting in Chihshang(Fig.1-1, Fig.1-2, Fig.1-3). In this theme, a 3-D topography around Chihshang area was designed to demonstrate the surface faulting along the Longitudinal Valley. The 3-D demonstration enhances the comprehension of basic geologic information in studied area.

Fig. 1-1 Active Faulting in Chihshang

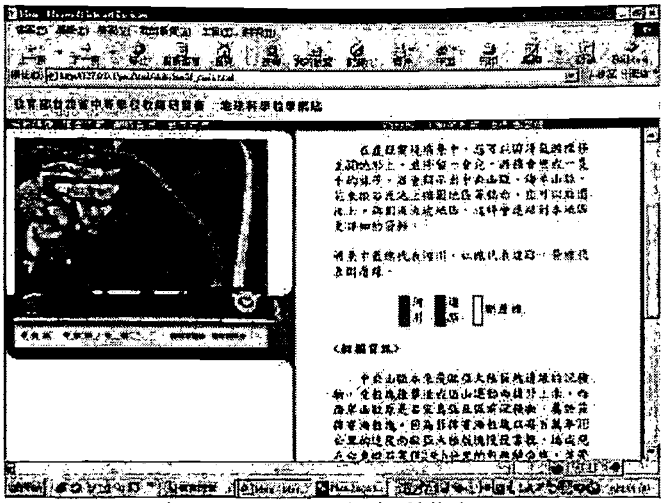

Fig. 1-2 3D topography in Chihshang

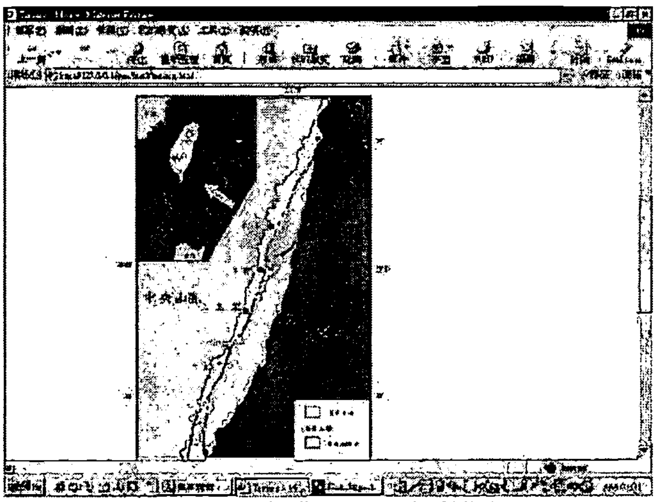

Fig. 1-3 A Longitudinal Valley in Chihshang

The second theme focuses on the arc-continent collision process(Fig.2-1, Fig.2-2, Fig.2-3), which was divided to five consecutive scenarios from late Miocene to present day. The mountain building process in Taiwan was demonstrated clearly the growth of mountain in Taiwan and the relationship of the collision process due to arc-continent collision. This demonstration will facilitate the teachers and students to well understand the plate movement and interaction during the collision process.

Fig. 2-1 the arc-continent collision process

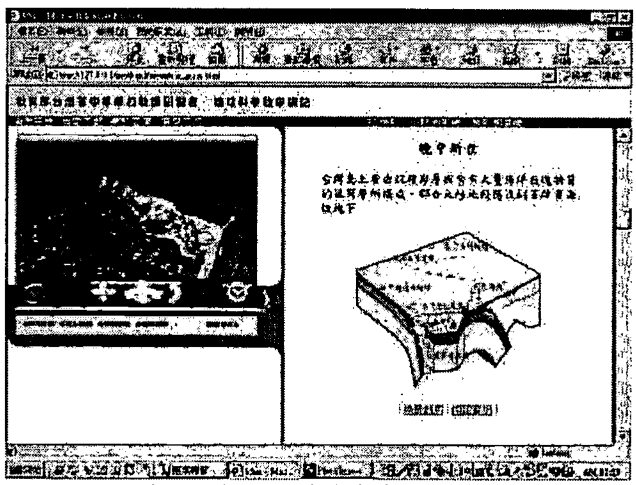

Fig. 2-2 the moutain building process

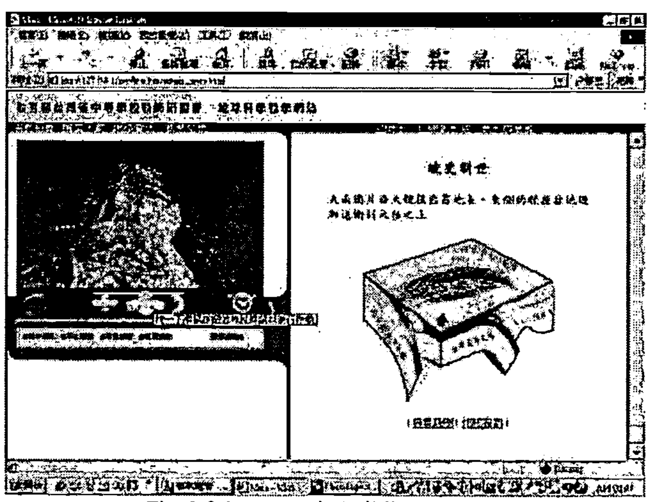

Fig. 2-3 3D moutain building process

Finally, the third theme shows the mechanism of the foehn due to geographic effects (Fig. 3-1, Fig.3-2,

Fig.3-3). The difference of rainfalls is deeply influence by the locality of windward slope or leeward slope. This VR scenario begins with the movement of the air stream and clouds from the windward slope. This scenario enhance the comprehension of the foehn in the leeward slope.

Fig. 3-1 the mechanism of the foehn

Fig. 3-2 the movement of the air stream and clouds from the windward slope

Fig. 3-3 The difference of rainfalls

In a pilot study, 120 secondary school geoscience teachers enrolled in 3 a-week workshops to use the VRGeo at The Institute for Secondary School teaches in Taiwan. Eighty percent of the teachers agreed that the use of the courseware facilitated secondary school student learning in Geosciences. The VRGeo project underlying theoretical framework combines constructionist educational theory with ideas that emphasize the importance of collaborative learning and narrative development. In the future research, we expect to integrate the VRGeo in a classroom activities with collaborative learning. The VRGeo is now on-line to be used through the Internet (http://www.isst.edu.tw) and will be collected the experiment data for the future research.

4 Conclusions

Offering a flexible learning environment and facilitating student learning with their own path will be the important issues to enhance the student learning effects in education. Virtual reality technology has the potential to support those issues and facilitate students better able to master, retain, and generalize new knowledge when they are actively involved in constructing that knowledge in a learning-by-doing situation (Youngblut, 1997).

This paper addresses the application of virtual reality as a facilitating educational tool in geoscience, designed to get students more deeply and flexible immersed in the VR environment, and to present educational experiences not possible using other methods. An important goal of VRGeo is to study the effectiveness of a virtual environment as a conceptual learning and evaluation medium.
Virtual reality has the potential to change the way we help students learn. For this to happen, we need to know how and when this new instructional tool with instructional concepts can be effectively to use, and it will be the main concern in the future research.

References

[1] Angelier, J., Chu, H.-T., Lee, J.-C. and Hu, J.-C. Active faulting and earthquake risk: the Chihshang Fault case, Taiwan, J. Geodynamics, 29, 151-185 (2000).

[2] Cass, M., Roblyer, M. D. A Review of Experimental Research on Virtual Reality in Special Education: The Status of the Dream. http://soe.eastnet.ecu.edu/vr/vrits/4-2cass.htm (1998).

[3] Cox, L. Introduction to Virtual Reality Through Music. http://soe.eastnet.ecu.edu/vr/vrits/2-4Cox.htm (1998).

[4] DE SOUZA, Antonio Lopes 1, SALGADO, Luiz Antonio 2, SOLLERO, Maria Karla V.3, & SUEMITSU, Walter Issamu4. An Internet-Based Environment for Support Teaching and Learning of Electrical Engineering. http://www.otc.kyit.edu.tw/ICEE1999/papers/291/291.htm (1999).

[5] ALLPORT, Christopher, SINES, Paul, SCHREINER, Brandon & DAS, Biswajit. Education in Three Dimensions: Using Virtual Reality in Education for Illustrating Spatial Relationships. http://www.otc.kyit.edu.tw/ICEE1999/papers/334/334.htm (1998).
[6] Ma, k.-F., Lee, C.-T., Tsai, Y.-B. and Shin, T.-C. The ChiChi, Taiwan earthquake: large surface displacements on an island thrust fault. EOS, 80, 605-611,(1999).
[7] The Institute for Secondary School teachers in Taiwan. The workshop of secondary school teachers in geoscience (1997).
[8] Tsai, Y.-B. Seismotectonics of Taiwan, Tectonophysics, 125, 17-37, (1986).
[9] Wang, H. S., Hargrave, C. P., Hsu, Y. S.(1999). The research of using different teaching and learning strategies in computer courses for inservice education. SITE99, Feb. 28-Mar. 4
[10] Youngblut, C. Educational Uses of Virtual Reality Technology. http://www.soe.ecu.edu/vr/vrits/3-1Young.htm(1997).

Virtual Inhabited 3D worlds and Internet Based Learning Environments

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This paper addresses some of the central questions currently related to 3-dimensional Inhabited Virtual worlds (3D-IVWs) and their virtual interactions and communication in Internet Based Learning Environments. First, 3D-IVWs-seen as a new and unique form of multimedia-are introduced and the social construction of the 3D-IVW technology is briefly discussed. Second, a selection of the basic concepts and identifiable entities in 3D-IVW s is denned and commented upon. Third, modes of interactivity and (virtual) interactions between users, avatar, bots, etc. in the new Virtual Worlds are briefly presented and typologized. Finally, two Internet based virtual inhabited 3D learning environments -one US-based and one based in Denmark- will be described and analysed.

*The paper was not available by the date of printing.

WALTZ: A Web-based Adaptive/Interactive Learning and Teaching Zone

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Web-based 3D life-like learning environment is becoming a major research topic. WALTZ supports dynamic, collaborative, and synchronous/asynchronous learning activity in 2D/3D virtual environments. In this paper, an overview of WALTZ's architecture and design philosophy is presented. Then, a WALTZ-style Pythagorean theorem learning space is shown to illustrate the powerfulness of the WALTZ environment. The ultimate goal of WALTZ is to provide an active and pleasant social learning environment for learners to study collaboratively and waltz happily in shared virtual, dynamic and yet exciting learning spaces.

Keywords: **Web learning, Virtual Reality, Collaborative Learning, CAI**

1 Introduction

The World Wide Web (WWW) opens a new learning space that learners can communicate and share their idea in this wonderful virtual world. The new learning space provides versatile ways of communication and interaction that would make learning more fun and entertaining than ever before. It has captured great attentions from CAI (Computer Assisted Instruction) researchers since its debut as it has great potential to surmount the difficulties and weakness of traditional CAI systems [5,7,8]. Up to date, most web-based CAI systems only support asynchronous learning and still use 2D hypermedia style to showcase their learning materials and instructions [13]. Some systems [3] might support collaborative learning additionally, however, they are still far away from success as the new way of learning also brings new problems that are even more challenging for educators. There is no simple way of knowing what the best web-based learning environment would be and how to utilize this environment effectively for teaching as well as learning. It is a research area that needs to be seriously explored through the cooperation of experts from different disciplines such as subject content experts, instruction developers, CAI researchers, and web engineers etc. Despite such problems, most educators would agree that discovering leaning, collaborative learning, learning by doing, and learning with fun are among those of effective learning methods according to Constructivism [2,9,12]. Fortunately, recent rapid progress of web technologies such as JAVA, VRML, and network technologies bring a new opportunity for implementing the learning methods described above. Before VRML was created in 1994, web spaces are flat. Most web systems are hypermedia style, which do not have enough expressive power of modeling real world entities. The living world specification [11,14] in 1997 illustrates emerging needs of dynamic and interactive 3D shared virtual worlds. Today there are many popular 3D avatar (virtual human) based virtual society (mainly for social meeting and chatting) websites [1]. The trend of web windowing systems is moving from 2D multimedia representation to 3D shared virtual space. WALTZ foresees the integration of the two media will become a popular form of presenting learning materials as well as a virtual fun place to play, learn and exchange idea. Many studies have also indicated that a successful web-based learning system not only has to be content-rich but also highly interactive as well as highly adaptive to meet the needs of learners [5,8]. Transforming 2D virtual classrooms into life-like 3D learning space is certainly one of the research directions that deserve special attention.

WALTZ, a research project under active development, is a web-based adaptive/interactive learning and teaching zone, which supports dynamic, collaborative, and synchronous/asynchronous learning in 2D/3D

virtual environment. WALTZ envisions that the CIA (Content, Interaction and Adaptivity) learning model will be an essential ingredient of future successful web-based CAI (Computer-Aided Instruction) systems. The CIA learning model is developed based on the Interaction Model of Gilbert [5] and Instruction Design Model of Moallem [15]. The CIA learning model has three corner stones: Content, Interaction and Adaptivity. The overlay areas of each neighboring corner stones are versatile representation, adaptive instruction and adaptive interaction. Figure 1 illustrates the CIA model in detail.

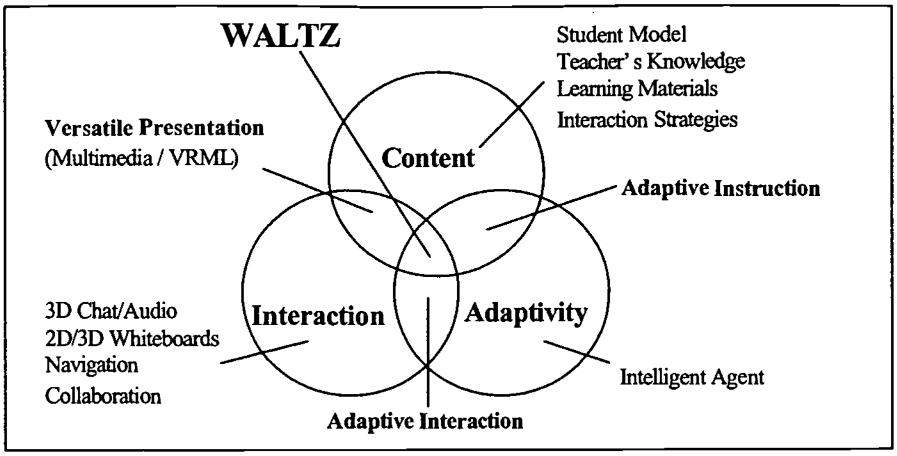


Figure 1. WALTZ' s CIA Learning Model

2 An Overview of WALTZ

The main goal of WALTZ is to develop a web-based interactive and adaptive environment based on the CIA learning model so that it can be easily adapted to any instructional and learning subjects according to the theory of constructivism. WALTZ is capable of supporting discovering learning, project-based learning and collaborative learning in 2D/3D shared virtual learning space. WALTZ supports the following features:

(1) Dynamic interaction and flexible communication

WALTZ supports two types of interaction: Human-Computer Interaction and Social Interaction. The former supports instructional interaction and emphasizes individual and adaptive learning. Learners can browse information, navigate virtual worlds, and respond to problems that are dynamically generated from the WALTZ' s system according to student' s learning status. The latter supports collaborative mechanism and emphasizes collaborative learning among students, student and teacher, groups of students, and the whole class. In addition to support asynchronous communication in traditional 2D virtual classroom setting, WALTZ also supports synchronous communication in both 2D shared and 3D shared learning space as well.

(2) Versatile presentation of multimedia and virtual reality

Both multimedia and virtual reality have their advantages and disadvantages. Multimedia learning has great success in instruction and learning in recent years. Virtual reality is the best technology to provide 3D life environment. Web-based multi-user environment are even envisioned as one of the popular user interface in the future [9]. However, it is still hard to construct a high quality VR system in terms of cost and technology. Furthermore, virtual reality might not be suitable for all types of instruction. Thus, the use of both multimedia and virtual reality technologies in alearning system will be able to support a rich and effective learning environment that attracts students.

(3) Agent-based learning environment

Based on Constructivism, an ideal learning system should provide adaptive learning scenarios, where teaching materials and learning activity would be individualized according to students' mental model and learning needs. WALTZ supports helper-agents, which would interact with learners in several ways. For

example, an instruction agent would present an easier course material to a learner if it found the current content is too difficult for him/her. An interaction agent would suggest a group of learners to use a 3D whiteboard instead of a 2D whiteboard if they were trying to understand the three dimensional structure of molecules. WALTZ's virtual classroom could be populated with shared objects and active agents, such as user agents (represented by virtual human) and helper-agents so that users can enjoy and learn effectively in the social learning environment.

(4) Collaborative mechanism for activity management

Recently, group learning has been found to have a positive effect during learners' learning process [6,17]. In order to effectively support WALTZ's virtual, shared, and interactive social world, a set of collaborative mechanisms has been developed to manage interactions among students, teachers, and instructional content. These mechanisms [4] include object association, automatic object notification and change management, object delegation, object negotiation, object constraint, and object history tracking. Built on top of these collaborative mechanisms; WALTZ constructs an agent-based group activity model, where each participant is modeled as a user agent to manages the dynamic behaviors of all participants in an activity.

(5) Standard VRML authoring language for shared multimedia contents

Content development plays an important role of a successful web-based learning system. WALTZ supports authoring tools for shard virtual worlds based on multi-user VRML living world specification. This feature will make developments of shared 3D contents almost as easy as non-shared static 3D contents. Message passing between shared objects on different computers will be through new prototyped VRML nodes and WALTZ communication subsystem will update the states of each shared object once they are changed.

(6) Open architecture and platform independent web-based learning environment

The enchantment of web-based learning environment in WALTZ is due to its global network connectivity, simplicity and yet friendly user interface, and extensible architecture. The implementation of WALTZ is based on JAVA, VRML and standard network technologies so that it can be easily applied to other systems or platforms. A client can use current popular web browsers, such as Microsoft Internet Explorer or Netscape Navigator (with VRML plug-ins, such as Cosmo player or Cortna player) to browse information, navigate, and communicate with other clients in the WALTZ.

WALTZ is expected to be able to

- represent different media information effectively,
- construct various learning scenarios by integrating the technologies of virtual reality, multimedia, and World Wide Web, and
- to provide activity management facilities and collaborative mechanisms to enable highly interactive collaboration among all students, teachers, and instructional material in collaborative learning activity.

3 The Architecture of WALTZ

WALTZ is basically a client/server distributed virtual reality system. The client side provides human-machine interface that uses the technologies of audio, image, HTML, VRML, and the Java Internet capabilities to provide a web-based multimedia/virtual classroom according to the theory of Constructivism. Its environment contains JAVA control applet, multimedia, virtual world interface and collaborative tools such as text chat tool and shared whiteboard. Figure 2 illustrates the architecture in detail. Each client (user) can join one to multiple sessions to collaborate with other participants in 2D/3D shared virtual classrooms (or learning spaces). The server side is composed of five main components: (1) collaborative mechanisms subsystem, (2) VRML world server, (3) intelligent agent-based server, (4) Web server, and (5) communication subsystem for supporting real-time synchronous or asynchronous message interchange. The collaborative mechanisms subsystem ensures that the inter-dependency/intra-dependency of all activities/participants will be maintained and validated during their interaction. In addition, notification, delegation or negotiation protocols will be executed once some events of interest are triggered. The VRML world server will handle all VRML events coming from the event manager and updates the states of each shared VRML objects. The agent-based helpers communicate with the activity manager in inferencing and discovering potentially new learning patterns of students based on the diagnosis and feedback of students'

learning history. A communication subsystem supporting TCP/UDP/RTP protocols is used by all components of WALTZ to facilitate the real-time synchronous or asynchronous communication of interacting objects (or entities). The web server is responsible for downloading multimedia and VRML representation of instructional materials or virtual learning space.

4 Pythagorean Theorem Learning Space

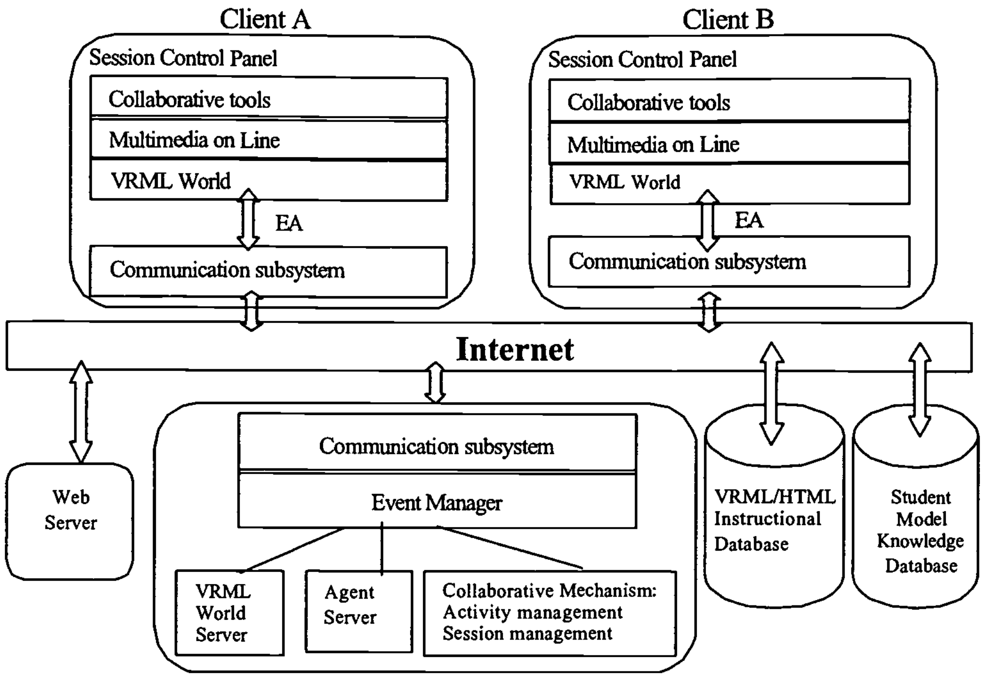


Figure 2. The Architecture of WALTZ

Pythagorean theorem is an interesting mathematical subject of the eighth grade students in Taiwan. It has rich heritage in mathematical history. Based on our survey, most current web-based systems teaching Pythagorean theorem only focus on the 2D interactive theorem proving process. WALTZ, in contrast, not only offers 2D interactive theorem proving process but also provides several key learning components to help students better understand the fundamentals of Pythagorean theorem. Figure 3 is an entry to the Pythagorean theorem learning space, where users can meet and navigate the virtual world dynamically or enter into any one of the learning components described below. The user interface contains two parts: VRML virtual world and JAVA applet control panel. The VRML virtual world is the learning space, provided by the WALTZ web server, where learners can navigate the virtual world, enter into a learning session, and meet other learners in the same session. The control applet provides chat tools so that a learner can talk to other learners for collaborative work.

The design of WALTZ-style Pythagorean Theorem learning space intends to support the features that are listed in Section 2. Current implementation of the WALTZ-style Pythagorean Theorem learning space consists of the following five learning components:

(1) Multimedia instructions

In WALTZ, instructional design of Pythagorean theorem covered three on-line learning sections: history of Pythagorean theorem, prerequisite knowledge and skills of Pythagorean theorem, and all the concepts about Pythagorean theorem. Since Pythagorean theorem is related to the mathematical concepts in both algebra and geometry and each concept need different multimedia features for presentation. Thus, different multimedia components such as text, graphic, animation, sound etc. were carefully designed and arranged in the interface to present the subject domain.

(2) Collaborative and interactive Pythagorean theorem proof/verification

One of the major features of WALTZ is the collaborative learning environment for Pythagorean theorem proof/verification. The activity manager in WALTZ provides facilities for instructors/learners to create/modify/delete/join an activity/session, to assign permission, to set constraints, to record the history of learners' Pythagorean practices, and to support group awareness during their collaborative learning. Figure 4 is an interactive program that allows users to learn Pythagorean theorem by experimental method. Students can drag each vertex of the triangle. If it is a right triangle then one can visually verify if it satisfies the Pythagorean equation: a^2+b^2=c^2. If it is an acute (or obtuse) triangle then the Pythagorean equation is not valid and a^2+b^2 >(<) c^2. Figure 5(a) shows a collaborative Pythagorean theorem proving program in action which not only support collaboration but also group awareness (i.e. can visually see who is making the move). All participants in a collaborative application is managed under the control of activity (or session) manager, as shown in figure 5(b).

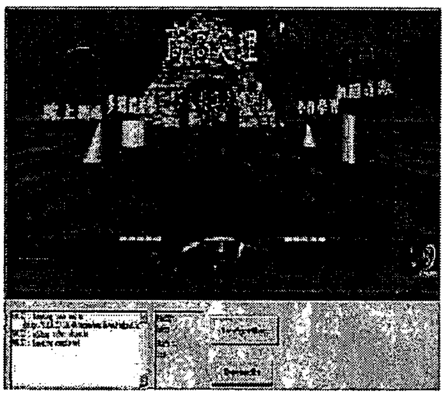


Figure 3. Pythagorean theory learning space

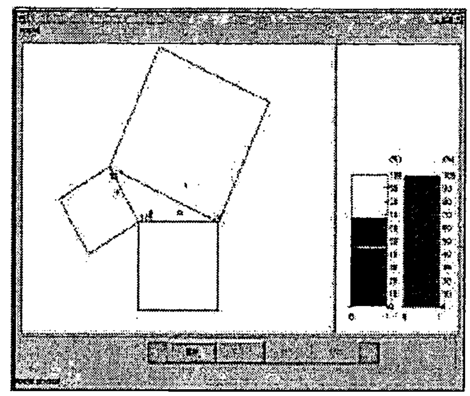


Figure 4. An obtuse triangle: a^2+b^2< c^2

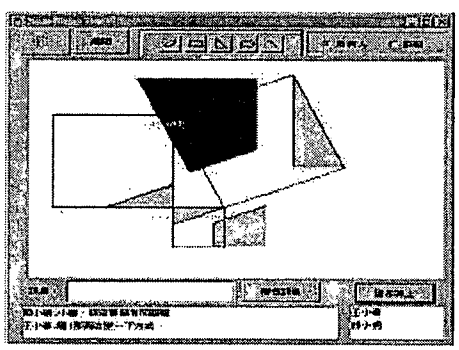


Figure 5(a). Collaborative Pythagorean application

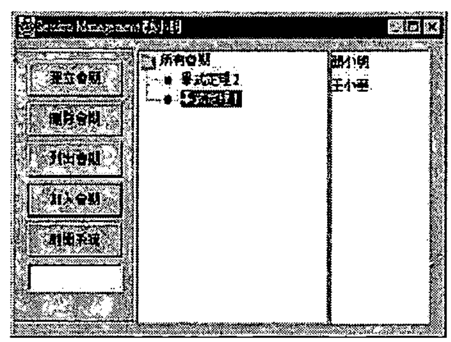


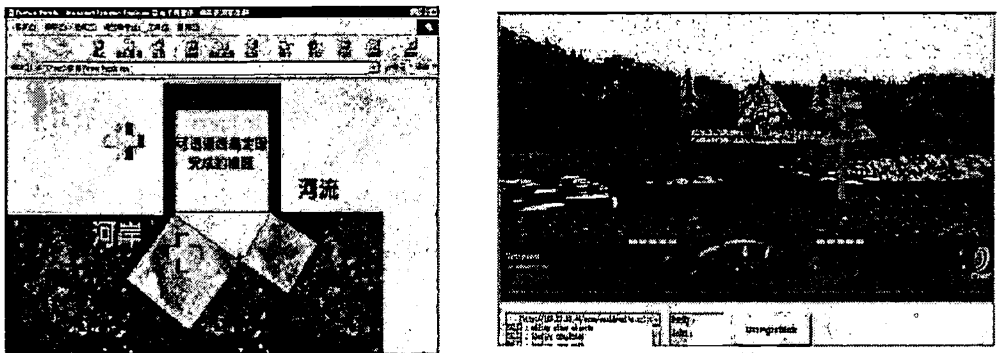
Figure 5(b). Session management

(3) Adaptive multimedia on-line testing

Traditional drill and practice CAI was criticized too boring to be used for young students. A web-based on line test without multimedia will have the same problem. A precompiled multimedia CAI program using Shockwave or Flash authoring technologies provides a better solution, however, it is not easy to change or add new contents adaptively into the program without recompiling the whole program. WALTZ is a dynamic virtual environment which can add/delete objects during users' learning journey. WALTZ intends to support an adaptive multimedia testing mechanism. Students will be given multimedia style test questions based on their current learning status. The multimedia test problems are generated on the fly by converting text -based questions stored in the database into multimedia representation. WALTZ will classify questions and suggest appropriate multimedia templates to make the conversion almost as easy as a PowerPoint presentation.

(4) Multi-user Project-based Pythagorean theorem virtual environment

To support project-based collaborative learning, a virtual environment is constructed. Team members can join the same session to solve the mathematical puzzles generated from the WALTZ system by interactively moving pieces of puzzle into the right place according to Pythagorean theory. Since WALTZ is a shared virtual environment that supports collaborative learning, each member of the team can see actions from other team members and they can communicate with each other to discuss how to solve the puzzle before they can go on to their next journey. Figure 6(a) & (b) illustrates a situation that a team must solve the puzzle of bridge using Pythagorean theorem before they can pass through the river and enter into the forest to continue their next journey.



(a) (b)

Figure 6 (a) & (b). Project-based multi-user collaborative learning space

(5) Pythagorean resource

Besides the aforementioned components, WATLZ also provide useful utility tools, such as online notepad and calculator that users can use conveniently. In addition, many different web sites relate to Pythagorean theorem were linked in WALTZ for learners to acquire various information easily.

5 Conclusion and Future Research

Due to progressively advanced development of 3D graphics and open network technologies, a web-based learning system that provides asynchronous and hyperlink-style environment might not attract young students in the feature. In addition, such systems will have great difficulty in constructing a situated, dynamic, and collaborative learning environment according to Constructivism. Therefore, This research proposed a CAI learning model from which a new architect of a web-based 3D life-like learning space, WALTZ, is created. By using Pythagorean theory as a case study, the study has demonstrated that WALTZ has a great potential to provide an improved learning environment over traditional virtual classroom setting.

Though WALTZ is still far from perfect, this research indicates that it deserves special attention among CAI research community. Next generation of WALTZ will focus on dynamic behaviors of agents via current state of the art MPEG-4 technology.

Acknowledgement

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References

[1] Blaxxun Interactive, http://www.blaxxum.com/ (accessed on June 2, 1998).
[2] Brooks, M. & Brooks, J., "In Search of Understanding: The Case for Constructivist Classrooms", Alexandra, VA:ASCD, (1995).
[3] Carlson, S. & Hawkins, R., "Linking Students Around the World: The World Bank's New Educational

Technology Program", Educational Technology (September-October), pp. 57-60, (1998).
[4] Chiang, H. K. & Lin, C. H., "A Study of Collaborative Mechanisms for Web Teaching and Learning", Journal of Da-Yeh University, Vol 8, No 2, pp. 63-79, (1999).
[5] Gilbert, L. & Moore, D. R., "Building Interactivity into Web Courses: Tools for Social and Instructional Interaction", Educational Technology (May-June), pp. 29-35, (1998).
[6] Harasim, L., "A Framework for Online Learning: The Virtual-U", Computer, pp. 44-49, (1999).
[7] Henin, I. & Droctor, L., "Incorporating the Web as Teaching Tool: Introduction", http://web.uvic.ca/~esg9/emo/emomain.html/ (accessed on May 1, 1999).
[8] Hughes, C. & Hewson, L., "Online Interactions: Developing a Neglected Aspect of the Virtual Classroom", Educational Technology (July-August), pp.14-55, (1998).
[9] Jung, B. & Milde, J., "An Open Virtual Environment for Autonomous Agents using VRML and Java", VRML 99 Proceeding, (1999).
[10] Kearsley, G. & Shneiderman, B. "Engagement Theory: A Framework for Technology -Based Teaching and Learning", Educational Technology (September-October), pp. 20-23, (1998).
[11] LW, "Living Worlds Specification, Draft 2", http://www.livingworlds.com/draft_2/index.htm (accessed on April 12, 1998).
[12] Merrill, M. D., "Constructivism and Instructional Design", Educational Technology, Vol 31, No 5, pp. 45-33, (1991).
[13] Merrill, P. F., Hammons, etc., "Computers in Education", NY: Simon & Schuster Company, (1996).
[14] Mitra, K., "Living Worlds", http://www.livingworlds.com/draft_1/lw_ideas.html (accessed on November 21, 1997).
[15] Moallem, M., "Instructional Design Model and Teacher Thinking: Toward a New Conceptual Model for Research and Development", Educational Technology (March-April), pp. 5-18, (1998).
[16] Pesce, M., "VRML: Browsing and Building Cyberspace", New Riders, (1995).
[17] Sherry, L. & Myers, K. M., "The Dynamics of Collaborative Design", IEEE Transactions on Professional Communication, Vol 41, No 2, pp. 123-139, (1998).

Web-Based Subject-Oriented Learning Program on Geophysics For Senior High School

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Homepages of contents on the topics of Earthquake, Plate Tectonics Theory and Chi-Chi Earthquake in the field of Geophysics have been composed for the subject-oriented learning program for senior high school students. Learning test activities were performed to testify the teaching and learning effect via Internet. The homepage contents bear the characteristics of (1) scientific theory-based descriptions, (2) more local examples, (3) highly relating to common life, (4) more dynamic illustrations, and (5) providing interesting practicing works. The results of subject- oriented learning test activities in this study show that the learning style, learning procedures and the homepage contents are all highly accepted by the participants from senior high school. And the learning effect is obvious as judged by comparing the pre-learning and the after-learning concept diagrams drawn by each individual participant.

Keywords: **subject-oriented learning program, learning test activities, concept diagrams**

1 Introduction

Internet system supplies plenty of knowledge conveniently and quickly, the explorer can achieve the purpose of self-learning by collecting, reading, analyzing and combining different kinds of data via Internet. For the purposes of improving the learning environment, enhancing the teaching quality, and raising the learning effect on Earth Sciences education for senior high school, web-based course contents on topics of Earthquake, Plate Tectonics Theory and Chi-Chi Earthquake in the field of Geophysics have been set up based on the idea of subject-oriented learning program [2]. Senior high school students can not only do the self-learning but also exchange their learning ideas with others through Internet learning system under different conditions of time periods and places. By joining the study results from fields of education, computer technology, geophysics and geology, subject-oriented learning test activities for each specific subject were performed respectively with the participation of volunteered teachers and students from different senior high schools so as to evaluate the learning effect of Internet learning system.

2 Objectives

By especially considering the educational idea of subject-oriented joint learning mode[1], homepage contents were set up. Internet learning test activities were performed by using joint learning software and concept diagram drawing software developed by the computer technologist's [3]. The major objectives of the study are as follows:

1) Setting up basic web-based contents on Earth Sciences so as to enhance the teaching and learning interests for high school education, the contents may also serve to a better understanding of the earth environment for social people.

2) Setting up the effective searching catalog so as to assist in surveying and collecting related data.
3) Assisting in solving educational problems and improving learning effect through Internet communication system.

3 Subject-Oriented Joint Learning Test Activity

Subject-oriented learning strategy was the major concern in the study. Participants were advised to carry out the learning program by reviewing and collecting related contents through Internet. All the communications were put through BBS posts or e-mails, there were volunteer helpers, college students, to respond all proposed questions from time to time. Team works were important besides individual learning as well, each would share personal learning results with others and came out a group report, individual learning effect was evaluated by comparing the pre-learning and after-learning concept diagrams.

After entering the web site "gepedu.gep.ncu.edu.tw" (Fig. 1), participants would click the right icon to choose the specified subject for the activity. Each one should draw a pre-learning concept diagram by connecting the provided concept terms with proper words after watching the "Miss story" (a short documentary film) prepared for the subject. And then, the major stages for the learning test activity were:

1) Participants were separated into groups of different topics on the specified subject based on his own study interest.
2) Every group set up its study assumptions and strategy; certain assignments were distributed to each individual member of the group.
3) Group members started to survey and collect related data for the topic, and all the working records were kept by using joint learning software.
4) Participants bearing the original role of topic group were re-divided into different groups of experts to cover more study fields. Members discussed and shared personal study ideas and results with others.
5) Each participant returned to his original group of topic and made after-learning concept diagram a group report for the study was also made with the efforts of all the group members.

4 Results and Discussions

Three learning test activities were finished in the study [2]; detailed descriptions of the activities are in Tables 1 to 3. When first learning test activity on Earthquake was being held; related software was not well developed. Internet function was limited to content reviewing. By the time of second learning test activity on Plate Tectonics Theory software was more fully developed, all works were done under Internet environment; more working records were preserved in personal joint learning files for the second and the third activities. All discussions and questions among the students were put through BBS posts and e-mails; volunteer helpers joined the discussions and also answered the questions in time. There are 119 posts from the second activity and 552 posts from the third activity, most of the posts are highly related to the learning program. Each participant finished drawing two concept diagrams in pre-learning and after-learning stages respectively, there are 24 diagrams from the second activity and 46 diagrams from the second activity. And each group had also submitted the group report as required in the learning activity in time, there are 2 and 3 reports for the first and the second activities respectively. Plenty of discussions and notes have also been recorded in the joint learning software in Internet. However, the insufficiency of the Internet system and the learning pressure under traditional education system may interrupt the continuous progressing of the learning program, occasional oral communications seem to be necessary. Though the ability in data analyzing, reducing and deducing may not be well satisfied, students show obvious improvement in the knowledge of the subject as judged by comparing and analyzing the individual pre-learning and after-learning concept diagrams and from group reports.

5 Conclusion

Homepage contents for all the three subjects are highly acceptable to high school students and teachers, most of them confirm with the learning effect of the subject-oriented joint learning program. If the traditional learning pressure would be suitably released, students will be more willing and free to perform self-learning program through Internet learning system even though they are not very well familiar with the operation of the used software.

References

[1] Chen, F. C., "The study of a cooperative project-based learning design in network-based environment", NSC Study Report, NSC-88-2511-S-008-002, pp. 1-8(1999)

[2] Chin B. H., Yang, R. K. and Wang, C. Y., "Development of a learning environment for solid earth (geophysics) through Internet", NSC Study Report, NSC-88-2511-S-008-005, pp. 1-5(1999)

[3] Lin, S. J., Chou, S. C., Chen, Y. M., Chan, T. W., "A study of Internet-based collaborative project learning environment", NSC Study Report, NSC-88-2511-S-008-003, pp. 1-8(1999)

Table 1 Learning Test Activity on Earthquake

Time	1998.5.3, 1 day
Location	computer room in Wuling Senior High School
Participants	12 high school students, 3 high school teachers, 17 volunteer helpers(students and teachers from Department of Earth Sciences, National Central University)
Subject	Earthquake
Group of Topic	Occurrence and Distribution, Intensity and Magnitude
Working Pattern	content reading via internet, one to one oral communication, working processes recorded by volunteer helpers
Evaluation Materials	concept diagram, questionnaires, working records

Table 2 Learning Test Activity on Plate Tectonics Theory

Time	1999.2.27~1999.3.6, 8 days
Location	computer rooms in Wuling Senior High School, ChenSheng High School and National Central University, personal working environments
Participants	6 students and 1 teacher from ChenSheng High School, 6 students and 1 teacher from Wuing Senior High School, 7 volunteer helpers from National Central University
Subject	Plate Tectonics Theory
Group of Topic	Continental Drift, Sea Floor Spreading
Group of Expert	Dynamics, Mechanism, Effect
Working Pattern	Besides software learning on the first day and evaluation meeting on the last day, all the other works were all carried out via Internet.
Evaluation Materials	pre-learning and after-learning concept diagrams, questionnaires, BBS posts, working records in joint learning software, three assignments

Table 3 Learning Test Activity on Chi-Chi Earthquake

Time	2000.2.2~2000.2.26, 25days
Location	computer room in National Central University, personal working environments
Participants	4 students and 1 teacher from ChenSheng High School, 2 students and 1 teacher from TaoYuan High School, 2 students and 1 teacher from Wuling Senior High School, 3 students and 1 teacher from HsinChu Experimental High School, 2 students from ChungLi High School, 5 students from HsinChu High School, 2 students from HsinChu Girls' High School, 2 students from ChenDer High School, 1 students from ChuTung High School, 7 volunteer helpers from National Central University
Subject	Chi-Chi Earthquake
Group of Topic	Mechanism, Analysis, Effect
Group of Expert	Focus, Magnitude, Focal Mechanism, Hazard
Working Pattern	Besides software learning on the first day and evaluation meeting on the last day, all the other works were all carried out via Internet.
Evaluation Materials	pre-learning and after-learning concept diagrams, questionnaires, BBS posts, working records in joint learning software

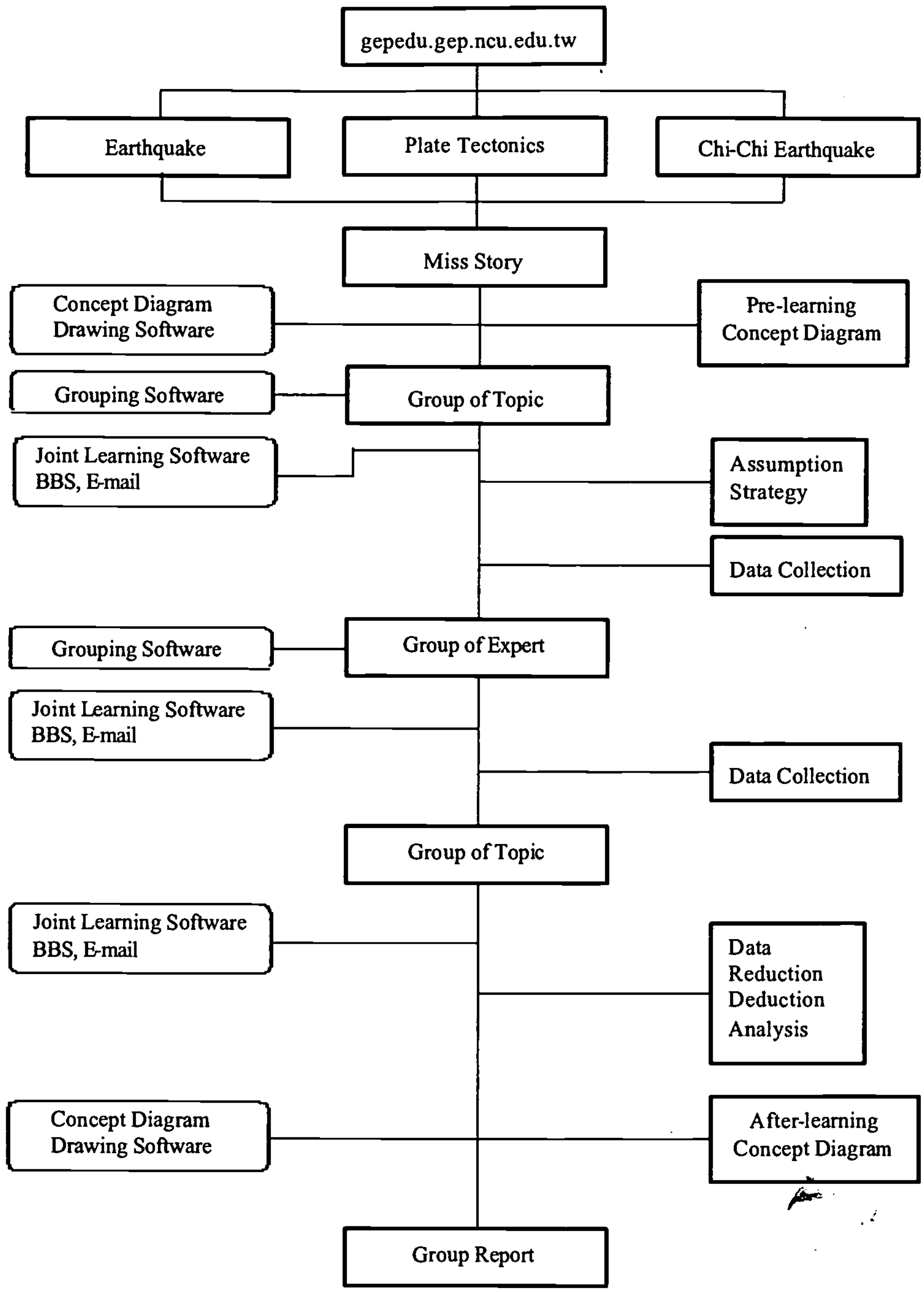

Figure 1 Flowchart for subject-based joint learning test activity

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